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JURASSIC STRATIGRAPHY AND HISTORY OF NORTH-CENTRAL BRITISH COLUMBIA

H. W. Tipper and T. A. Richards

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JURASSIC STRATIGRAPHY AND HISTORY OF NORTH-CENTRAL BRITISH COLUMBIA

H. W. Tipper and T. A. Richards

PREFACE

For nearly a century the Mesozoic rocks of the Intermontane belt of British Columbia have been studied both on reconnaissance scale and in detail. During this period many new names have been applied to the rock units, some have become obsolete, and others have been used in an inconsistent manner. The study upon which this report is based was started in 1969 in order to provide a better understanding of the Mesozoic stratigraphy of the area and to enable the establishment of stratigraphic subdivisions to which new or redefined group and formational names may be applied.

The stratified rocks of the area are in the same relative positions as when they formed. There is little evidence for dislocation along transcurrent faults, no regional high-grade metamorphism, and only minor thrust faults. This apparently simple deformational history has enabled the authors to reconstruct the paleogeography and the tectonic evolution of this part of the Canadian Cordillera during the Mesozoic.

Studies such as this contribute to the Geological Survey's on-going program of improving the description and understanding of the geological framework of Canada, a program that contributes greatly to meeting one of our principal objectives: determining the mineral and fuel resources available in Canada.

D. J. McLAREN,
Director-General,
Geological Survey of Canada.

OTTAWA, February 1976

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PLATE I. Hazelton Group, within the Nilkitkwa Depression, southern Bait Range, looking southerly, showing Bait and Ankwell members and the Nilkitkwa Formation; Telkwa Formation on Frypan Peak in the left distance.

JURASSIC STRATIGRAPHY AND HISTORY OF NORTH-CENTRAL BRITISH COLUMBIA

Abstract

The Mesozoic rocks of north-central British Columbia are divided into five groups: the Upper Triassic basic volcanic Takla, the Lower to Middle Jurassic volcanic and sedimentary Hazelton, the mainly sedimentary Middle to Upper Jurassic Bowser Lake, the coal-bearing Lower Cretaceous Skeena, and the nonmarine Upper Cretaceous to Eocene Sustut. The Hazelton Group is subdivided into three formations, the Telkwa, Nilkitkwa, and Smithers, and these are further subdivided into several facies and members. The Hazleton Group accumulated in a nonmarine and marine basin, the Hazelton Trough, and, in the central Nilkitkwa Depression, up to 4200 m of marine volcanics and sediments accumulated. Intermittent but pervasive volcanism characterizes the group; transgressions and regressions throughout Hazelton time are recorded along the flanks of the trough; and subsidence by graben faulting in the Nilkitkwa Depression and *en bloc* movements of the entire trough persisted. The Hazelton Trough is one of several Early Jurassic basins of deposition in the Canadian Cordillera, which, with the exception of the Vancouver Basin, are still in their original positions relative to each other. In this report detailed information is provided on the stratigraphy, paleontology, volcanic chemistry and physical characteristics, history, and paleogeography of the Hazelton Group.

Résumé

Les roches du Mésozoïque du centre-nord de la Colombie-Britannique se répartissent en cinq groupes: le groupe de Takla, constitué de roches volcaniques basiques du Trias supérieur; le groupe d'Hazelton, constitué de roches sédimentaires et volcaniques datant du Jurassique inférieur et moyen; le groupe de Bowser Lake, principalement constitué de roches sédimentaires du Jurassique moyen et supérieur; le groupe de Skeena, composé de roches porteuses de charbon du Crétacé inférieur et celui de Sustut, composé de roches non marines dont l'âge s'étend du Crétacé supérieur à l'Éocène supérieur. Le groupe d'Hazelton se divise en trois formations: les formations de Telkwa, de Nilkitkwa et de Smithers, elles-même subdivisées en plusieurs faciès et membres. Le groupe d'Hazelton s'est déposé dans un bassin en partie marin et en partie non marin, la dépression d'Hazelton; et dans la dépression centrale de Nilkitkwa, il y a une accumulation de roches volcaniques et sédimentaires marines atteignant jusqu'à 4200 mètres d'épaisseur. Le groupe est caractérisé par un volcanisme intermittent mais envahissant; les flancs de la dépression portent la marque de régressions et de transgressions qui se sont succédées pendant toute la période de formation du groupe d'Hazelton; la subsidence due aux failles d'effondrement de la dépression de Nilkitkwa et aux mouvements en bloc de la dépression toute entière a continué. La dépression d'Hazelton est l'un des bassins sédimentaires du début du Jurassique de la Cordillère canadienne qui, à l'exception du bassin de Vancouver, n'ont pas changé de position relative. Le rapport donne des renseignements détaillés sur la stratigraphie, la paléontologie, les caractéristiques chimiques et physiques des roches volcaniques, la chronologie et la paléogéographie du groupe d'Hazelton.

INTRODUCTION

For nearly a century the Mesozoic rocks of the Intermontane belt of British Columbia have been studied both broadly and in detail by many geologists (Fig. 1). Unfortunately, a general lack of detailed biostratigraphic work, coupled with an ignorance of the regional distribution and of the character of the Mesozoic rocks, has led to a confused stratigraphic terminology. Current understanding of group names such as Bowser, Hazelton, and Takla is vague and inconsistent, and many formational names appear redundant. An aim of this report is to present a revised terminology for Jurassic strata in the region in the hope that it will aid in future studies concerned with Mesozoic stratigraphy. The discussion on terminology is supported by a detailed account of the nature, distribution, and evolution of Jurassic rocks in the southern and southeastern parts of Bowser Basin.

A study by the writers of Mesozoic rocks, particularly the Jurassic, has been in progress since 1969 in the Hazelton (93M) (Richards, 1974a, 1974b), Smithers (93L) (Tipper, 1971), and McConnell Creek (94D) (Monger, 1976; Richards, 1976; Tipper, 1976) map-areas (Fig. 2) of British Columbia. The aim has been to better understand the Mesozoic stratigraphy of these areas, thus permitting the establishment of stratigraphic subdivisions to which may be applied new or redefined group and formational names. The recognition of distinct lithological units is not simple because of rapid facies changes, erratic volcanism, structural complexities, and only fair to poor exposure. Partly compensating for these difficulties is the prolific marine fauna, and great effort was devoted to collecting fossils for correlation of seemingly unrelated lithofacies. We are indebted to Dr. Hans Frebold for his invaluable assistance and encouragement and to him

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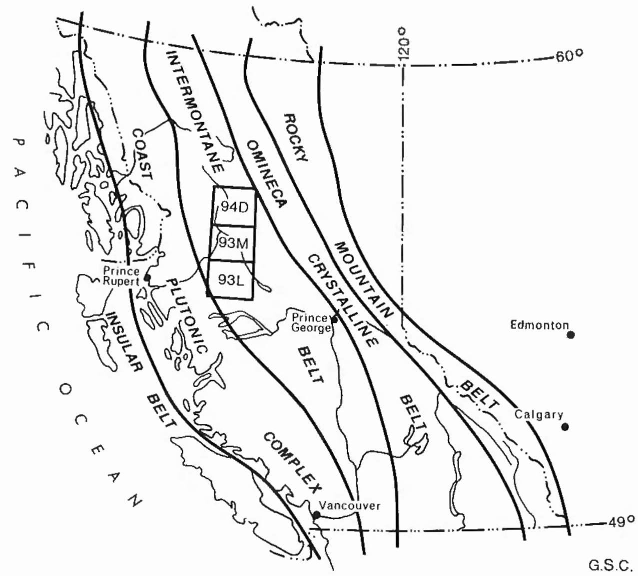


FIGURE 1. Location of Smithers (93L), Hazelton (93M), and McConnell Creek (94D) map-areas.

must be credited the bulk of the fossil identifications. With the aid of critical fossils, relative ages of rock-units were determined and structural complexities recognized. It became apparent that lithological characteristics, commonly subtle, could be ascribed to time-correlative rock-units and that meaningful formations and groups could be erected.

DEVELOPMENT OF THE MESOZOIC NOMENCLATURE

Almost 100 years ago the Mesozoic rocks of north-central British Columbia were first examined and named. Since then, many new names have been introduced by a few geologists, but most workers were content to use names already in vogue, commonly following precedent but not adhering to any rigid definition. Table 1 indicates the origin and development of group and formational names and variations in interpretations thereof.

Porphyrite Group

In 1875 Dawson (1877, p. 250–253) introduced the name Porphyrite Group for rocks of volcanic origin, commonly porphyritic, comprising flows, breccias, and tuffs in a type area around Tatlayoko Lake, about 300 km north-northwest of Vancouver, where he thought the group underlay the Early Cretaceous Jackass Mountain Group and overlay the late Paleozoic Cache Creek Group. In 1876 he extended the use of this name to rocks of the Iltasyuko River valley northeast of Bella Coola (Dawson, 1878, p. 58–74), and in 1879 included rocks around François Lake and along Skeena River near Terrace (Dawson, 1881, p. 99B–142B). It is clear from Dawson's writings that he considered the Porphyrite Group to be Jurassic and to lie conformably below the Early Cretaceous Jackass Mountain Group. However, as a stratigraphic unit it was, and is, unusable. The rocks in the type area are Late Cretaceous rather than Jurassic, and in other areas extensive Tertiary and Triassic rocks were inadvertently included because of general lithological similarities. Not even the bulk of the rocks included originally by Dawson in the Porphyrite Group were Jurassic, although later geologists tended to restrict the name to paleontologically dated Jurassic volcanic rocks. The name continued in use in north-central British Columbia for several years (Leach, 1907a, 1907b, 1908, 1909; Brock, 1921), but eventually fell into disuse and was abandoned in favour of somewhat more definitive stratigraphic names.

Hazelton Group and Skeena Series

Leach (1910) discontinued the use of Porphyrite Group in the Smithers and Hazelton areas and introduced two new names. The Hazelton Group was described as a Jurassic Group, with volcanic rocks at its base near Telkwa, that passed northward in a gradual transition to sedimentary rocks near Hazelton. The Skeena Series was considered to be a sedimentary Lower Cretaceous unit characterized by coal and resting unconformably on the Hazelton Group. Leach generally experienced no difficulty in recognizing the Skeena Series, particularly near Telkwa, but near Hazelton there was difficulty in separating the unit from sediments of the Hazelton Group. For the next thirty-five years, these two stratigraphic units were accepted by most geologists in the Smithers-Hazelton region. However, their definition was vague and interpretations varied. Sections that could be shown to be probably Jurassic were commonly included in the Hazelton Group. An Early Cretaceous age or the presence of coal commonly labelled a section of sediments as Skeena Series. As a result, confusion with Hazelton Group sediments was a problem, particularly where Hazelton Group beds contained coal, however thin and discontinuous. In 1944 Armstrong (1944a, 1944b) included the Skeena Series with the Hazelton Group as he felt that no stratigraphic division could be made between the two. The Skeena Series as a stratigraphic name was abandoned.

The Hazelton Group was accepted and applied to rocks far removed from the Hazelton area and became firmly entrenched in the literature. Hanson (1925) divided the group into three units: a Lower Volcanic Division, a Sedimentary Division with Middle Jurassic fossils, and an Upper Volcanic Division. Jones (1926) accepted Hanson's three divisions and added a fourth, an Upper Sedimentary Division. Armstrong (1944a, 1944b) proposed a fivefold subdivision of the Mesozoic rocks of the Hazelton area, namely:

(1) a pre-Middle Jurassic volcanic division
(2) a Middle Jurassic marine sedimentary division
(3) a Middle or Upper Jurassic volcanic division
(4) an Upper Jurassic or Lower Cretaceous marine and continental sedimentary division, and
(5) a Lower Cretaceous or later volcanic division

In 1960 Sutherland Brown (1960) gave the names Red Rose Formation and Brian Boru Formation to Armstrong's upper two divisions of the Hazelton Group, the Lower Cretaceous sediments and the Cretaceous volcanics, respectively. Even

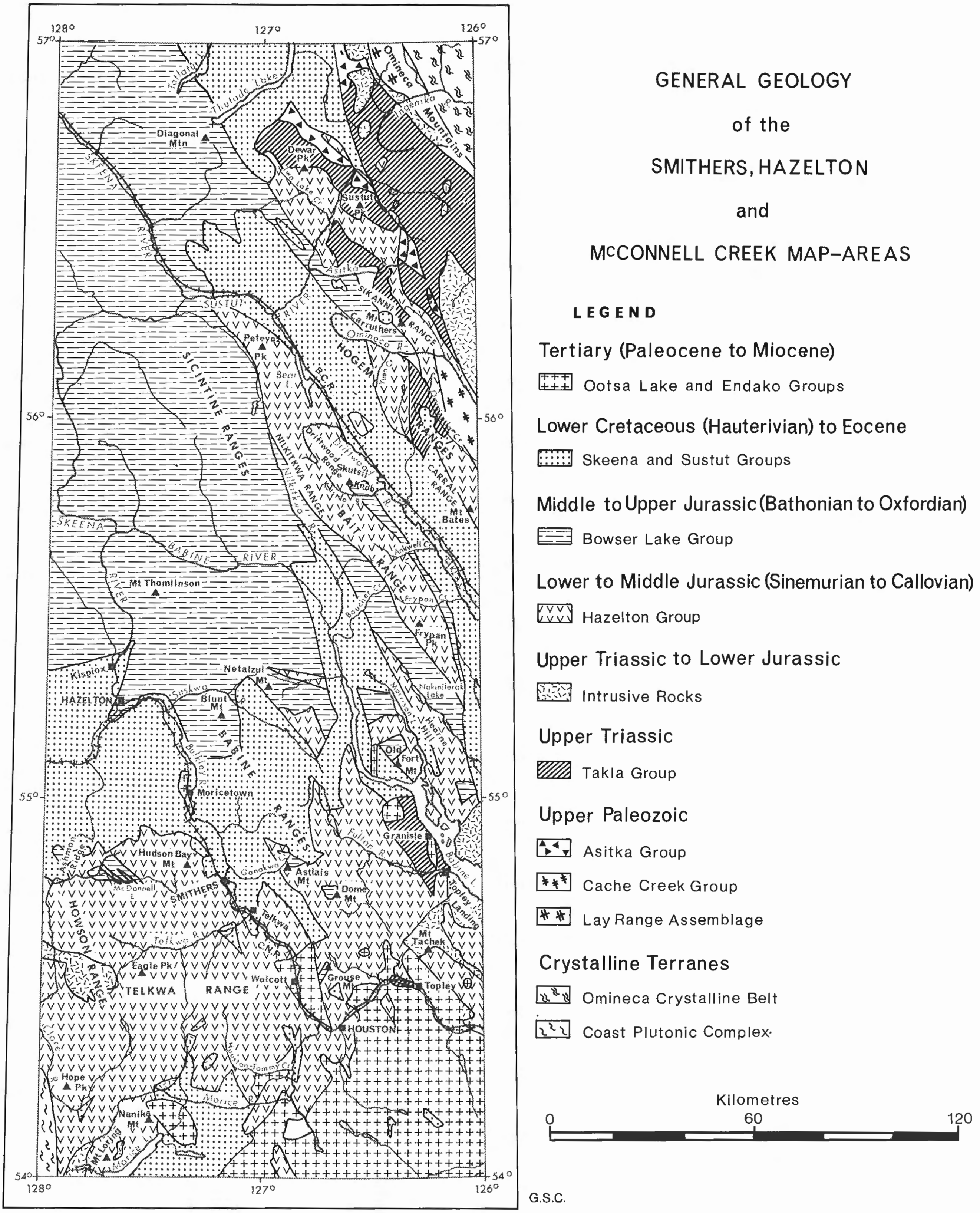

GENERAL GEOLOGY
of the
SMITHERS, HAZELTON
and
McCONNELL CREEK MAP-AREAS
LEGEND
Tertiary (Paleocene to Miocene)
Ootsa Lake and Endako Groups
Lower Cretaceous (Hauterivian) to Eocene
Skeena and Sustut Groups
Middle to Upper Jurassic (Bathonian to Oxfordian)
Bowser Lake Group
Lower to Middle Jurassic (Sinemurian to Callovian)
Hazelton Group
Upper Triassic to Lower Jurassic
Intrusive Rocks
Upper Triassic
Takla Group
Upper Paleozoic
Asitka Group
Cache Creek Group
Lay Range Assemblage
Crystalline Terranes
Omineca Crystalline Belt
Coast Plutonic Complex
Kilometres
0
60
120
G.S.C.
128°
127°
126°
57°
56°
55°
54°
Diagonal Mtn
Dewar Pk
Sustut Pk
Mt Carruthers
Peteyaz Pk
SICINTINE RANGES
HOGEM
SKEENA
BABINE RIVER
Mt Thomlinson
Mt Bates
Frypan Pk
Kispiox
HAZELTON
Netalzul Mt
Blunt Mt
Moricetown
Old Fort Mt
Granisle
Hudson Bay Mt
SMITHERS
Astlais Mt
Dome Mt
Mt Tachek
Eagle Pk
TELKWA RANGE
Walcott
Grouse Mt
Topley
HOUSTON
Hope Pk
Nanika Mt

FIGURE 2

TABLE 1. *Mesozoic stratigraphic names used in north-central British Columbia*

Unit Name	Originator	When Named	Type Area	Lithology	Defined Age	Reference	Present Status
Porphyrite Group	G. M. Dawson	1875	Tatlayoko Lake	volcanic	Jurassic	Dawson (1877)	Abandoned
Nechacco Series	G. M. Dawson	1876	Nechako River near Isle Pierre	shale, augite porphyry	not indicated, post-Paleozoic	Dawson (1878)	Abandoned and included with Takla Group
Hazelton Group	W. W. Leach	1909	Telkwa Range to Hazelton	volcanics sediments	Jurassic	Leach (1910)	Redefined this report as volcanics of Early Jurassic to early Middle Jurassic age
Skeena Series	W. W. Leach	1909	No specific area. Scattered coal basins in Smithers-Hazelton area	sediments with coal, shale predominates	Early Cretaceous	Leach (1910)	Abandoned, then resurrected and redefined this report as Lower Cretaceous sediments and volcanics
Nass Formation	R. G. McConnell	1910	Portland Canal	volcanics with interbedded shales	pre-Late Jurassic	McConnell (1911)	Abandoned and included with Hazelton Group by Hanson (1924)
Bear River Formation	R. G. McConnell	1910	Portland Canal	greenstones	pre-Late Jurassic	McConnell (1911)	Abandoned and included with Hazelton Group by Hanson (1924)
Bitter Creek Formation	R. G. McConnell	1910	Portland Canal	argillites	pre-Late Jurassic	McConnell (1911)	Abandoned and included with Hazelton Group by Hanson (1924)
Kitsalas Formation	R. G. McConnell	1912	Lower Skeena River	volcanics and sediments	Triassic?	McConnell (1914)	Abandoned and included with Hazelton Group by Hanson (1924)
Salmon River Formation	S. J. Schofield and G. Hanson	1920	Salmon River District	conglomerates	Late Jurassic	Schofield and Hanson (1921)	Abandoned and included with Hazelton Group by Hanson (1924)
Dolly Varden Formation	G. Hanson	1921	Kitsault Valley	varicoloured volcanics	Jurassic	Hanson (1922)	Abandoned and included with Hazelton Group by Hanson (1924)
Kitsault River Formation	G. Hanson	1921	Kitsault Valley	argillites	Jurassic	Hanson (1922)	Abandoned and included with Hazelton Group by Hanson (1924)
Takla Group	J. E. Armstrong	1945	Takla Lake	basic volcanics and interbedded sediments	Late Triassic and Jurassic	Armstrong (1945)	Redefined this report as basic volcanics and minor sediments of Late Triassic age
Sustut Group	C. S. Lord	1948	Sustut River	conglomerate, greywacke, shale	Late Cretaceous to Paleocene	Lord (1948)	Valid name. Formation further subdivided to members by Eisbacher (1974)
Tachek Group	J. E. Armstrong	1949	Tachek Mt.	varicoloured volcanics	probably Jurassic	Armstrong (1949)	Abandoned this report and included with the Hazelton Group
Red Rose Formation	A. Sutherland Brown	1960	Rocher Deboule Range	sediments mainly shale and greywacke	Late Jurassic to Early Cretaceous	Sutherland Brown (1960)	Removed from Hazelton Group and defined as part of Skeena Group in this report.
Brian Boru Formation	A. Sutherland Brown	1960	Rocher Deboule Range	volcanics	Early Cretaceous	Sutherland Brown (1960)	Removed from Hazelton Group and defined as part of Skeena Group in this report
Bowser Group	S. Duffell and J. G. Souther	1964	Bowser Lake area	sediments	Late Jurassic to Early Cretaceous	Duffell and Souther (1964)	Name expanded in this report to Bowser Lake Group and age restricted to late Middle Jurassic and Late Jurassic

with these refinements, however, the Hazelton Group has remained an imprecise stratigraphic Jurassic–Cretaceous "catch-all" term.

Takla Group

Armstrong (1945, 1946) introduced the name Takla Group for a complex section of sedimentary and volcanic rocks in the Takla Lake area, east of the exposures of Hazelton Group rocks. Lord (1948) extended the use of the name to the McConnell Creek map-area mainly because of a lithological similarity, but also because the rocks in question appeared to be in the same structural and depositional belt. The age was considered to be Late Triassic to Late Jurassic. No formational names were proposed, although Lord used a twofold system, upper and lower divisions, that corresponded roughly to Jurassic and Upper Triassic rocks. The fact that there was an overlap in age with the Hazelton Group did not present a problem as the intervening area between the two groups was unmapped.

Hazelton and Takla Groups

In the Nechako River area, Tipper (1959, 1963) mapped rocks that could be included partly with the Hazelton Group or entirely with the Takla Group according to current terminology, and an attempt was made to redefine the groups. The Hazelton Group was defined as Middle Jurassic to Lower Cretaceous andesitic, rhyolitic, and basaltic volcanic rocks, with dominantly coarse clastic sedimentary strata. The Takla Group was restricted to Upper Triassic and Lower Jurassic basalt and andesite with argillite, shale, and limestone.

Bowser Group

This name has come into use essentially by accident. In 1956 J. A. Roddick (Geol. Surv. Can., 1957) mapped a wide area of sediments, shale, greywacke, and conglomerate around Bowser Lake to which he applied the name Bowser Group in the field. Although the group was not defined formally in the literature, Duffell and Souther (1964) used the name for the southward extension of these rocks into the Terrace area. The age was stated to be Late Jurassic and Early Cretaceous, thus including sediments that were correlative with Armstrong's upper sedimentary division of the Hazelton Group or Sutherland Brown's Red Rose Formation.

Other Names

Many other group or formational names have enjoyed temporary or local recognition in north-central British Columbia, but currently most geologists employ some variation of the three main groups, Takla, Hazelton, and Bowser (*see* Groves, 1971). Table 1 lists the names that have been used in the Smithers–Hazelton–McConnell Creek and adjacent regions.

PROPOSED NAMES FOR MESOZOIC GROUPS IN NORTH-CENTRAL BRITISH COLUMBIA

From a study of the literature and from the experience of the writers, it is apparent that there are five recognizable Mesozoic groups of rocks in north-central British Columbia (Fig. 2) – the Takla, Hazelton, Bowser Lake, Skeena, and Sustut groups. No new names are proposed, but some are redefined or restricted. Each group represents paleogeographical, structural, volcanological, and sedimentological conditions that have combined to produce lithologically distinct assemblages readily distinguishable in the field.

Takla Group

The Takla Group comprises basaltic and andesitic volcanic rocks, with a preponderance of augite porphyry, pelitic sedimentary rocks, and minor carbonate rocks. Its age is mainly Late Triassic (Late Karnian to Middle Norian, possibly Late Norian). The type area, as defined by Armstrong (1949, p. 51), is in the vicinity of Takla Lake, although it is much better exposed to the north in the McConnell Creek area. There, this definition fits remarkably well with Lord's Lower Division of the Takla Group (Lord, 1948). A refining of the Takla Group has recently been undertaken (Monger, 1974, 1976; Monger, *in press*; Church, 1974), and its definition in these works is used in this report. This definition would make the Takla Group correlative with the Nicola Group (Tipper, 1959, p. 38). Not everywhere is the Takla–Nicola Group volcanism confined to the Late Triassic as, in the Bonaparte Lake area, augite porphyry volcanics continued to accumulate until Early Sinemurian time (Campbell and Tipper, 1971). Paleontological evidence in the present study area, however, indicates that Takla volcanism ceased before Early Jurassic time.

Hazelton Group

The Hazelton Group is a thick and widespread assemblage of basaltic to rhyolitic volcanic rocks, sedimentary rocks, their tuffaceous equivalents, and minor limestone that were deposited in Early and Middle Jurassic (Sinemurian to Early Callovian) time. The group is divided into formations, members, and facies whose description and interpretation form the basis of this paper. There is no type section that defines the Hazelton Group.

The definition proposed here is more restricted than that envisaged by Leach (1910) because it excludes Middle Jurassic and mid-Cretaceous strata now included within the Bowser Lake and Skeena Groups (*see* below). The name Hazelton Group could logically be abandoned as it was originally intended for sediments and volcanics near the town of Hazelton that are no longer part of the group. However, to most geologists, the Hazelton Group is synonymous with sequences of varicoloured Jurassic volcanic rocks as specified by the definition. Addition of a new name would add further confusion to an already chaotic nomenclature. As further defense to the retention of the name, it should be recalled that the volcanics of the Telkwa Range were originally included in the group by Leach, and are retained as a type area for a formation within the redefined Hazelton Group.

Bowser Lake Group

The Bowser Lake Group comprises a thick assemblage of marine and nonmarine sediments composed predominantly of shale, siltstone, sandstone, and conglomerate, with one interbedded volcanic assemblage of green to grey, feldspathic, andesitic breccia, tuff, and flows. It includes most of the Jurassic sediments of the Bowser Basin, including basin, nearshore, deltaic, alluvial, and turbidite facies. Its age is Middle and Late Jurassic (Late Bajocian to ?Early Kimmeridgian or later).

Typical sections in the study areas are Ashman Ridge west of Smithers, and Tenas Creek of the Telkwa Range in the Smithers map-area; Netalzul Mountain, Mount Seaton, Blunt Mountain, Mount Thomlinson in the Hazelton map-area; and Diagonal Mountain and ridges south of Mount Carruthers in McConnell Creek map-area.

The basin of deposition of the Bowser Lake Group is the Bowser Basin, bounded on the south by the Skeena Arch, on the north by the Stikine Arch, and on the east by the Columbian Orogen. The basin apparently opened westward to the Pacific Ocean.

The name Bowser Group was originally proposed for rocks around Bowser Lake, but the use of the name is preempted by the Bowser Member or Formation of the Tuxedni Group in Alaska (Kirschner and Minard, 1949). As the name Bowser is entrenched in the geological literature of British Columbia and in the common usage of working geologists, it is practical to retain the name by expanding it to Bowser Lake Group, thus retaining the original name and recognizing the original geographical feature. This definition also removes Cretaceous strata from the group because of lithological distinctions. It should be noted also that a major hiatus is recognized between Cretaceous and Jurassic assemblages and that the Cretaceous depositional basin is not coincident with the Jurassic Bowser Basin.

Several formations and members can be recognized, and one is described in detail in this report. The group, formation, and member nomenclature as conceived here is now applicable mainly to the southern and southeastern margins of the Bowser Basin, although the group definition is sufficiently encompassing to be applicable to the entire basin.

Skeena Group

The Skeena Group comprises interbedded marine and nonmarine sedimentary and volcanic strata. The sediments are greywacke, sandstone, shale, and conglomerate with common minor or major coal seams. Volcanics are grey to green or varicoloured basaltic to rhyolitic breccias, tuffs, and flows. The proportion of volcanics to sediments in the group varies from place to place. Its age is Early Cretaceous to ?earliest Late Cretaceous (Hauterivian to Albian or ?Cenomanian).

The sediments of the Skeena Group are, in places, difficult to distinguish from Hazelton and Bowser Lake sediments. The sediments of the Skeena Group contain fine flakes of detrital muscovite which are lacking in Hazelton and Bowser Lake sediments. Sediments in the lower part of the Skeena Group were deposited in a different basin than were those of the older Bowser Lake Group. A few paleocurrent determinations in the Smithers map-area indicate a southwest paleoslope during deposition of the Lower Cretaceous strata and a north-northwest slope for the Upper Jurassic strata.

Typical sections of the group are exposed along Bulkley Valley east of Smithers, the Telkwa coalfield, Rocky Ridge, and west of Kitsuns Creek in the Smithers map-area; and in Rocher Déboulé Range, and along Skeena River near Skeena Crossing in the Hazelton map-area. Commonly the group is topographically low and poorly exposed except where intruded by Tertiary granitic stocks or where volcanics are the dominant lithology.

The sea in which the marine sediments accumulated apparently transgressed an area of low relief, spreading outward from the Skeena Valley, crossing the Skeena Arch, and inundating most of central British Columbia. The eastern margin of the basin lay west of the Pinchi belt of Cache Creek Paleozoic rocks, and the western extremity is, as yet, undefined.

The name Skeena Group is resurrected to encompass the coal-bearing Cretaceous rocks, as initially intended by Leach, and the interlayered and closely associated volcanics not originally included. Where the unit is in contact with Hazelton Group, it is readily recognized, but only subtle lithological and sedimentological differences, as well as paleontological criteria, permit separation from the Bowser Lake Group. The Brian Boru and Red Rose formations of Sutherland Brown are two valid subdivisions that are retained. Other units, still unnamed, will undoubtedly be added as work progresses. This report simply emphasizes that the Skeena Group exists as a distinct assemblage of sedimentary and volcanic rocks.

Sustut Group

Lord (1948, p. 34) defined the Sustut Group as "a thick assemblage of conspicuously bedded and banded continental strata of relatively simple structure." It includes conglomerate, sandstone, shale, and bands of tuff. Eisbacher (1974a, p. 8–11) subdivided the group into two formations: a lower, Tango Creek, and an upper, Brothers Peak, and these, in turn, were subdivided into several members, the Niven and Tatlatui for the former, and the Laslui and Spatsizi for the latter. The age is believed to be Late Cretaceous (Cenomanian) to Tertiary (Eocene).

The Sustut Group is the youngest regionally significant sedimentary assemblage in the region. The reader is referred to Eisbacher's definitive report on the Sustut Basin (1974a) for further information.

MESOZOIC BASINS AND THEIR EVOLUTION IN NORTH-CENTRAL BRITISH COLUMBIA

The Intermontane belt (Fig. 1) of north-central British Columbia is underlain mainly by Mesozoic rocks (Fig. 2). The stratified Mesozoic rocks are in the same relative positions in which they formed. Although block faults and intrusive rocks are common, there is little evidence for dislocation along transcurrent faults, no regional high-grade metamorphism, and only minor thrust faults. The rocks all display widespread subgreenschist facies metamorphism. With such an apparently simple deformational history, it is possible to construct a model depicting the tectonic evolution and paleogeography of the Mesozoic basins.

Each Mesozoic group comprises volcanic and sedimentary rocks that define a depositional and tectonic environment that is distinct from its predecessor and its precursor, and represents an evolution from eugeosynclinal to molasse basins. The record begins in Late Triassic time with the deposition of the dominantly alkaline, basalt, and andesite island-arc volcanics of the Takla Group which was superseded in Early to mid-Jurassic time by the dominantly calc-alkaline island-arc basalt to rhyolite volcanics and sediments of the Hazelton Group. Development of the Bowser Basin and deposition of deltaic clastic rocks of the Bowser Lake Group derived from the older Takla, Hazelton, and older groups in Middle to Late Jurassic (Late Bajocian to Oxfordian) time defines an end to island-arc volcanism in north-central British Columbia. A major hiatus, between latest Jurassic and earliest Cretaceous (Kimmeridgian to Hauterivian), probably marks a period of uplift and erosion before deposition of the successor basins of the Skeena and Sustut groups on folded faulted terrane of the Bowser Lake and older groups. This present study focuses on a period of island-arc volcanism and sedimentation of the Hazelton Group that is stratigraphically between an earlier distinctively different arc-assemblage of the Takla Group and a deltaic basin assemblage of the Bowser Lake Group.

The Late Triassic sea had no obvious margins within north-central British Columbia, but was apparently a broad basin or area characterized by chains of volcanic islands marginal to a continent (Fig. 3A). The Takla Group resulted from widespread, mainly submarine, volcanism, whose present outcrop pattern suggests a general northwest linear expression. Clastic sedimentary rocks were derived mostly from erosion and reworking of contemporaneous volcanic rocks. Throughout the region, there is little evidence of emergent older terrane. The basin extended north to the Yukon, and south beyond the 49th Parallel. It is not yet clear whether there was a direct, open connection with the Triassic miogeoclinal sedimentary basin of northeastern British Columbia, nor is it possible to describe its western margin.

During the Early Jurassic to early Middle Jurassic deposition of the Hazelton Group, the Triassic marine basin was effectively split into two distinctive basins (Fig. 3B). Uplift of the Pinchi belt of late Paleozoic (Cache Creek and Asitka groups) and late Triassic (Takla Group) rocks in the eastern part of the area separated the seas into a dominantly sedimentary, successor basin of the Whitehorse and Fernie troughs to the north and east, and a trough that was dominantly volcanogenic to the west, defined here as the Hazelton Trough. This uplift provided detritus to both newly formed troughs. The western margin of the Hazelton Trough is marked by an extensive area (>50 000 km^2) of subaerial volcanics of the lower part of the Hazelton Group, now juxtaposed against the Coast Plutonic Complex, although it probably once extended over the present Coast Mountains. Between the uplift terrane to the east and the nonmarine volcanic mass to the west lay the marine part of the Hazelton Trough. In Late Sinemurian time, the marine part of the trough attained its maximum areal extent, shrinking to a minimum in the early Toarcian, and expanding to a new maximum in the late Bajocian. Only in the eastern part of the Hazelton Trough was marine deposition continuous. This region marked a basin within the Hazelton Trough (the Nilkitkwa Depression) in which subsidence was continuous during most of Lower and Middle Jurassic time. In Bajocian time, a new, east-northeasterly trending, positive element linked the nonmarine, western volcanic landmass of the Hazelton Group with the Pinchi belt to the east. This uplift region defines the Skeena Arch which divided the Hazelton Trough into two separate basins, the Bowser Basin to the north, and the Nechako Basin to the south (Fig. 3C). The development of the Skeena Arch involved only uplift and was not accompanied by any significant deformation or plutonism.

In Late Bajocian to Late Oxfordian time, marine and nonmarine sedimentary rocks and minor basic volcanic rocks accumulated in the Bowser Basin. Sediments were derived from the Pinchi belt to the east, and the Skeena Arch to the south, and unlike the earlier Takla and Hazelton groups, represent clastic detritus derived entirely from a pre-existing older terrane. This sedimentation was a continuation of deposition initiated near the close of Hazelton time, except that these were fairly mature sediments in contrast to the volcanic accumulation of the Hazelton Group. In north-central British Columbia, paleontological evidence indicates a major hiatus in Late Jurassic and Early Cretaceous time that represents a period of uplift, deformation, and erosion.

The Skeena and Sustut groups were deposited on this Upper Jurassic–early Lower Cretaceous erosion surface and rest with unconformable and disconformable relationship on the Bowser Lake and older groups (Fig. 3D). In mid-Early Cretaceous (Hauterivian) time, the sea readvanced from the west, in the area of the Skeena Valley, inundating nonmarine, late Lower Cretaceous coal basins (Telkwa and Lake Kathlyn coal basins), and spread easterly to Babine Lake by mid-Cretaceous (Albian) time. The sediments and volcanics of this interval comprise the Skeena Group, and are correlative with the Taylor Creek and Gambier groups to the south that were deposited in a sea extending across the Coast Plutonic Complex into most of central British Columbia. The sediments of the Skeena Group were derived from an uplifted Pinchi belt–Columbian Orogen. They were deposited in a southerwesterly direction, across the Skeena Arch, which apparently had little influence on the shape of the basin receiving Skeena clastics. The Sustut Group lies to the east of the Skeena Group and is composed entirely of nonmarine clastic rocks and minor acid tuff (Eisbacher,

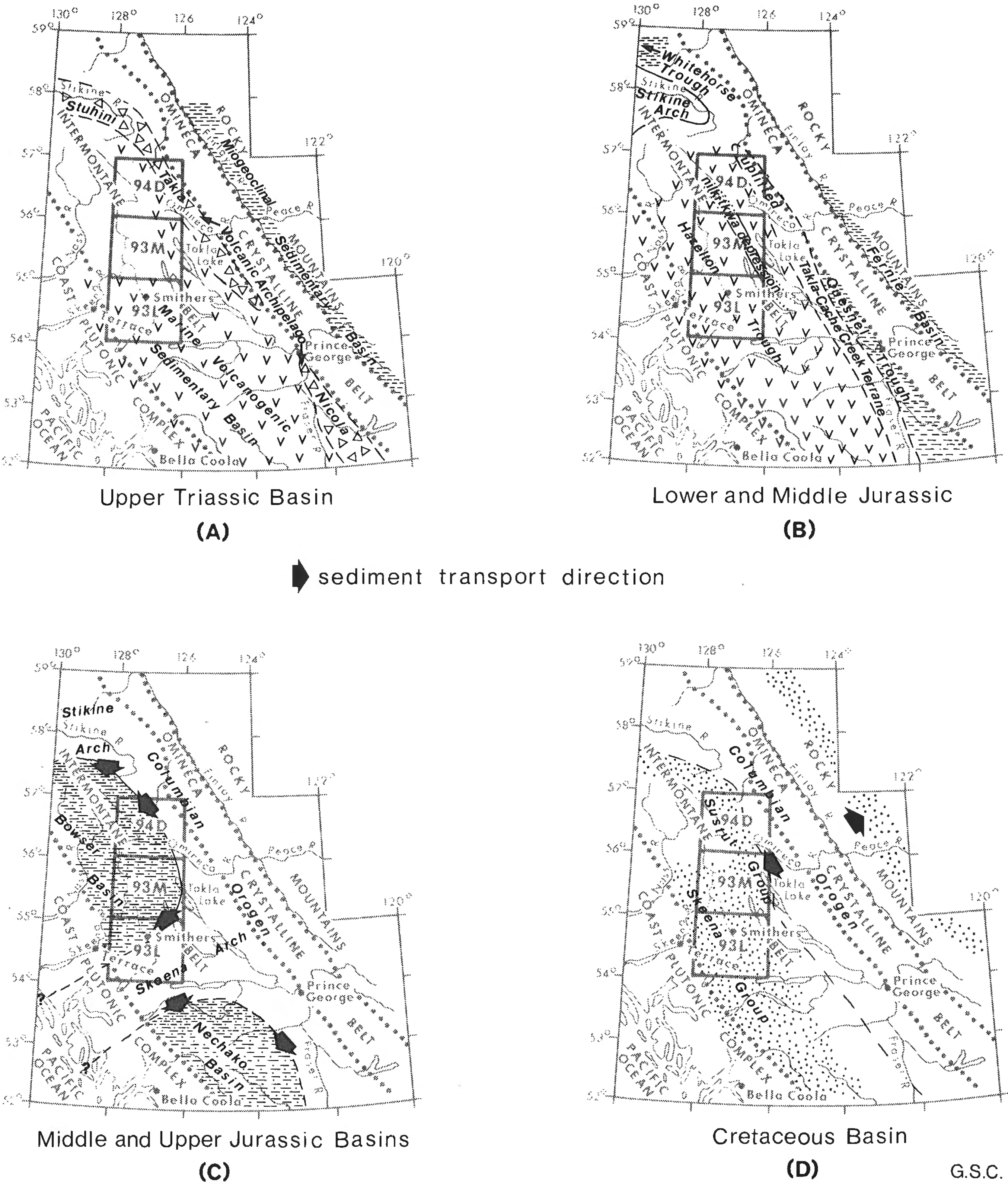


FIGURE 3. Mesozoic basins in north-central British Columbia.

1974a). Although the relation of the two groups is unknown, the Mesozoic part (Upper Cretaceous on paleobotanical evidence) of the Sustut Group may be the nonmarine correlative of the upper part of the Skeena Group.

The foregoing has been an outline of Mesozoic basins in north-central British Columbia. The most reliable and comprehensive information concerns the Hazelton Group, and the Takla and Bowser Lake groups will be discussed mainly in relation to it. The Skeena Group is poorly known, and the Sustut Group has been described by Eisbacher (1974a).

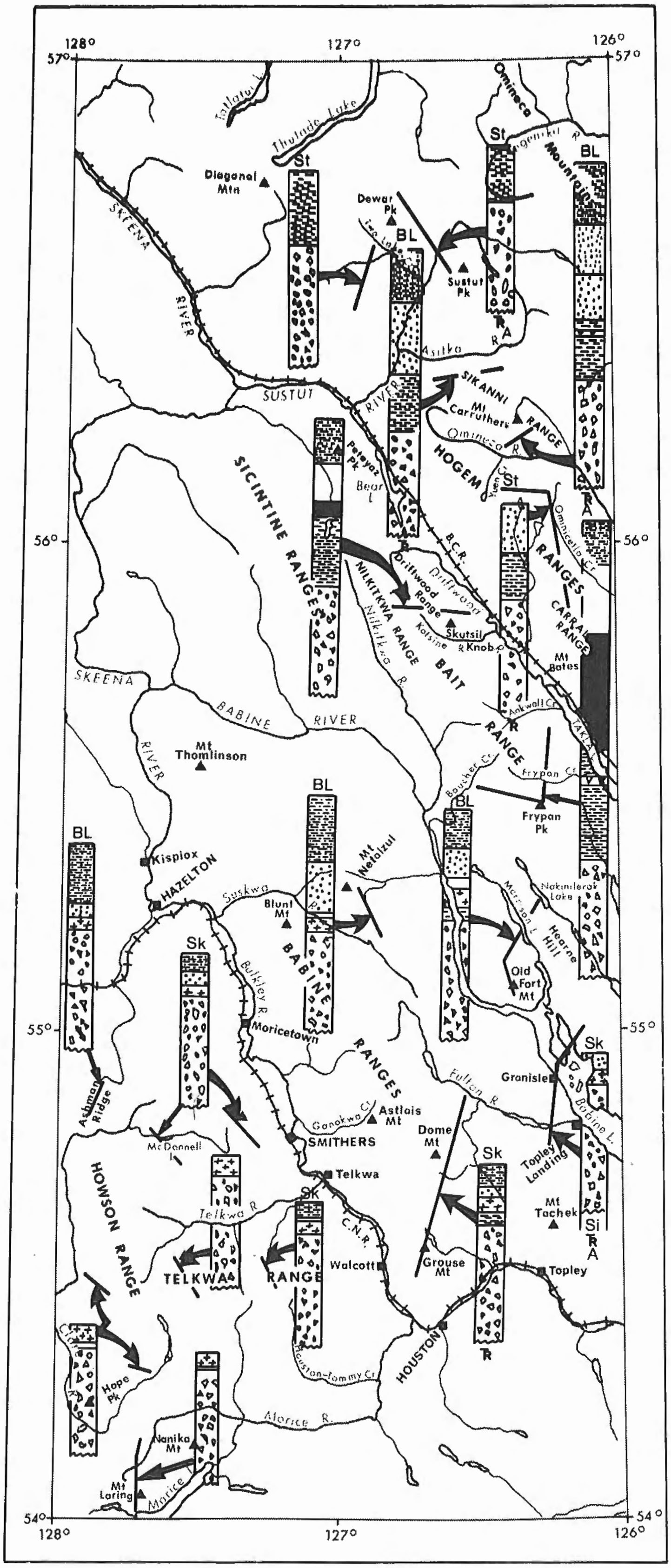
HAZELTON GROUP

The Hazelton Group represents an eugeosynclinal island-arc volcanic and sedimentary assemblage deposited within the Hazelton Trough between Early Jurassic (Sinemurian) and Middle Jurassic (Lower Callovian) time. The northeastern margin of the trough was the uplifted late Paleozoic and Upper Triassic terrane. Its southwest margin may have been uplifted Paleozoic and Triassic strata that are now part of the Coast Plutonic Complex, but, if so, it did not contribute appreciable detritus to the trough.

The group has been divided into three formations (Table 2; Figs. 4, 5). The oldest, termed the Telkwa Formation of Sinemurian to earliest Pliensbachian age, is represented by a thick suite of calc-alkaline volcanics that covers the entire report-area. These volcanics were, for the most part, subaerial eruptives, but within the Nilkitkwa Depression, were of subaqueous origin. The Telkwa Formation has been subdivided into five distinctive facies belts. The Lower Jurassic Topley Intrusions and, possibly, parts of the Hogem batholith are probably coeval with the Telkwa volcanics. Conformable above the Telkwa Formation are the fine-grained clastic and tuffaceous assemblages of the Lower Pliensbachian to Middle Toarcian Nilkitkwa Formation. This formation outlines an abrupt and regional facies change from the underlying volcanic rock. The formation is thickest and most extensive within, and east of, the Nilkitkwa Depression. Volcanic rocks are prevalent throughout the formation, but are most voluminous near, or at its top, where three members, the Carruthers, Ankwell, and Red Tuff, have been defined. The uppermost formation of the Hazelton Group, the Smithers Formation, is characterized by a widespread, shallow-marine, clastic-tuff assemblage of Middle Toarcian to Lower Callovian age. A distal to deep-water,

TABLE 2. *Formations, members, and facies of the Hazelton Group*

Unit	Lithology	Thickness (m)	Age
Smithers Formation	Greywacke, argillite, siltstone, sandstone, sharpstone, conglomerate, glauconitic sandstone, ash-fall tuff, tuffaceous sediments	40–800	Middle Toarcian to Lower Callovian
Bait Member	Argillite, siltstone, fine-grained greywacke, limestone, sharpstone conglomerate, tuff, and tuffaceous sediments	30–450	Middle Toarcian to Middle Bajocian
Yuen Member	Siltstone, tuffaceous siltstone, reddish tuff, fine tuffaceous greywacke	780	Toarcian to Middle Bajocian
Nilkitkwa Formation	Shale, siltstone, greywacke, limy shale, limestone, rhyodacite airfall tuff and breccia, basalt	30–1200	Early Pliensbachian to Middle Toarcian
Carruthers Member	Pillow basalt, aquagene tuff, breccia, minor flows and limestone	60	Late Pliensbachian to Early Toarcian
Ankwell Member	Subaerial and subaqueous alkali olivine basalt, minor sandstone and limestone	10–1000	Middle Toarcian
Red Tuff Member	Subaerial airfall tuff, lapilli tuff, rhyolite to basalt flow breccia and tuff, minor subaqueous volcanics	50–300	Middle and ? Late Toarcian
Telkwa Formation			Late Sinemurian to Early Pliensbachian
Howson subaerial facies	Calc-alkaline basalt to rhyolite flows, breccia, tuff; intravolcanic sediments; minor marl	1000–2500	
Babine shelf facies	Calc-alkaline basalt to rhyolite; subaerial and subaqueous flow, breccia, and tuff; limestone, greywacke, siltstone, and shale	1000?	
Kotsine subaqueous facies	Calc-alkaline basalt and rhyolite; subaqueous flow, breccia, tuff, pillow breccia; limestone, greywacke, siltstone, and shale	30–1500	
Bear Lake subaerial facies	Calc-alkaline basalt to rhyolite flow, breccia, and tuff; and intravolcanic sediments	2000	
Sikanni clastic-volcanic facies	Subaerial conglomerate, sandstone, mudstone, lahar, rhyodacite flow, breccia, basalt, andesite; minor shallow-marine sandstone and conglomerate	200–1000	



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DISTRIBUTION of FORMATIONS and MEMBERS of the LOWER to MIDDLE JURASSIC HAZELTON GROUP

LEGEND

JURASSIC

Bowser Lake Group

Bathonian to Lower Oxfordian

- Ashman Formation

Hazelton Group

Middle Toarcian to Lower Callovian

- Smithers Formation
  - Yuen Member
  - Bait Member

Lower Pliensbachian to Middle Toarcian

- Nilkitkwa Formation
  - Red Tuff Member
  - Ankwell Member
  - Carruthers Member

Sinemurian to Lower Pliensbachian

- Telkwa Formation

OVERLYING STRATA

- St Sustut Group (Cenomanian to Eocene)
- Sk Skeena Group (Hauterivian to Albian)
- BL Mid Oxfordian to Lower Kimmeridgian facies of the Bowser Lake Group

UNDERLYING STRATA

- Si Sterrett Island facies (Hettangian or Sinemurian)
- Ꞧ Takla Group (Upper Triassic)
- A Upper Paleozoic–Asitka Group and unnamed strata

vertical scale represents relative thickness
1 cm ≈ 150 metres

FIGURE 4

fine-grained clastic-tuff facies of the formation, deposited within the Nilkitkwa Depression, is mapped as the Bait Member, and a well-bedded, tuffaceous siltstone facies along the eastern and northeastern margin of the trough as the Yuen Member.

The Hazelton Group overlies the Takla Group and underlies the Bowser Lake Group. The contact with the Takla terrane is found only in the northeast margin of the study area near Sustut River, in association with the Sikanni clastic-volcanic facies. There, the contact is defined by a transition from subaerial and shallow-marine volcaniclastic and epiclastic sediments and basalt-andesite volcanics of the Takla Group into a conglomeratic-fanglomeratic basic to acidic volcanic facies of the Hazelton Group. The contact is not abrupt, and its interpretation is open to speculation (Monger, 1974, 1976, *in press*). To the south, in the Sikanni Range, nonmarine red bed clastic and pyroclastic facies related to the Hazelton Group overlie disconformably different facies of shale, breccia, and volcanic sandstone of the Takla Group. Elsewhere, contacts between the two groups are faulted. Around the periphery of the Bowser Basin, fine-grained argillite and siltstone of the Bowser Lake Group with no volcanics overlie volcanic sandstone and tuffaceous greywacke of the Hazelton Group. This contact is conformable to disconformable and represents a change in style of sedimentation from the primarily cannibalistic character of the Hazelton Group to the deltaic assemblages of the Bowser Lake Group. Across the Skeena Arch, Lower Cretaceous sediment rests unconformably on the Hazelton Group.

Telkwa Formation

The typical lithology of the Hazelton Group is the reddish, maroon, purple, grey, and green pyroclastic and flow rocks that underlie the Telkwa Range, the type area of the Telkwa Formation. The formation comprises a varied assemblage of marine and nonmarine volcanics at the base of the Hazelton Group and is its most voluminous and widespread unit, deposited across the width of the Hazelton Trough (Fig. 4). Five distinctive depositional facies are recognized (Table 2), dominated by basaltic to rhyolitic volcanics (Fig. 6). Three are nonmarine, one partly marine, and one entirely marine. All are of Sinemurian (Early Sinemurian?) to ?earliest Pliensbachian age.

To the southwest, adjacent to the Coast Plutonic Complex, the Howson subaerial facies underlies more than 8000 km^2 of reddish coloured, well-bedded volcanics with calc-alkaline chemical affinities (Fig. 16) and intravolcanic sediments. Between Babine Lake and Bulkley River, a broad region is underlain by poorly exposed volcanic and sedimentary rocks with marine and nonmarine depositional features (*see* Appendix II) that belong to the Babine shelf facies. The transition between this facies and the Howson subaerial facies is defined by a series of limestone bodies and marine clastic rocks interfingering with volcanics west of Bulkley River.

Between the axes of Babine and Takla valleys, greenish tuff, breccia, and marine clastic rocks define the Kotsine subaqueous facies deposited within the Nilkitkwa Depression. The relation of this facies to the Babine shelf facies to the west is speculative because the transition zone is not exposed.

The Bear Lake subaerial facies underlies an extensive area from west of Two Lake Creek, southwesterly to the Bait Range, west of Takla Lake. In the northern part of the Nilkitkwa Depression, it underlies the Kotsine subaqueous facies. Lithologically, it is identical to the Howson subaerial facies but tends to be more alkaline (Fig. 16). The assemblage that defines the eastern margin of the Telkwa Formation is the Sikanni clastic-volcanic facies comprising fanglomerate, conglomerate, pyroclastics, and flows that apparently were deposited in a northwest-trending graben-like basin. Except for a small marine section east of Takla Lake, they are nonmarine.

Howson Subaerial Facies

Strata of the Howson subaerial facies are bright red, maroon, purple, pink, grey, green, well-bedded, slightly deformed basalt to rhyolite (dominantly andesite-dacite), pyroclastic, flow and sedimentary rocks deposited in a terrestrial environment. Pyroclastic rocks predominate. No section is typical of this facies, but three representative sections are described (Appendix III, Sections I, II, III).

The commonest strata comprise andesitic to dacitic pyroclastics, including dense, fine-grained tuff, crystal-lithic-vitric tuff, lapilli tuff, accretionary lapilli tuff, lahar, and fine- to coarse-grained breccia. Coarser grained members are widespread, but are most common in sections between Morice Lake and Zymoetz River. The intermediate pyroclastics are in beds of fine-grained ash a few millimetres thick, to beds of coarse fragmentals more than 20 m thick, the average of which is 25 cm to 2 m. Acidic volcanics of rhyodacite to rhyolite composition (Pls. II, V) include flow-banded and spherulitic flows, welded tuff, eutaxitic welded tuff, dense vitric, vitric-crystal, and vitric-crystal-lithic tuff to unwelded tuff and breccia with abundant altered pumice fragments. Thickness of individual members varies from a few centimetres to more than 40 m. The thickest accumulation is in the northern Howson Range where composite sections reach 300 m. Significantly, these concentrations of acidic volcanics coincide with centres of Early Jurassic plutonism, the Topley Intrusions, dated by the K-Ar method as 195 to 205 m.y. Elsewhere, rhyolites are common as thick, individual blanket-like beds of probable ignimbrite origin. Associated with extrusive acidic pyroclastic rocks, particularly around the perimeter of the Howson Range (and the Topley Intrusions), are domes and small plugs intrusive into the volcanic pile, but identical in chemistry and appearance to the extrusive rocks. One of these near the mouth of Howson Creek is dated as 173 m.y. Flows are subordinate to pyroclastic volcanics and include olivine basalt, tholeiite basalt, and feldspar porphyry andesite. The flows commonly are found in areas distal from the Howson Range (centre of volcanism?) and the acidic volcanics. Many flows are thin (1 to 3 m thick), but are laterally extensive and interbedded with fine-grained pyroclastic rocks and accumulations of interbedded, intravolcanic sediments. This suggests that the flows were deposited within local topographic lows, a relationship in keeping with their low viscosity as compared to acidic members. The intravolcanic sediments (Pl. IV)

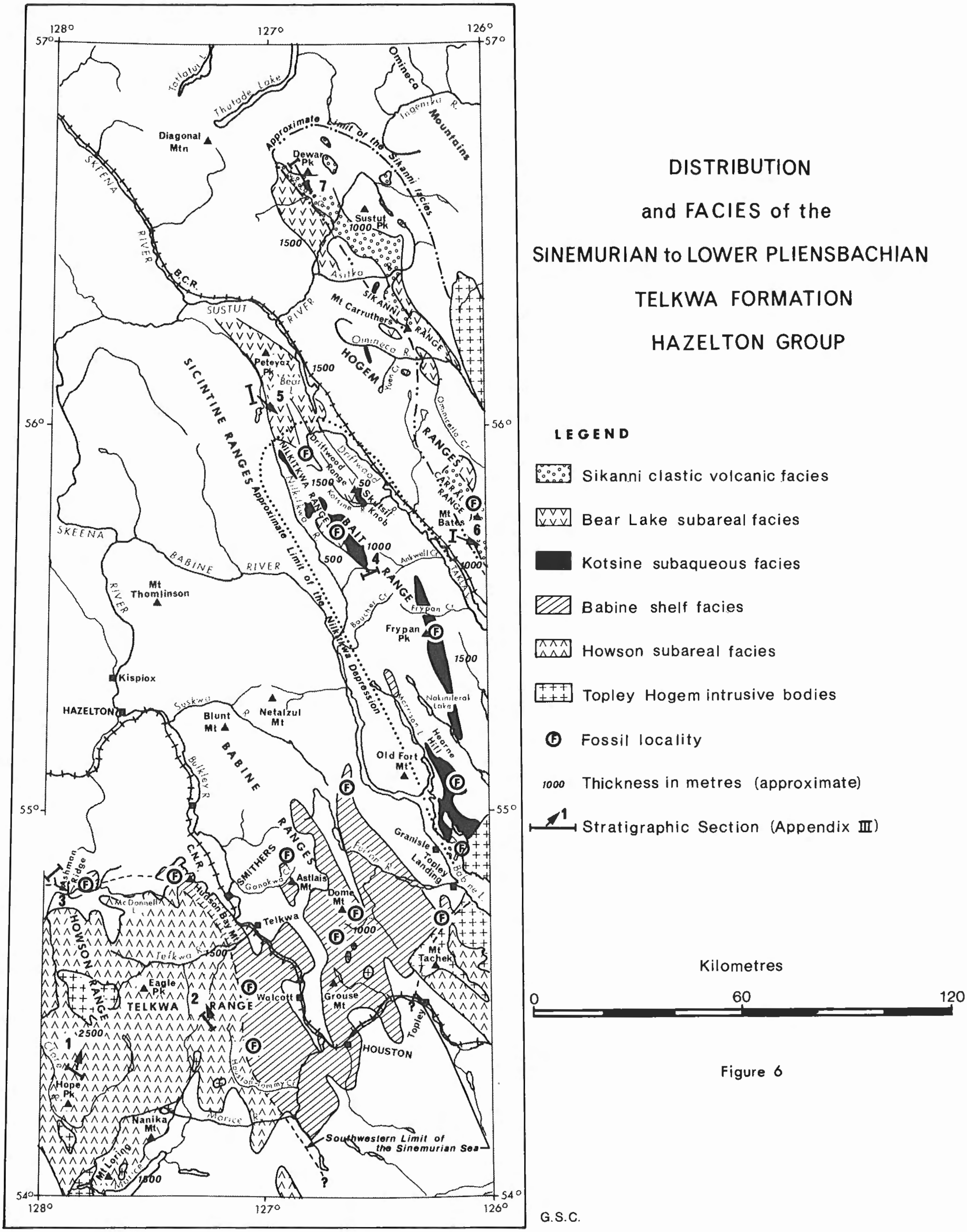
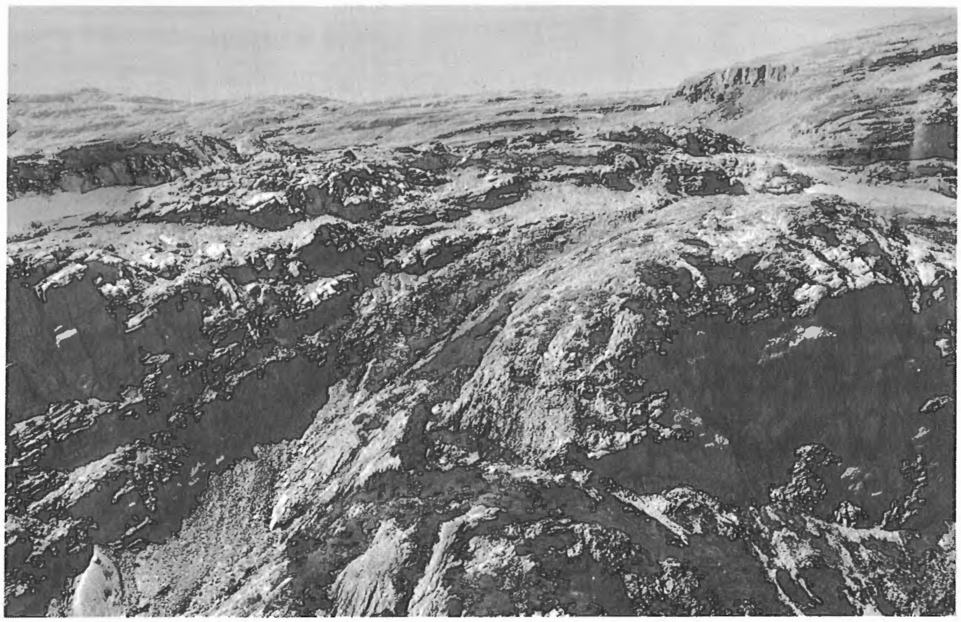

DISTRIBUTION
and FACIES of the
SINEMURIAN to LOWER PLIENSBACHIAN
TELKWA FORMATION
HAZELTON GROUP
LEGEND
Sikanni clastic volcanic facies
Bear Lake subareal facies
Kotsine subaqueous facies
Babine shelf facies
Howson subareal facies
Topley Hogem intrusive bodies
Fossil locality
1000 Thickness in metres (approximate)
Stratigraphic Section (Appendix III)
Kilometres
0
60
120
Figure 6
Approximate Limit of the Sikanni facies
Approximate Limit of the Nilkitkwa Depression
Southwestern Limit of the Sinemurian Sea
SICINTINE RANGES
HOGEM RANGES
BAIT RANGE
BABINE RANGES
TELKWA RANGE
HOWSON RANGE
SMITHERS
HAZELTON
HOUSTON
Telkwa
Kispiox
G.S.C.

FIGURE 6

203022-A
PLATE II. Rhyolite dome intrusive into well-bedded air-fall lapilli tuff; Howson facies, Telkwa Formation, east of Clore River, Smithers map-area.



203022-B
PLATE III. Zeolite (wairakite) cemented breccia, Howson facies, Telkwa Formation, Sunsets Creek, Smithers map-area.

include conglomerate, sandstone, siltstone, mudstone, and marl, probably representing stream and lacustrine deposits derived from the associated volcanics.

Rocks of the Howson subaerial facies have been extensively altered. A regional development of a variety of zeolitic minerals (Pls. III, VI) is found in pyroclastic and sedimentary rocks surrounding the Topley Intrusions in the Howson Range. Epidote and prehnite, and potash feldspar are almost always present. The mineral assemblages belong to the subgreenschist zeolite regional metamorphic facies, but their origin may be more akin to a paleo-hot spring system, contemporaneous with volcanism.

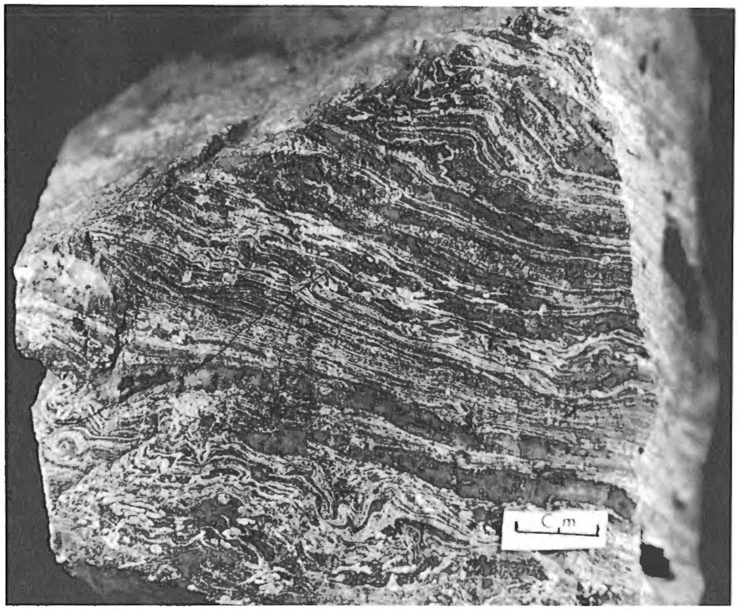
Babine Shelf Facies

Between Bulkley River and Babine Lake, predominant subaqueous and subaerial pyroclastic rocks are intercalated with marine sediments and intravolcanic nonmarine sediments. As exposures are poor, stratigraphic relations are conjectural (Pl. VII).

In the Dome Mountain area, two volcanic members may be present. A lower assemblage comprises interbedded, red, maroon, purple, grey, and green tuff and breccia with interbeds of shale and greywacke. Discontinuous limestone beds and lenses, in places with a pelecypod and ammonite fauna, are common. This unit is overlain by about 100 m

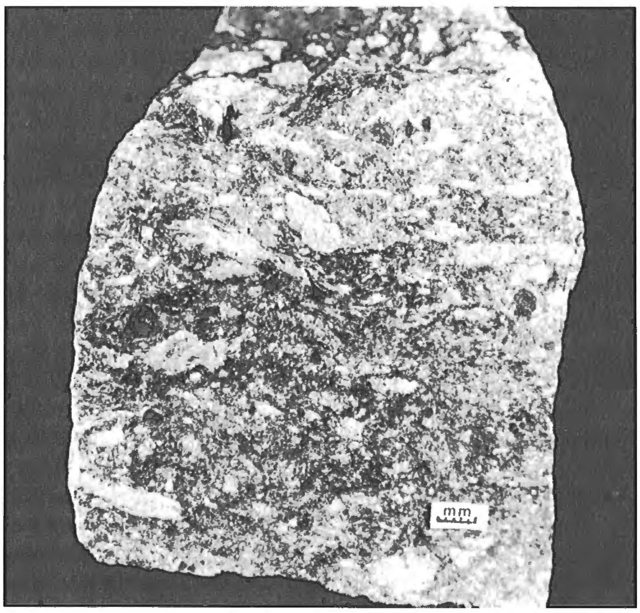
203022-C

PLATE IV. Interbedded sandstone, siltstone, and mudstone intravolcanic sediments, Howson facies, Telkwa Formation, head of Howson Creek, Smithers map-area.



203022-D

PLATE V. Flow-layered extrusive rhyolite, Howson facies, Telkwa Formation, Howson Range, Smithers map-area.



203022-E

PLATE VI. Air-fall lapilli tuff with flattened, zeolitized (laumontite) pumice fragments, Howson facies, Telkwa Formation, Telkwa Mountains, Smithers map-area.

of black shale, separating it from a second volcanic member, estimated to be 900 m thick, of mainly green aquagene tuff, breccia, and flows at the base, grading upward into a mainly subaerial assemblage of reddish coloured lapilli tuff and fine- to medium-grained (basaltic to rhyolitic) breccia and flows. Elsewhere, the separation of the volcanics into two members is not possible.

The transition zone between the Howson subaerial facies to the west, and the Babine shelf facies is a broad (5 km), arcuate belt with limestone reef and reefoid bodies, marine sediments with shell coquinas, and minor aquagene tuff interfingered with the prominent reddish coloured volcanics typical of the subaerial facies. This belt (Fig. 6) defines the westernmost Sinemurian marine advance in the Hazelton Trough.

Kotsine Subaqueous Facies

In the Nilkitkwa Depression, marine volcanics and associated sediments are thickest. In the southern part of the depression, the facies is over 1500 m thick, but thins to less than 200 m northward. This assemblage has been named the Kotsine subaqueous facies.

The subaqueous volcanics within the Nilkitkwa Depression display a varied lithology (Appendix III, Section IV). Included are amygduloidal flows, coarse breccias to finely laminated tuffs, peperite breccias and tuff, pillow and broken pillow breccia in various shades of green and grey, weathering brown (Pl. VIII). Massive beds and flows to finely laminated layers are characteristic. Many breccias are polymictic, with fragments ranging in composition from basalt to rhyolite. The textures in the fragments vary but comprise mainly chilled basalt and andesite clasts with few albitized feldspar laths set in a fine-grained chloritic matrix. Fragments may be angular, rounded, to irregular and are usually finely amygduloidal and spheroidal. Amygdules and spaces between the fragments are commonly filled with calcite, quartz, albite, prehnite, and minor epidote and pumpellyite (Pl. IX). Lenticular limestone bodies, from a few centimetres to 20 m thick, are common, many containing abundant volcanic clasts in a fine-grained, grey, limy mud. Interbedded rusty weathering tuffaceous shale, greywacke, siltstone, and grit a few metres to 60 m thick are common; slump features and flame structures, in places, indicate a general easterly dipping paleoslope.

203022-F

PLATE VII. Typical exposures of Babine shelf facies, Telkwa Formation; looking south to Hearne Hill, Hazelton map-area.

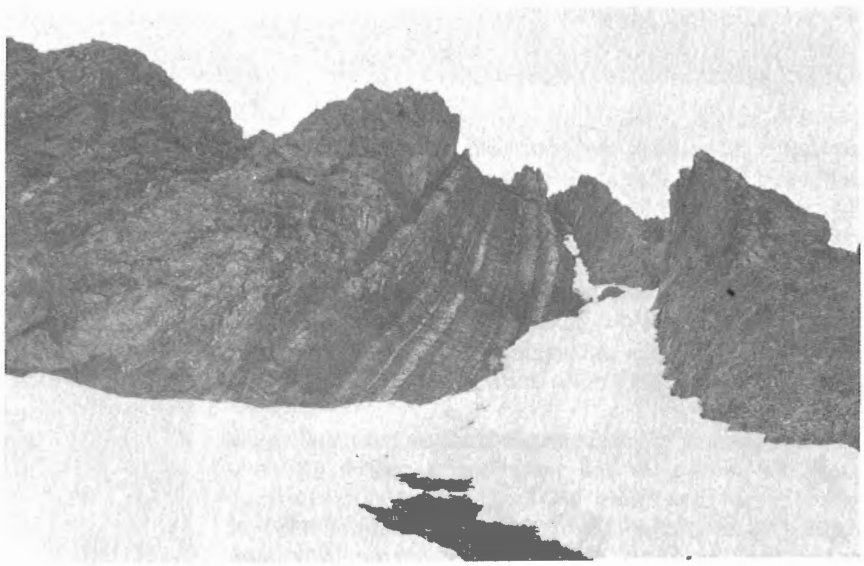


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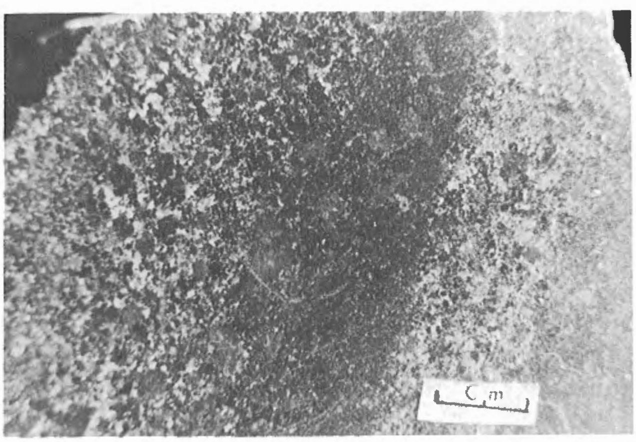
PLATE VIII. Massive bedded, aquagene breccia interbedded with well-bedded limestone, Kotsine facies, Telkwa Formation, Nilkitkwa Range, Hazelton map-area.



203022-H

PLATE IX. Bedded aquagene tuff, dark fragments composed of chilled, chloritic basalt-andesite in a white matrix of quartz-calcite-prehnite and albite, Kotsine facies, Telkwa Formation, Skutsil Knob, Hazelton map-area.

Bear Lake Subaerial Facies

The Bear Lake subaerial facies is composed of reddish coloured basalt to rhyolite pyroclastic, flow and sedimentary rocks that are similar in many respects to the Howson subaerial facies. Thickness is unknown but exceeds 1000 m, except east of Two Lake Creek fault where the facies interfingers with the Sikanni clastic-volcanic facies or is replaced by it. No section of this assemblage is typical of the facies as a whole, but two are listed in Appendix III, Sections IV, V.

The facies ranges from basalt to rhyolite; mainly andesite-dacite and fine- to coarse-grained lapilli tuff and fine-grained breccia are dominant (Pl. X). Flows are common, forming, in places, impressive mesa-like exposures. Olivine basalt and aphanitic basalt are common as individual or composite flows seldom exceeding 50 m in thickness. Fine-feldspar and bladed-feldspar andesitic porphyry is abundant, particularly between Red Creek and Two Lake Creek, as composite piles more than 200 m thick. Acidic rocks (rhyolite and rhyodacite) are ubiquitous in the facies, but are insignificant compared to those of the Howson subaerial facies. They are 1–5-m-thick, well-bedded breccias

203022-I
PLATE X. Massive bedded andesite flow and interbedded red lapilli tuff; Bear Lake facies, Telkwa Formation, head of Two Lake Creek, McConnell Creek map-area.

and tuff to 50-m-thick individual ash-tuff flow units. In the Driftwood Range, they attain their greatest thickness, but no obvious vents were found. Domes, or rhyolitic plugs, common in the Howson subaerial facies, are rare, as are intrusives correlative with the Topley Intrusions, although two small plugs near Sustut River gave K-Ar ages of 184 and 186 m.y. (Church, 1974). Dense, bright red to brick-red, fine-grained tuffaceous mudstone with rare small limestone clasts is characteristic. Coarse-grained breccia and lahar are rare.

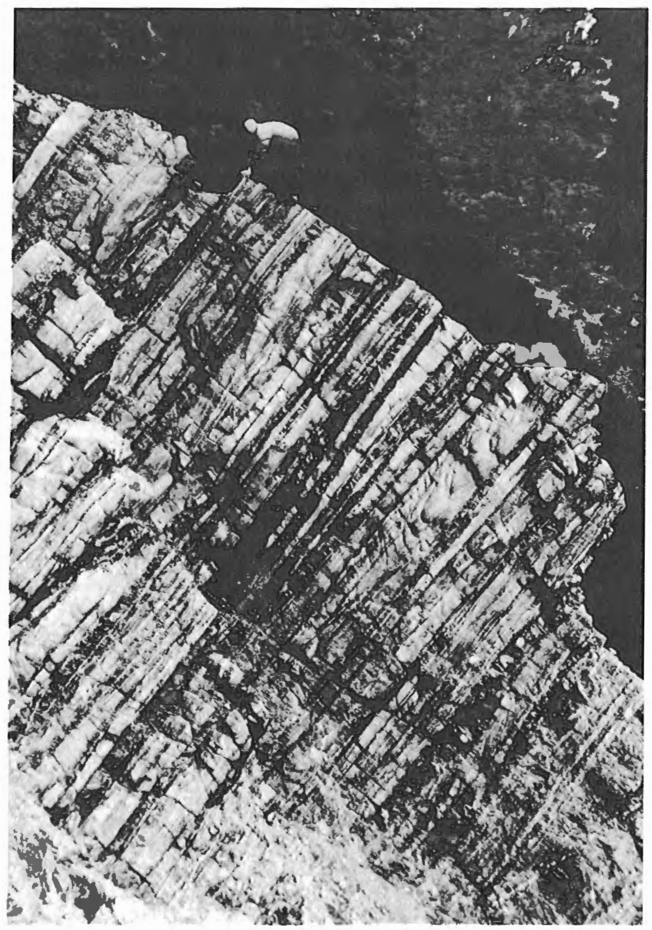
Intravolcanic sediments are reddish, immature siltstone, sandstone, mudstone, and minor conglomerate evidently derived from reworking of the interbedded pyroclastic material by intermittent streams. They are common north of Peteyaz Peak and near Two Lake Creek, but are uncommon in the Driftwood and northern Bait ranges.

Although physically similar to the Howson subaerial facies, the rocks differ in chemistry (Appendix V, Figs. 16, 17). Within the Nilkitkwa Depression, the Kotsine subaqueous facies overlies the Bear Lake subaerial facies. The overlying submarine units thicken rapidly southward, from 30 m in the north, to more than 1500 m in the Bait Range where the subaerial facies is absent. The marine-nonmarine transition is abrupt.

Sikanni Clastic-Volcanic Facies

The Sikanni facies occupies a northwesterly elongated area along the eastern margin of the Hazelton Trough. Strata are a mixture of well-bedded pyroclastics and reworked pyroclastics ranging from lahar, fanglomerate to conglomerate, and their finer grained equivalents (Pl. XI). The strata are various shades of red and mainly subaerial. The thickness exceeds 1000 m, but probably thins abruptly to nil east and west.

Polymictic conglomerate is typical with clasts, up to one metre in diameter, derived locally from older strata. In the north, from Dewar Peak to Omineca River, this polymictic



203022-J
PLATE XI. Interbedded conglomerate, sandstone, mudstone, and tuff, Sikanni facies, Telkwa Formation, west of Willow Creek, McConnell Creek map-area; note cross-bedding.

conglomerate has clasts derived from the early Permian Asitka Group and from granitic bodies (Hogem batholith?), and defines the base of the Sikanni facies near Dewar Peak as cut-channels into the Upper Triassic Takla Group (Monger, 1976). To the south, it occurs 50 to 300 m above the base. A second conglomerate, east of Takla Lake, comprises cobbles derived from the Takla Group and abundant boulders from a granitic terrane (Pl. XII).

The bulk of the unit comprises immature epiclastic and volcaniclastic sedimentary rocks, tuff, and breccia dominated by an assortment of fine-grained feldspar porphyries that may contain olivine, augite, hornblende, or biotite. Unlike the polymictic conglomerate members, these strata rarely contain detritus correlated with older groups. Volcanic rocks range from basalt to rhyolite, with intermediate-acidic types dominant. Ash-flow tuff, rhyolitic breccia, waterlain pumice, tuff, fine red breccia, red lapilli tuff, and tuffaceous mudstone are common; basaltic and andesitic flows are rare. Many rock-types are intermediate between chaotic tephra and alluvial deposits, and include 2- to 20-m-thick breccia, lahar, and fanglomerate beds, and massive members that fine upward to sandstone, siltstone, and mudstone with occasional mudcracks and cross-beds. The last tend to be of low angle, and a general southerly transport direction is indicated.

The rocks are altered, with conspicuous development of either zeolite (dominantly laumontite) or epidote along selected beds such as porous permeable unwelded ash tuff, sandstone, and conglomeratic horizons. Alteration is generally absent in dense, indurated, massive breccia, lahar, fanglomerate, or mudstone. Zeolitization or epidotization along fractures can be locally pervasive.

Marine Sinemurian Sediments along Northeast Margin of Hazelton Trough

Along the northeastern extremity of the Hazelton Trough is an anomalous, thin section of fossiliferous Upper? Sinemurian strata. This section is at Vega Creek in Fort Grahame map-area where Sinemurian ammonites were reported (Roots, 1954) from a thin section of interbedded argillite, tuff, breccia, and conglomerate, a section not unlike parts of the Sikanni facies. The conglomerate contains well-rounded quartzite cobbles, suggesting a northeast provenance. The section could be correlated with the earliest marine Sinemurian beds of the Telkwa Formation and is the most northeasterly exposure of Upper Sinemurian strata in northern British Columbia; it is at least 75 km from the nearest marine Upper Sinemurian in the Nilkitkwa Depression to the southwest.

At least two possible explanations can be offered for its present isolated position and for its former connection to a Sinemurian basin. First, this occurrence could be a remnant of a thin Upper Sinemurian sequence correlative with the deposits of the earliest and broadest marine transgression that are well documented in Smithers map-area. Erosion must have stripped away all other evidence of correlative marine strata along the northeast margin, and the marine strata must stratigraphically overlie the Sikanni facies of the Telkwa Formation. This deposit would probably represent the most northeasterly facies of the Telkwa Formation, if this interpretation is correct. The second possibility is that the section represents a fragmentary record of the southeasterly extension of the Whitehorse Trough, and a connection to the Quesnel Trough to the southeast. If this is possible, then the Sikanni facies of the Telkwa Formation was the subaerial northeast margin of the Hazelton Trough throughout Telkwa time. Either interpretation is possible, or both are, if one considers the possibility of a short-lived marine connection between the Hazelton and Whitehorse troughs across the Pinchi belt in Late Sinemurian time.

Contact Relations of the Telkwa Formation

The base of the Telkwa Formation is exposed in only two areas, on Sterrett Island in Babine Lake, and in the

203022-K

PLATE XII. Interbedded conglomerate, sandstone, tuff and breccia, Sikanni facies, Telkwa Formation, looking west from Mount Bates to the Takla Lake Valley, Hazelton map-area.

northeast between Dewar Peak and Sikanni Range. On Sterrett Island, well-bedded fossiliferous shale, siltstone, and conglomerate, over 30 m thick, and of possible Sinemurian or Hettangian age, is overlain by red and green volcanics of the Telkwa Formation. A coarse boulder conglomerate apparently marks the contact at this locality. Except for a small area of conglomerate within the Howson Range, in the western part of the area, no comparable section has been recognized elsewhere; hence the unit has not been given formal status. It may represent a remnant of strata deposited in the interval between Takla and Hazelton time (Middle Norian to Early Sinemurian).

In the northeast, Sikanni facies overlies the Takla Group. There, the base of the Hazelton is defined, in part by the polymictic conglomerate containing Permian Asitka Group and granitic clasts in the Dewar Peak region and by a nonmarine clastic-volcanic red bed facies containing feldspar porphyry clasts overlying marine argillite and augite porphyry volcanic-clastics of the Upper Triassic Takla Group in the Sikanni Range. The most probable age for the Sikanni facies is Sinemurian, based on *Weylas* and poorly preserved ammonites from Carrall Ridge, east of Takla Lake. A Sinemurian age for the entire Sikanni facies is speculative as no fossils were found in the Dewar–Sustut area. There, the Asitka-cobble conglomerate overlies disconformably Lower Norian strata, implying a hiatus between the Takla and Hazelton groups encompassing Late Norian, Rhaetian, Hettangian, and possibly Early Sinemurian stages.

The Telkwa Formation is overlain both conformably and nonconformably by the Nilkitkwa Formation. From Dome Mountain in the Smithers map-area, to Two Lake Creek in the McConnell Creek map-area, a distance of some 225 km, the volcanics of the Telkwa Formation are overlain conformably and abruptly by fine-grained clastics of the Nilkitkwa Formation. To the west, the Howson subaerial facies is overlain disconformably by Toarcian marine sediments and the Red Tuff Member of the Nilkitkwa Formation.

Age of the Telkwa Formation

All fauna from the various facies of the Telkwa Formation indicate a Sinemurian, probably Late Sinemurian, age (Appendix IV). It may be as young as Early Pliensbachian, but this is suggested only in the Dome Mountain area. Over the broad area including the Babine shelf and the Bear Lake subaerial facies, fauna at the base of the Nilkitkwa Formation suggest an Early Pleinsbachian age.

Topley Intrusions in Relation to the Telkwa Formation

The Topley Intrusions are calc-alkaline stocks and batholiths of Early Jurassic age that intrude the Telkwa Formation of the Hazelton Group. They form a series of bodies coincident with the Skeena Arch, of which the Howson batholith in the west and the Tachek batholith to the east are the largest. Although they strike directly into the Coast Plutonic Complex, they have not been recognized within it. K-Ar ages range from 173 to 205 m.y., with older ages restricted to the batholithic bodies (Howson batholith, 189 m.y.; Tachek batholith, 195 to 205 m.y.). These intrusive bodies are thought to be contemporaneous with, and intrusive into, the Telkwa Formation. The intrusions are coincident with the thickest piles of volcanics and are associated with the greatest abundance of acidic extrusives.

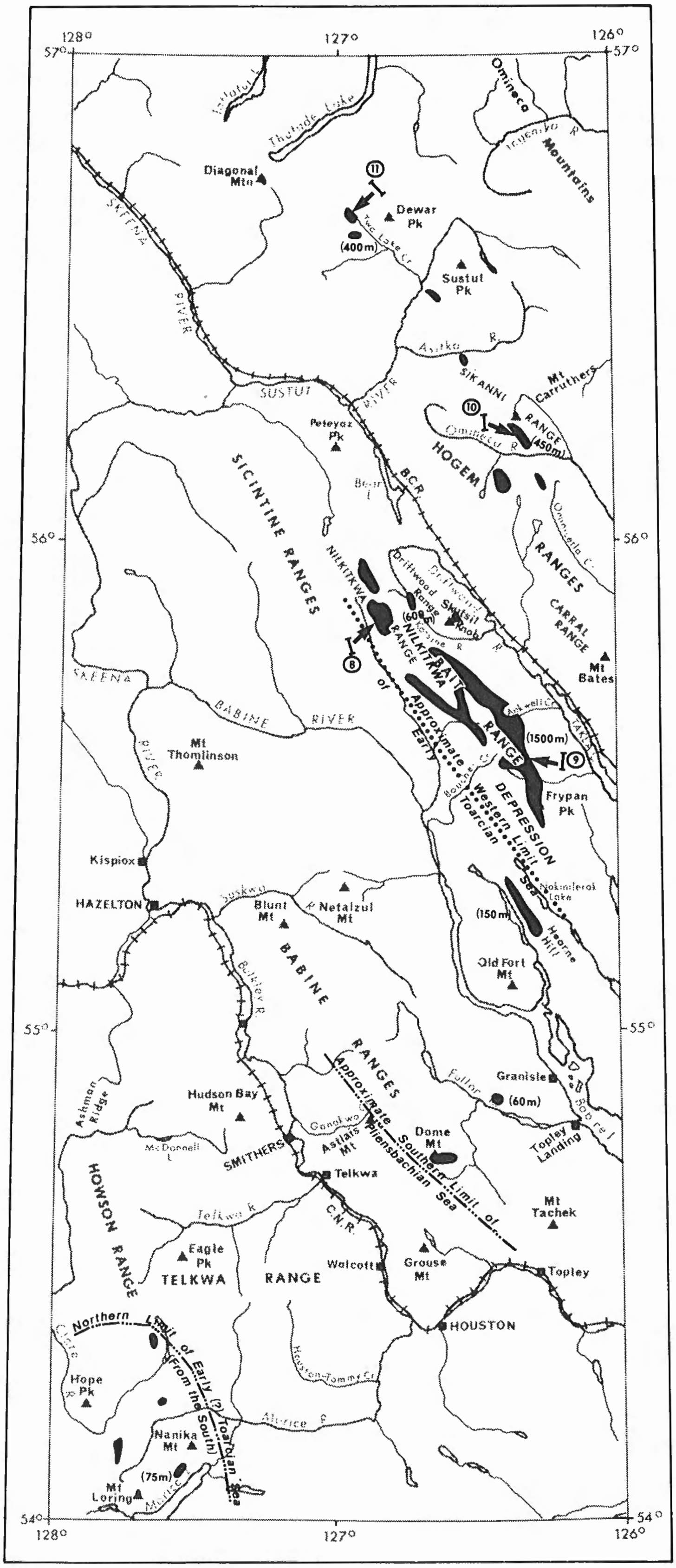
The intrusives are of epizonal type. Roofs of volcanic strata are well preserved, and porphyry bodies are common. Contacts are sharp, and metamorphic effects are mainly baking, although there is evidence of K-feldspar metasomatism adjacent to the Tachek batholith. The larger bodies are composite and commonly unfoliated. The Tachek batholith comprises a megacrystic K-feldspar, hornblende quartz monzonite, with large areas underlain by leucocratic quartz monzonite or granite. Fine-grained rhyodacite stocks and dykes are common. The Howson body comprises mainly tonalite and granodiorite. The rocks are usually altered to saussuritic assemblages.

The Topley Intrusions outcrop in an east-northeast-trending belt along the axis of the Skeena Arch. They are probably correlative with the Hogem batholith, from which K-Ar ages of 170 to 200 m.y. have been obtained (Woodsworth, 1976). The loci of the Topley and Hogem intrusive rocks outline the margins of the Bowser Basin, successor to the Hazelton Trough.

Nilkitkwa Formation

The Nilkitkwa Formation comprises as much as 1000 m of interbedded shale, greywacke, andesitic to rhyolitic tuff and breccia, and minor limestone (Fig. 7). The formation is well exposed with a nearly complete type section in Nilkitkwa Range, Hazelton map-area, but is thickest 30 km south, in the Bait Range (Pl. XIII). In McConnell Creek map-area, the most complete section is exposed north of Omineca River, southeast of Mount Carruthers, but the section is not typical of the group in all aspects; northward the group becomes more shaly. The formation outcrops intermittently as far west as Dome Mountain, Smithers map-area, where it is much thinner. It is not known to be present immediately west of Bulkley River, but in the southwestern part of Smithers map-area, near Morice Lake and in the southern Howson Range (Fig. 7), a thin shale facies is included with the formation (Pl. XVIII). Except for a small area near Morrison Lake, the formation is entirely marine and was deposited in Early Pliensbachian to Middle Toarcian time. Acidic volcanic activity was dominant, and no thick piles of volcanic rocks accumulated except the basaltic Ankwell Member in mid-Toarcian time, the basaltic Carruthers Member in latest Pliensbachian time, and the calc-alkaline Red Tuff Member in mid-Toarcian time. At no time was volcanism as significant as in the underlying Telkwa Formation. The aforementioned three members of the Nilkitkwa Formation represent three short-lived volcanic episodes.

Four representative sections are described, one about 500 m thick in the southern Nilkitkwa Range, one about 1000 m thick on an east-trending ridge in the southern Bait Range, one about 630 m thick north of Omineca River, and one about 380 m thick at the head of Two Lake Creek (Appendix III, Sections VIII, IX, X, XI). In its type area the formation includes well-bedded, laminated to massive shale, argillite, siltstone, fine-grained greywacke (turbiditic in part), andesite



G.S.C.

DISTRIBUTION
of the
CLASTIC-TUFF FACIES
of the
LOWER PLIENSBACHIAN-MIDDLE TOARCIAN
NILKITKWA FORMATION

LEGEND

Nilkitkwa Formation

(100m) Approximate thickness in metres

⑧ Stratigraphic sections (Appendix III)

Kilometres
0 60 120

FIGURE 7

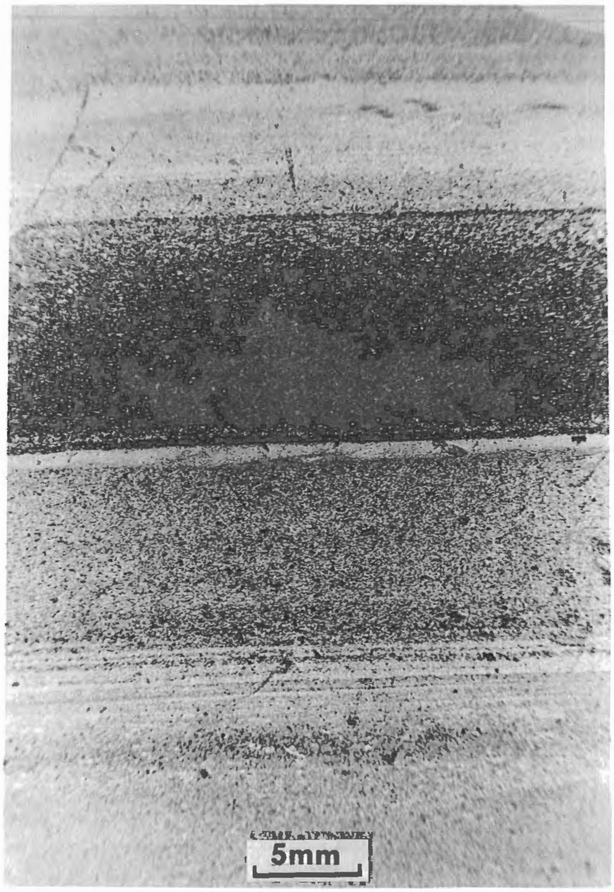
203022-L
PLATE XIII. Exposure of Nilkitkwa Formation looking west from east flank of the Bait Range, Hazelton map-area.

203022-M
PLATE XIV. Interbedded siliceous tuff (light coloured) and argillaceous siltstone, Nilkitkwa Formation, southern Bait Range.

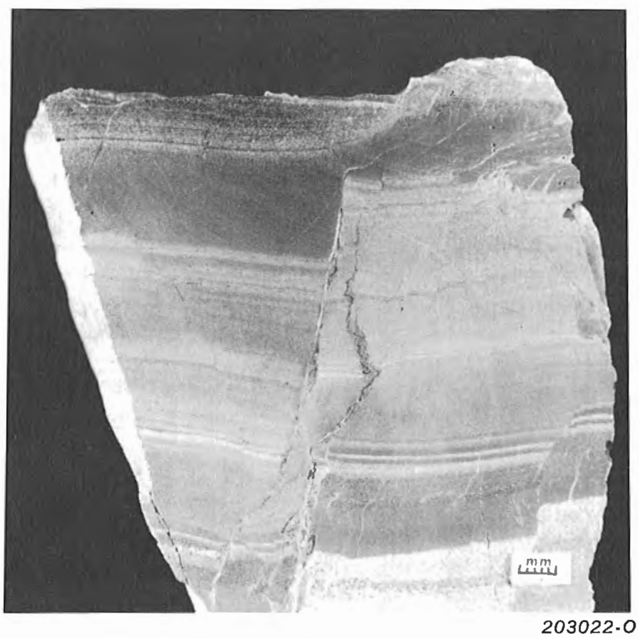
to rhyolite tuff, tuffaceous sediments, and fine- to medium-grained breccias, minor limestone, and green aquagene tuff and breccia (Pls. XIV, XV). Altered or fresh diabase sills form integral parts of the section, but are thought to be feeders to basalts of the Ankwell and Carruthers members. Characteristic rusty weathering results from abundant disseminated synsedimentary pyrite grains and concretions. Bedding ranges in thickness from a few millimetres in ash-tuff members, to 10 m in massive greywackes, to 60 m in rhyolites. Sedimentary structures include graded beds, some with terminated tops, rip-up clasts, flame structures, syndepositional faulting, and flow rolls (Pls. XVI, XVII). In the Nilkitkwa Depression, the last feature indicates slumping in an east to northeast direction.

The type section and the section in the southern Bait Range (Appendix III, Sections VIII, IX) characterize the formation within the Nilkitkwa Depression and, although these and other sections are characteristically shale, siltstone, tuff, and greywacke, variations are common. Typically the basal 200 to 350 m is black, commonly sulphurous, argillite and shale, feldspathic greywacke, and minor tuff and tuffaceous greywacke. An exception to these fine-grained strata is on Skutsil Knob where limestone, sandstone, and pebbly sandstone, 6 m thick, locally with coquinas and wood fragments, suggest the only shallow-water depositional facies in the type area. These lower beds are succeeded by a variety of pelitic sediments, intermediate to acid tuffs, tuffaceous greywacke, greywacke, and a few interbeds of green breccia and tuff. The upper beds are argillite, greywacke, tuff, and tuffaceous sediments. Limestone is uncommon but limy concretions are plentiful. Volcanic sediments are generally subordinate.

Farther north, in McConnell Creek map-area north of Omineca River, the formation is well exposed, with few faults



203022-N
PLATE XV. Interbedded, finely laminated ash-fall tuff (light coloured) and siltstone, Nilkitkwa Formation, Nilkitkwa Range.



203022-O
PLATE XVI. Syndeposition slump-faulting in ash-fall tuff-siltstone and greywacke, Nilkitkwa Formation, head of Ankwell Creek, Hazelton map-area.

203022-P
PLATE XVII. Slump-folding in siltstone-greywacke of the Nilkitkwa Formation, southern Bait Range, Hazelton map-area.

and depositional breaks (Appendix III, Sections X, XI). The lower part, the Pliensbachian beds, is characterized by fine rhyolitic tuff and tuffaceous siltstone overlying shale and limy shale. One or two green, basic breccias as much as 8 m thick are interlayered. The upper part, the Lower to Middle Toarcian beds, is tuffaceous siltstone and fine sandstone, with an abundant ammonoid, belemnoid, and pelecypod fauna. Northward, the volcanic character disappears, and shale, limy shale, and reefoid limestone with only minor tuff beds are characteristic. Exposure of the formation becomes limited, and it disappears beneath the younger Bowser Lake Group.

In the Morrison Lake area to the southwest, the formation is poorly exposed and occurs as small fault slices. There, marine black shale, medium- to coarse-grained greywacke, pebbly lithic sandstone, isolated limestone pods to 2 m thick, ash-tuff, and tuffaceous sandstone are interbedded with red, maroon, and green volcanic flow, breccia and tuff, and intravolcanic sediments. The volcanics and some sediments may be of subaerial origin. The presence of pebbly conglomerates, with shell coquinas, some winnowed sandstone, abundant wood fragments in sandy members, and a paucity of ammonite fauna suggests that this facies represents shallower water deposition than does that found to the east.

In Smithers map-area, the Nilkitkwa Formation is rarely encountered. Between Dome Mountain and Fulton Lake, the formation is characterized by a black shale facies that is as much as 150 m thick. In the area of Mount Loring–southern Howson Range the formation is represented by about 60 m of black shale, limestone, minor conglomerate, and greywacke grit. Although there is little doubt that this facies is correlative with part of the formation, lack of good paleontological control puts its precise age in question. As these sections are about 90 km southwest of the nearest Nilkitkwa Formation exposures, there is a possibility that a landmass separated the depositional areas.

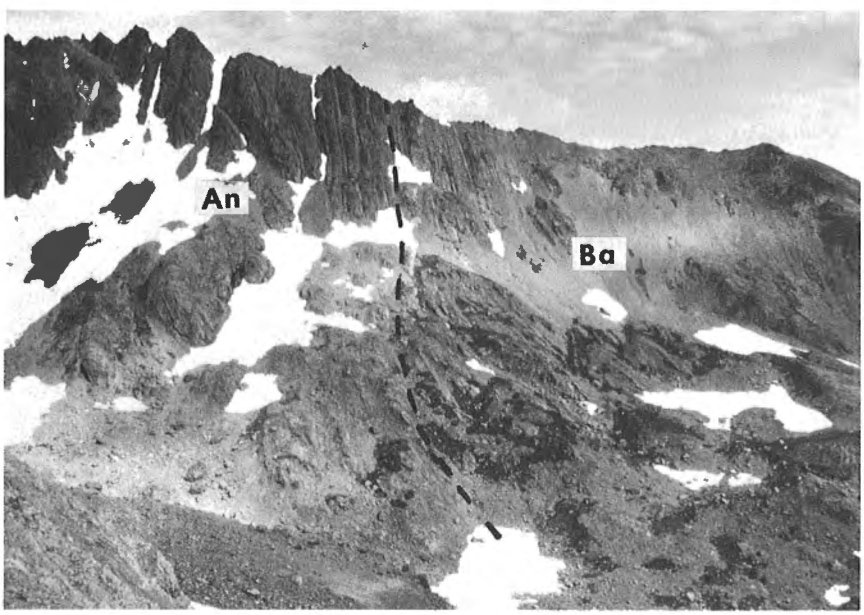
Contact relations with overlying and underlying formations vary. In the Driftwood and Nilkitkwa ranges, Hazelton map-area, the formation rests conformably on green aquagene volcanics of the Telkwa Formation. The transition

203022-Q
PLATE XVIII. Folded argillite-limestone-greywacke of Nilkitkwa Formation, looking north towards Burnie Lake, Howson Range, Smithers map-area.

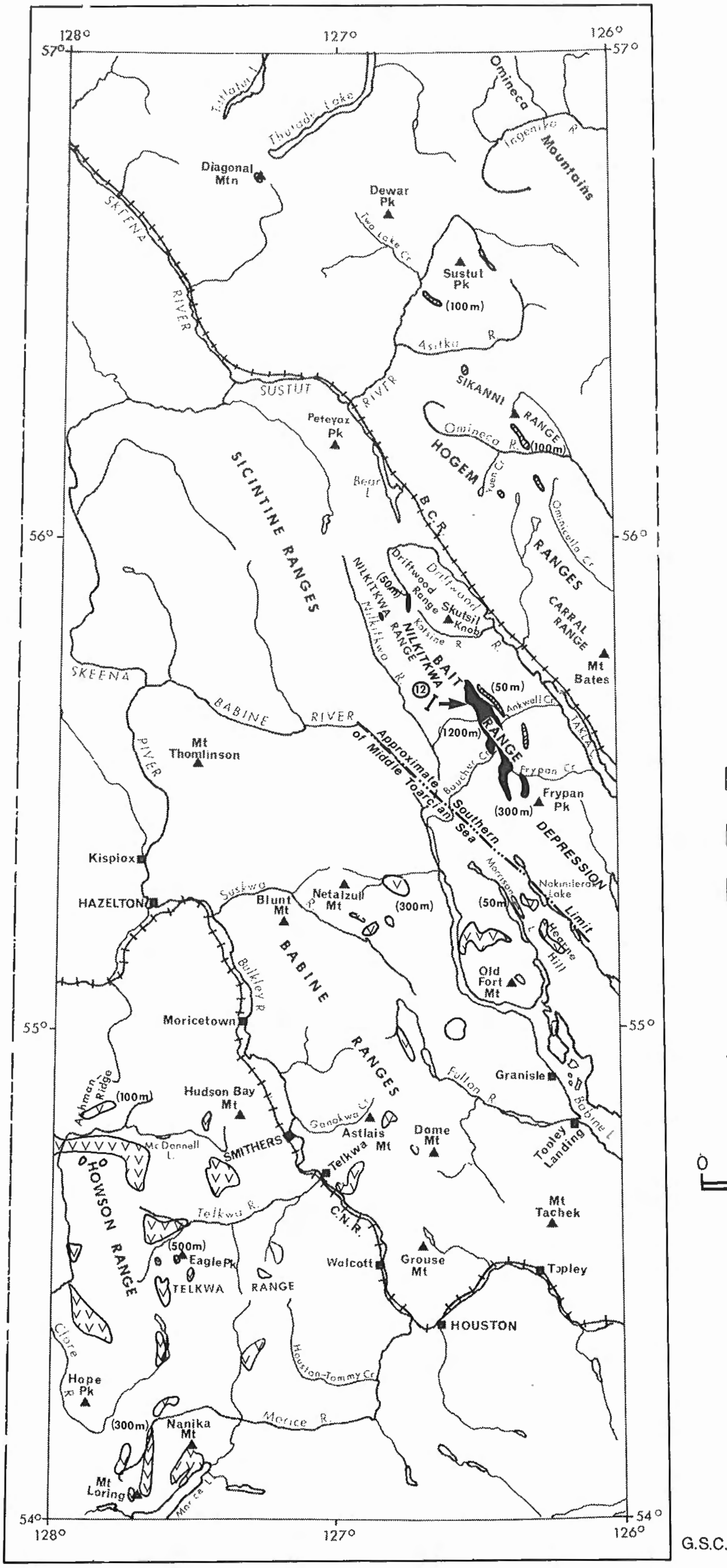
from a volcanic to a sedimentary environment is abrupt. Near Skutsil Knob, the transition from volcanics to sediments is marked by 6 m of shallow-water clastic sediments that grade into fine-grained tuffaceous sediments typical of the Nilkitkwa Formation. On the north end of the Nilkitkwa Range, 30 m of limestone and volcanic-limestone breccia overlies, the submarine Telkwa Formation, whereas in the south part of the range, black shale overlies broken pillow breccia and aquagene tuff. In the Bait Range, the contact relations between the Telkwa and Nilkitkwa formations is less well defined as beds of aquagene breccia 3 to 20 m thick are interbedded with fine-grained clastics and tuffs in the lower 200 m of the Nilkitkwa Formation. Its upper contact with the Ankwell Member is gradational over 50 m (Pl. XIX). On Dome Mountain, the base of the Nilkitkwa Formation is black shale resting on red volcanics of the Telkwa Formation, and at its upper contact, black shale underlies conformably the Red Tuff Member. On Mount Loring, the formation is conformable with the underlying Telkwa Formation and the overlying Red Tuff Member.

The Nilkitkwa Formation ranges in age from Early Pliensbachian to Middle Toarcian with a diverse fossil fauna. The ammonoid fauna is particularly varied and abundant, and in areas marginal to the basin, pelecypods, gastropods, crinoids, belemnoids, and corals abound. Plant remains, although not abundant, are commonly found as solitary specimens.

Three volcanic members of the Nilkitkwa Formation are recognized (Fig. 8). They are interbedded with the upper part of the formation and may be partly correlative with



203022-R
PLATE XIX. Contact of Ankwell (An) and Bait members (Ba), southern Bait Range, Hazelton map-area.



DISTRIBUTION of the VOLCANIC CARRUTHERS ANKWELL and RED TUFF MEMBERS of the NILKITKWA FORMATION

LEGEND

- Red Tuff Member
- Ankwell Member
- Carruthers Member
- Toodoggone volcanics
- (100 m) Thickness in metres
- ⑫ Stratigraphic sections (Appendix III)

Kilometres: 0 — 60 — 120

FIGURE 8

one another. They are not considered to be formations as they are of local importance, but they are sufficiently distinct to warrant discussion as members of the Nilkitkwa Formation with which they are inextricably linked.

Carruthers Member

The Carruthers Member is a suite of basaltic volcanics, mainly submarine, that erupted across the area from Morrison Lake to Mount Carruthers. It represents a brief period of volcanism in the upper Nilkitkwa Formation during Late Pliensbachian to Early Toarcian time. It seldom exceeds 100 m in thickness and is absent locally. The member was probably not spread across the whole area, but rather formed a series of isolated lenses or mounds. Peperite breccia, tuff and pillows, and broken pillow breccia are dominant in the Bait and Sikanni ranges. Along the east shore of Morrison Lake, augite porphyry amygduloidal breccia and flow rocks are interbedded with Upper Pliensbachian shallow-water marine sediments of the typical Nilkitkwa Formation, and represent a shallow-water to nonmarine facies of the member. These volcanics are similar to, and represent a precursor to, the more voluminous, but more restricted Ankwell Member. In the Bait Range, where both members occur, they are separated by up to 200 m of strata.

The age of the member is not precisely known, but ranges persistently between the Late Pliensbachian ammonite *Arieticeras* sp. and the Early Toarcian ammonite *Harpoceras* sp. The event was of short duration.

Ankwell Member

The Ankwell Member consists of dominantly subaqueous alkali olivine basalt (Figs. 16 and 17) in the Bait and Nilkitkwa ranges. In the Bait Range, near Ankwell Pass, a representative section is 946 m thick, but total thickness may be nearer 1200 m (Appendix III, Section XII). The formation thins to 20 m in the Nilkitkwa Range about 30 km north, and to 200 m in the most southwesterly part of the Bait Range. Its age is Middle Toarcian, the time of the last major episode of marine volcanism in the Hazelton Group. Penecontemporaneous volcanics to the west are mainly subaerial and are named the Red Tuff Member (*see* below).

The member is characterized by massively bedded, brown-weathering, light to dark green aquagene tuff, fine- to medium-grained breccia, broken pillow breccia, peperite breccia, and thick (10 to 30 m) amygduloidal flows. Throughout, but particularly near the top of the unit, are interbeds of green, volcanic, lithic, winnowed sandstone that locally are cross-bedded and contain abundant thick-shelled pelecypod fauna. Limestone pods up to 10 m thick are common, and contain a rich shelly fauna, including the pelecypods *Myophorella* and *Trigonia*, belemnites, star-shaped crinoid columnal sections, a characteristic high-spired, *Turitella*-like gastropod, and various brachiopods and corals. The limestone pods are replete with green volcanic clasts (Pl. XX). Many aquagene tuffs and breccias have fine-grained limestone mud matrix, termed limestone-volcanic breccias (Pl. XXI).

Just south of Ankwell Pass, near the top of the formation in its thickest part, the aquagene tuff passes upward into red, maroon, purple and grey, massively bedded olivine basalt, with local columnar jointing. These are interpreted to be subaerial and suggest the building of a volcanic island (Pl. XXII). Interbedded with the flows are subordinate, brilliant red, brick-red to maroon, fine-grained lapilli tuff to fine-grained breccia with minor interbedded reddish intravolcanic mudstone and sandstone. The subaerial assemblage reaches a maximum thickness of 300 m immediately south of Ankwell Pass, and disappears rapidly in about 5 km north and south. Except where thickest, the subaerial basalts pass upward into a repetition of the green aquagene tuff-breccia assemblage and are associated with volcanic sandstone containing thick-shelled pelecypods and some thin limestone pods.

In the southern Nilkitkwa Range, the member is 20 m

203022-S
PLATE XX. Clasts of amygduloidal basalt in biohermal limestone pod, Ankwell Member, Bait Range, Hazelton map-area.

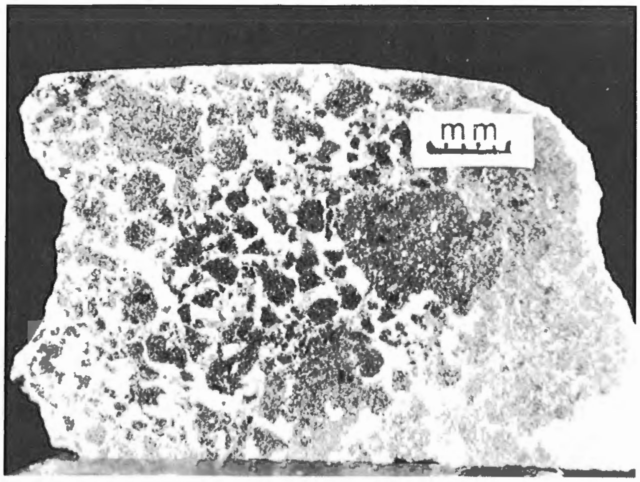


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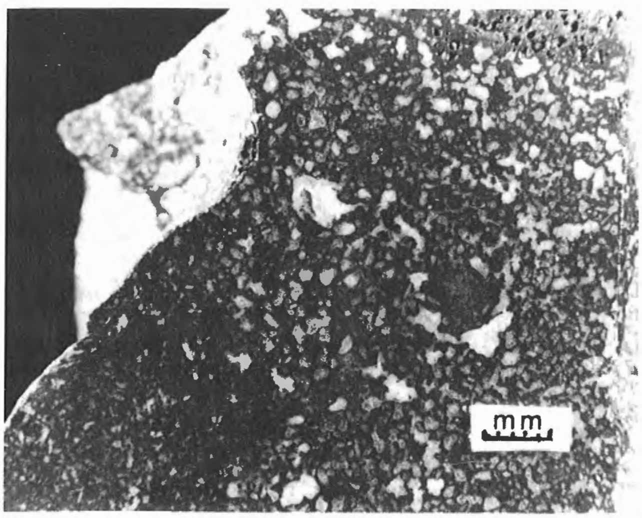
PLATE XXI. Aquagene tuff; dark clasts of chilled chlorite albite altered basalt in matrix of quartz-calcite-prehnite, Ankwell Member, Bait Range, Hazelton map-area.



203022-U

PLATE XXII. Amygduloidal, scoriaceous top in subareal basalt flow, Ankwell Member, Bait Range, Hazelton map-area.

thick, medium- to khaki-green, massive, fine- to medium-grained peperite aquagene breccia.

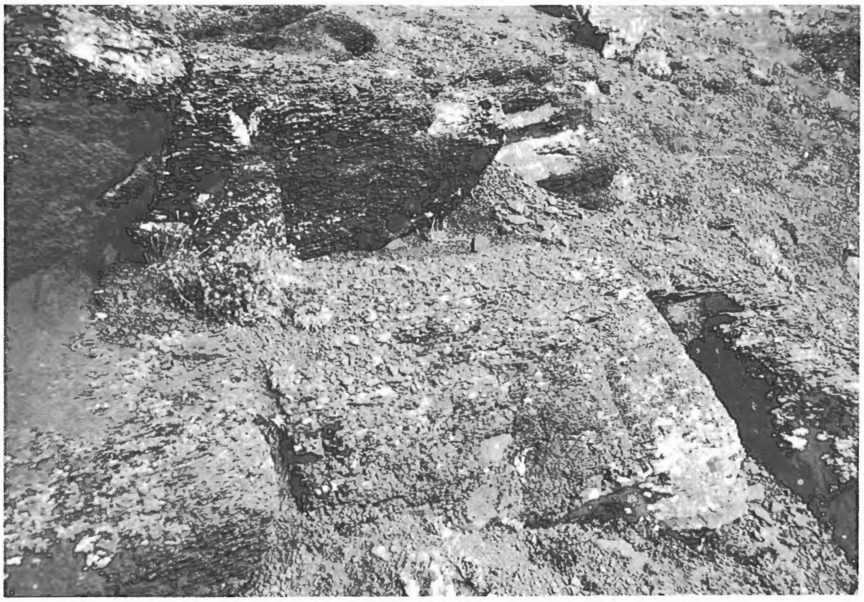
The Ankwell Member is conformable with and, in part, gradational into the overlying Bait Member of the Smithers Formation. The Bait Member has different facies resting on the Ankwell Member: lithic sandstone and lithic-feldspathic greywacke on its central, thickest parts and black shale and siltstone on its more distal parts. The member is bracketed by Middle Toarcian faunas in the overlying Bait Member and in underlying beds of the main Nilkitkwa Formation. Thin interbeds of aquagene tuff and breccia in the 50 m of Nilkitkwa sediments below the Ankwell Member mark a gradational transition. The presence of Middle Toarcian faunas above and below the Ankwell Member demonstrates conclusively that as much as 1200 m of volcanic strata was deposited in a short span of time, possibly within the span of a single faunal zone.

Red Tuff Member

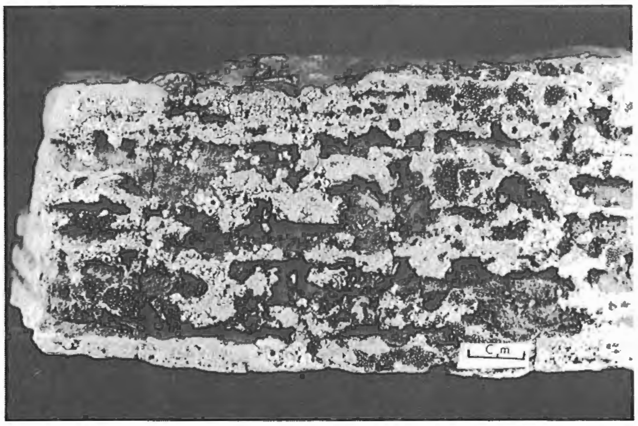
The Red Tuff Member comprises reddish calc-alkaline volcanics exposed between Morice Lake and Morrison and Babine lakes. They are almost entirely nonmarine and in part a time-equivalent facies of the previously described Ankwell Member. The type area is in the Telkwa Range, particularly near Eagle Peak (Pl. XXIII). Bright red to brick-red, well-bedded, fine-grained crystal-lithic tuff is characteristic. The tuff beds, although typical of the formation, do not everywhere constitute its dominant lithology. In its more eastern exposures, particularly east of Netalzul Mountain and Fulton River, the volcanics comprise a suite of basalt to rhyolite flows, tuffs, breccias, and sediments of red, maroon, purple, and green, lithologically similar to the Telkwa volcanics. A distinction between the two formations is their relationship to underlying and overlying formations, but when these other formations are absent the separation of the Telkwa Formation and the Red Tuff Member is difficult and dependent upon subtle lithological differences. From the overlying and underlying strata, its age is established as Middle Toarcian and ?younger.

Volcanics of the Red Tuff Member include minor fine-grained volcanic sediments and marls as much as 200 m thick. In the area west of Fulton River, minor coarse-grained tuff and rare breccias are included. Columnar jointed, well-bedded basalt flows are known only on Mount Loring. The tuffs occur in beds measuring a few centimetres to 2 m thick. They weather readily into rubbly, rounded outcrops, commonly producing a sandy veneer, particularly in alpine exposures. Internally, the beds are unsorted with fine feldspar, quartz or lithic clasts in a red, hematitic matrix of ash and volcanic-derived mud. A few units are waterlain, probably lacustrine, showing incipient grading and containing common, 1–10-cm, irregularly shaped clots of fine-grained, grey limestone (Pl. XXIV). Fine-grained sandstone, siltstone, and mudstone with mudcracks are interbedded.

East of Fulton Lake, the red tuffaceous unit is characteristic of the top of the sequence, but in the lower beds the formation includes rocks ranging from basalt to rhyolite. Exposures there are confined to fault blocks in poorly exposed terrane, and no typical section could be measured. Red lithic-crystal lapilli tuff and breccia predominate with less basalt and andesite feldspar porphyry, dacite to rhyolite tuff, breccia and spherulitic and laminated flow, and welded rocks. Some green breccias of probable subaqueous origin are present. In a small area between Nakinilerak Lake and Morrison Lake, up to 50 m of well-bedded, cream, buff, rusty weathering, acidic tuff containing numerous *Turitella*-like gastropods, brachiopods, and pelecypods is probably a shallow-water, nearshore facies. The fauna is similar and probably coeval with that in the Ankwell Member to the east, but the reddish acidic pyroclastics are Red Tuff Member rather than Ankwell Member. No measured thickness of the formation east of Fulton River is available, but in places it may be as much as 300 m.

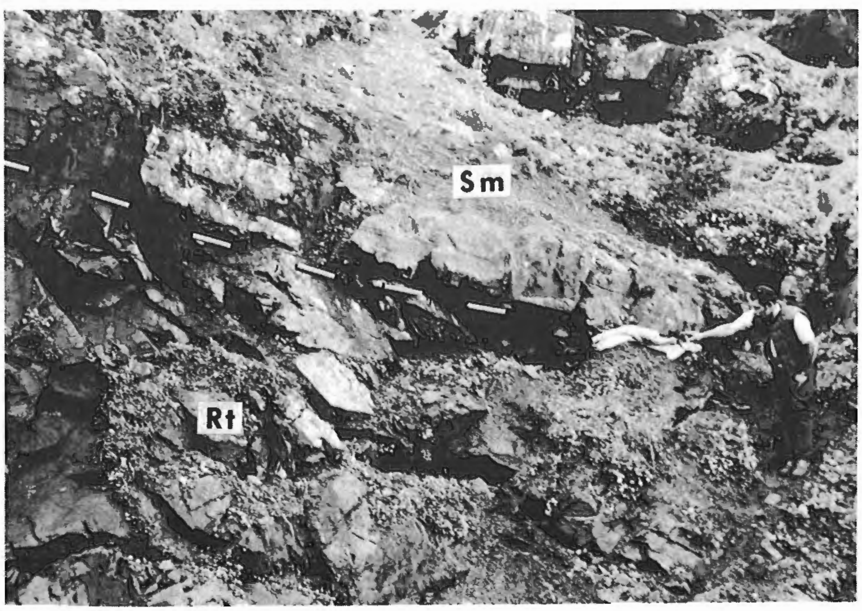


203022-V
PLATE XXIII. Typical rubbly exposure of massive bedded red lapilli tuff, Red Tuff Member, Eagle Peak area, Smithers map-area.



203022-W
PLATE XXIV. Interbedded siliceous ash-fall tuff and marl, Red Tuff Member, south of McDonnell Lake, Smithers map-area.

In Smithers map-area on Mount Loring, Herd Dome, and the southern Howson Range, the Red Tuff Member overlies black shale and greywacke of the Nilkitkwa Formation containing the pelecypod *Posidonomya*. In the Telkwa Range, about 200 m of well-exposed, flat-lying or gently dipping, fine-grained ash-fall tuffs overlies the more massive, diversified volcanics of the Telkwa Formation. These tuffs are distinguished from the underlying Telkwa volcanics by an apparent greater degree of faulting and alteration in the lower beds and a widespread abrupt change in the type of volcanics. On Ashman Ridge, Telkwa Range, and Hudson Bay Mountain, these bright coloured tuffs underlie Middle Bajocian sediments of the Smithers Formation (Pl. XXV). To the east, on Dome Mountain, the tuffs of the Red Tuff Member underlie lithic sandstone and shale of the Smithers Formation containing *Tmetoceras* of Early Bajocian age. Throughout the Hazelton east-half map-area, red tuffs and



203022-X
PLATE XXV. Contact of glauconitic sandstone of Smithers Formation (Sm) above massive bedded, blocky fracturing red tuff of the Red Tuff Member (Rt), Tenas Creek, Smithers map-area.

minor, coarser pyroclasts and flows are interbedded with the Bait and Smithers formations. On Old Fort Mountain and Netalzul Mountain, the ammonite *Tmetoceras* occurs in glauconitic lithic sandstone immediately above the interfingering boundary of the Red Tuff Member and the Smithers Formation. On the east slope of Hearne Hill, a belemnite of probable Toarcian age (J. A. Jeletzky, pers. com., 1974) is in black gritty shale of the Bait Member of the Smithers Formation, just above interfingering volcanics and shallow marine sediments. East of Nakinilerak Lake, the volcanics are mostly marine and are included in the Ankwell Member.

In the Toodoggone River map-area and other areas of northwestern British Columbia, a group of volcanic rocks, informally referred to as the Toodoggone volcanics (Carter, 1972; Gabrielse, 1975), may be partly correlative with the Red Tuff Member. These are mainly tuffs, breccias, and flows of dacite and latite composition (Fig. 17). Bright red to reddish brown colours are characteristic. The only fossil locality associated with these volcanics indicates that part, possibly the upper part, is Middle Bajocian in age. Several hundred metres of volcanics near the base of the unit may be correlative with the Red Tuff Member in whole or in part, or to the other volcanic members of the Nilkitkwa Formation. Further work is required to fully understand the stratigraphic relations of the Toodoggone volcanics.

Smithers Formation

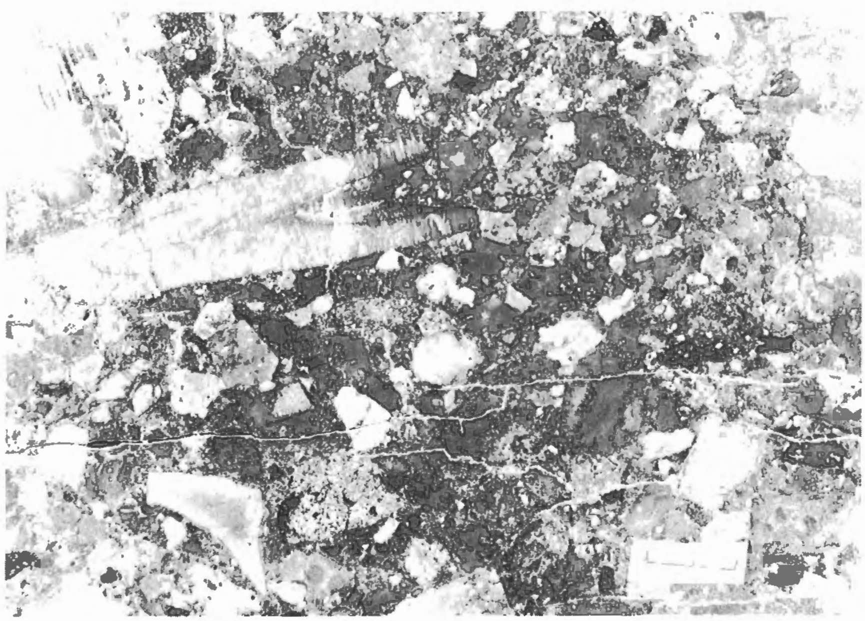
The Smithers Formation is a light grey-brown, greenish grey to drab grey assemblage of greywacke, lithic sandstone, siltstone, tuffaceous shale, tuff, volcanic breccia, grit, glauconitic sandstone, rare poorly sorted pebble conglomerate, and rare, thin limy siltstone or silty limestone (Fig. 9). Typically, the sediments are immature, poorly sorted, well consolidated, and commonly fossiliferous. Except for its two members, the formation seldom displays good bedding but generally forms massive poorly sorted beds, with a few thin beds here and there.

The formation, although of varied lithology, displays certain characteristics that pertain over wide areas, if not throughout the whole basin. The lower beds are commonly shale and sandstone, generally fine- to medium-grained clastic sediments. Higher beds are commonly coarser sandstone and grit (Pl. XXVI, Pl. XXVII). The detritus is mainly, if not entirely, volcanic, derived to a great extent from erosion and reworking of Lower Jurassic volcanics. No clasts in the coarse clastic rocks are considered to be Triassic or older, hence the drainage systems did not apparently cut deeply at that time. The characteristic heterogeneity is widespread, and shelly faunas are almost always present. The depositional basin is thought to have been generally shallow and unstable in which marine areas shifted laterally in response to slight uplift or depression of the sea bottom.

Thicknesses are variable, ranging from a maximum of 827 m on Netalzul Mountain, to 194 m on Ashman Ridge, but at neither of these localities nor any other locality is a complete section known.

No single type section fully depicts the lithological character of the Smithers Formation. Two sections have been selected as typical. They are sections on Ashman Ridge in the Smithers area and on Netalzul Mountain in Hazelton area. Detailed descriptions are in Appendix III, Sections XIII, XIV, XV.

The relation of the Smithers Formation to overlying and underlying formations is well documented. In the Smithers area on Ashman Ridge, Lower Callovian beds of the Ashman Formation overlie Lower Callovian beds of the Smithers Formation conformably. A short hiatus may exist, but no structural discontinuity is recognizable. Isolated occurrences of probable or possible Upper Bajocian and Bathonian fossils suggest that Bathonian–Upper Bajocian beds of the Ashman Formation are widespread in the Smithers and Hazelton areas, but poor exposure prevents



203022-Y
PLATE XXVI. Sharpstone conglomerate, Smithers Formation, Knicks Knob, Hazelton map-area.

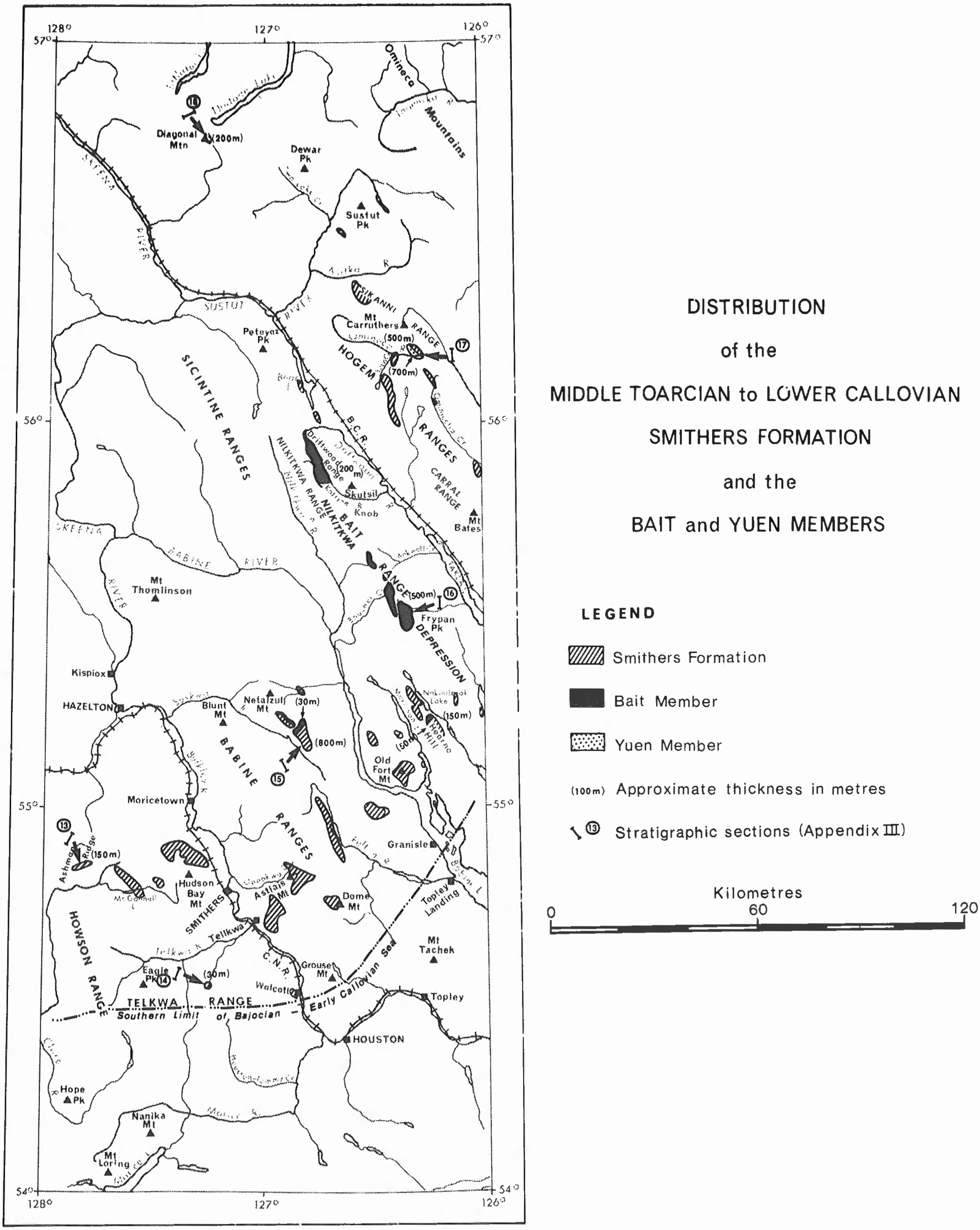
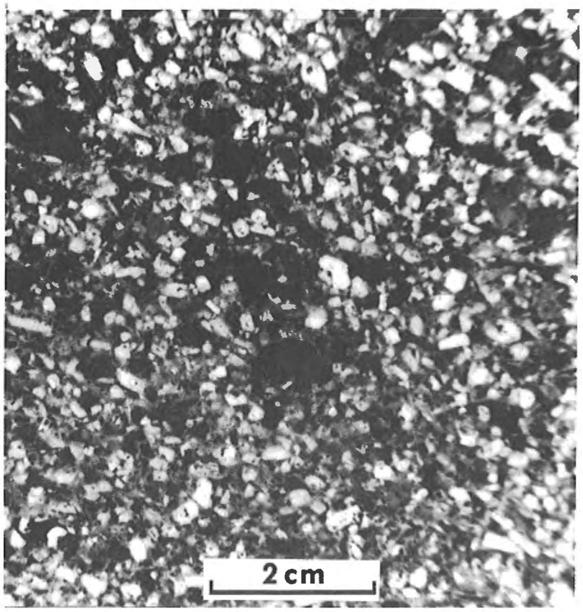

DISTRIBUTION
of the
MIDDLE TOARCIAN to LOWER CALLOVIAN
SMITHERS FORMATION
and the
BAIT and YUEN MEMBERS
LEGEND
Smithers Formation
Bait Member
Yuen Member
(100m) Approximate thickness in metres
Stratigraphic sections (Appendix III)
Kilometres
0
60
120
128°
127°
126°
57°
56°
55°
54°
Omineca Mountains
Diagonal Mtn
(200m)
Dewar Pk
Sustut Pk
SKEENA RIVER
SUSTUT RIVER
SIKANNI RANGE
Mt Carruthers
(500m)
(700m)
HOGEM RANGES
Peteyaz Pk
SICINTINE RANGES
B.C.R.
Driftwood Range
(200 m)
Skutsil Knob
NILKITKWA RANGE
BAIT RANGE
CARRAL RANGE
Mt Bates
SKEENA
BABINE RIVER
Mt Thomlinson
(500m)
Frypan Pk
NILKITKWA DEPRESSION
Kispiox
HAZELTON
Netalzul Mt
(30m)
Blunt Mt
(800m)
BABINE RANGES
(150m)
Old Fort Mt
Moricetown
Granisle
(150m)
Ashman Ridge
Hudson Bay Mt
SMITHERS
Astlais Mt
Dome Mt
Topley Landing
HOWSON RANGE
Telkwa
C.N.R.
Mt Tachek
Eagle Pk
(30m)
Grouse Mt
Walcott
Early Callovian Sea
Topley
TELKWA RANGE
Southern Limit of Bajocian
HOUSTON
Hope Pk
Nanika Mt
Mt Loring

FIGURE 9



203022-Z

PLATE XXVII. Feldspathic-glauconitic sandstone of Smithers Formation, Babine Lake, Hazelton map-area.

demonstrating the relations to the Smithers Formation. There is no evidence for a profound unconformity or an extended hiatus. In McConnell Creek map-area, several unfaulted sections confirm that the Ashman Formation of the Bowser Lake Group is structurally conformable with the Yuen Member of the Smithers Formation. There is, however, insufficient fossil evidence to rule out the possibility of a short hiatus, although none is suspected.

The base of the formation is not everywhere the same age. In the Smithers map-area on Ashman Ridge and on the west side of Hudson Bay Mountain, Middle Bajocian (Sauzei Zone) beds rest directly on the Red Tuff Member of the Nilkitkwa Formation. On Netalzul Mountain in the Hazelton map-area, Middle Toarcian beds of the Bait Member of the Smithers Formation are on the Red Tuff Member. However, the Bait Member rests directly on the Ankwell Member in the Bait Range. In McConnell Creek map-area, Middle Toarcian beds of the formation are structurally conformable with Lower Toarcian beds of the Nilkitkwa Formation. and no significant hiatus is suggested. A common basal marker bed in many areas is glauconitic sand seen along Tenas Creek on Netalzul Mountain, around Nakinilerak Lake, on Old Fort Mountain, and north of Omineca River.

Internally, the formation appears to be structurally conformable, but in reality major breaks interrupt any section. Apparently the formation was deposited in a very shallow sea in which a varied pelecypod fauna thrived. Repeated lateral shifts of the sea produced interruption in the faunal succession without appreciable erosion. So far, no continuous section of the formation has been found, even in more central parts of the basin.

The age of the Smithers Formation is Middle Toarcian to Middle Bajocian generally, but in Smithers map-area is as young as Early Callovian. Although only a few of the classical European fossil zones have been identified from numerous collections, the sequence may be complete in that the zone ammonites may not yet have been found, or their geographical range did not include western British Columbia. A characteristic of the fossil collections, in general, and of the Middle Bajocian, in particular, is the great number of individuals, genera, and species in the ammonite fauna, and the great variety of ornate pelecypods, gastropods, brachiopods, and belemnites. Of all the Mesozoic formations, this is the most fossiliferous.

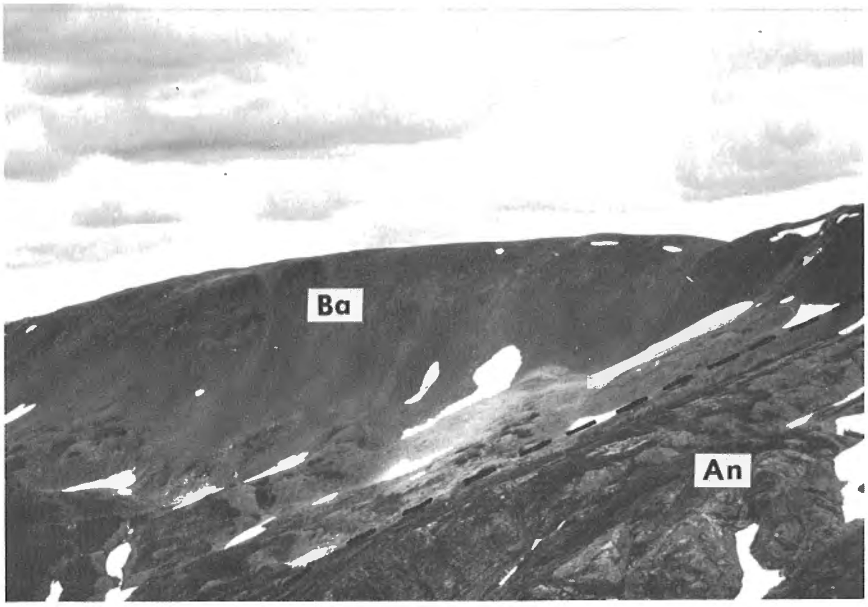
Two facies of the Smithers Formation have been designated as members—the Bait Member deposited in a central, starved area of the Nilkitkwa Depression, and the Yuen Member representing an eastern part of the basin. These members are compositionally compatible with the Smithers Formation but are finer grained, better sorted, and well bedded.

Bait Member

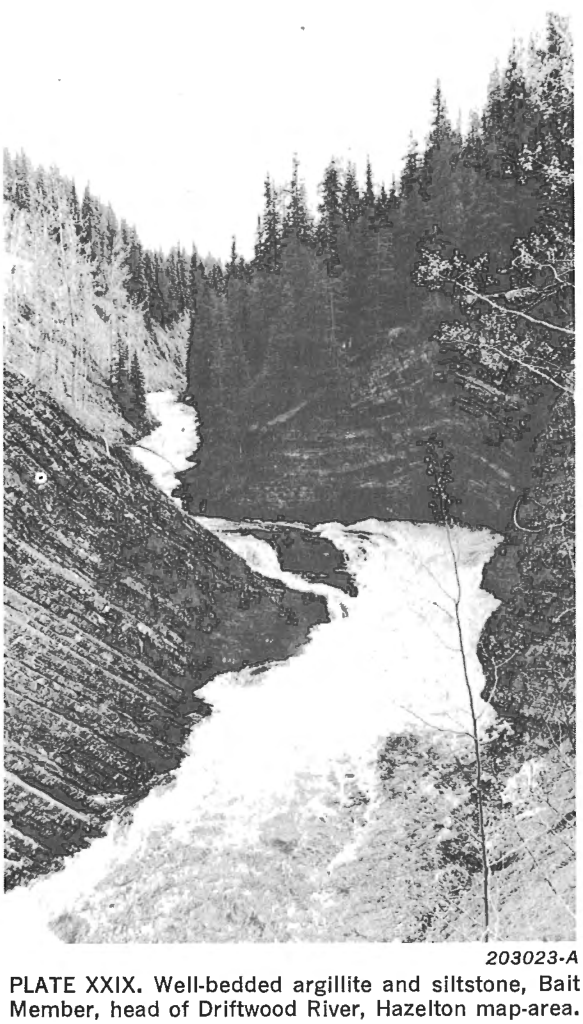
The Bait Member is an assemblage of fine-grained, marine, tuffaceous, and clastic rocks that form the uppermost strata in the southern Bait Range. The best exposure is the type section on a small east-trending spur at the head of Frypan Creek (Pl. XXVIII). There, the member is thickest (nearly 400 m) and extends northerly to the Driftwood-Nilkitkwa ranges, but thins rapidly to the west where, on Netalzul Mountain, it is only 30 m thick. Between Morrison Lake and Fulton River, the member pinches out. In McConnell Creek map-area it is exposed on one mountain east of Yuen Lake where it interfingers with the Yuen Member. Its age is Middle Toarcian to Middle Bajocian and represents the final phase of fine-grained clastic sedimentation in the Hazelton Trough.

Most of the member in the type area consists of fine-grained feldspathic argillite, siltstone and greywacke, and tuffaceous equivalents. The lower units consist of two interfingering facies: a proximal facies of volcanic sandstone, greywacke, and siltstone resting on the thickest part of the Ankwell Member of the Nilkitkwa Formation, and shaling out to the north and south into a distal facies that comprises mainly fine-grained, gritty, black argillite and shale. The proximal assemblage may be as much as 50 m thick and, in part, is interbedded with subaqueous basalts of the upper part of the Ankwell Member. Its central exposures contain a preponderance of fine-grained, silicified, tuffaceous sediments, and rare, medium-grained, thick-bedded greywacke overlain by fine-grained, finely bedded to massive argillite, shale, and siltstone. Limestone beds are rare and abundant small limestone concretions occur in some shale units. Coarse-grained clastic rocks are uncommon, but poorly sorted sharpstone conglomerate to 6 m thick of probable slump or turbidite origin is present.

To the north, the Bait Member is exposed in stream canyons between the Driftwood and Nilkitkwa ranges (Pl. XXIX) as interbedded feldspathic greywacke, siltstone, pebble sandstone, argillite, carbonaceous limestone, and tuffs. Graded bedding, basal scour, and some cross-beds in sandstone noted there are absent to the south in the type locality. The intense folding and faulting, and the limited



203023
PLATE XXVIII. Argillite, siltstone, and siliceous tuff of Bait Member (Ba), overlying massive volcanic breccias of the Ankwell Member (An), head of Frypan Creek, Bait Range, Hazelton map-area.



203023-A
PLATE XXIX. Well-bedded argillite and siltstone, Bait Member, head of Driftwood River, Hazelton map-area.

exposure in canyons, precludes a reliable estimate of thickness, but it must exceed 150 m.

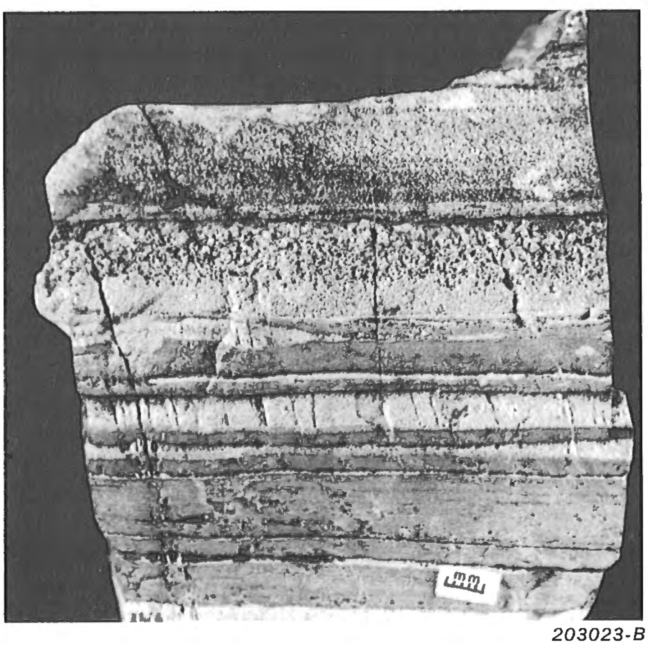
West of Ominicetla Creek, 60 m of greywacke, siltstone, feldspathic grit, and minor siliceous tuff in a small fault slice is the most easterly known exposure of the Bait Member. West of the type area, the member outcrops on Hearne Hill and on the south end of Netalzul Mountain. On Hearne Hill, black, gritty argillite and fine-grained greywacke are interbedded with thick-bedded (to 6 m) volcanic-lithic sandstone and pebbly sandstone. On Netalzul Mountain, 30 m of black shale, black sulphurous limestone, and minor cherty tuff is the most westerly exposure of the member.

In the type locality, distal black shale of the Bait Member rests conformably on the Ankwell Member, whereas its proximal sandy facies interfingers with the volcanics. To the north, separation of the Bait Member from the Nilkitkwa Formation is difficult, as the intervening Ankwell Member is only 20 to 40 m thick. However, it has been noted (Poulton, 1974) that the diabase dykes so common in the Nilkitkwa Formation are unknown in the Bait Member. On Hearne Hill, the Bait Member interfingers with both typical Smithers Formation and Red Tuff Member. On Netalzul Mountain, the Bait Member rests conformably on red volcanics of the Red Tuff Member, and underlies glauconitic-lithic sandstone of the typical Smithers Formation, the only locality where this upper relationship is known.

Age of the member in the type locality is Middle Toarcian to Middle Bajocian. The member contains locally a fauna replete with star-shaped crinoid columnals, various gastropods, including the characteristic *Turitella*-like form, pelecypods, and brachiopods that are also common in the Ankwell Member, and in the marine part of the Red Tuff Member near Morrison Lake. The Bait Member is a fine-grained facies deposited mainly within the Nilkitkwa Depression, and its younger strata (Lower to Middle Bajocian) is a distal facies correlative with the Smithers Formation.

Yuen Member

Along the northeastern segment of the basin in which the Smithers Formation accumulated is a facies that differs somewhat from the type sections of the formation. This facies has been named the Yuen Member from exposures in McConnell Creek map-area along Yuen Creek and north of Omineca River. Whereas the Smithers Formation is typically poorly sorted and in massive beds, the Yuen Member is well sorted and displays a prominent bedding. Compositionally, the member is typical of the formation but is generally coarse sand to silt size. Remarkably uniform, 10- to 20-cm-thick beds, with thin 2- to 3-cm interbeds of shale, characterize the sections. In places, ripple-marks and graded bedding are noted, but current features are generally absent. The rocks are siliceous and break with a rectangular fracture, and the talus is characteristically coarse and blocky. Consistently the highest beds (with Humphresianum zone ammonites) are dark grey to black siltstone and fine greywacke, with minor tuff beds in places. Underlying these beds are similar siltstone and greywacke with thin beds of tuff or fine volcanic breccia, in places comprising more than half the section. Commonly these tuffaceous sediments yield Middle Bajocian ammonites (Sauzei zone), but on Diagonal Mountain their age apparently ranges downward to Toarcian. The source of the tuffs is speculative. In the southern part of the McConnell Creek area near Omineca River, the tuffs are coarse, white weathering, and are commonly mixed with silt. Their source is unknown, but because of the coarseness and thickness of the beds, they are thought to be of local origin. On Diagonal Mountain, fine-grained, red-weathering, rhyolitic ash-fall tuffs in beds to 15 cm are interlayed without appreciable admixing with siltstone (Pl. XXX). These red tuffs are of probable Early Toarcian to Middle Bajocian age and may have a source in the possibly correlative Toodoggone volcanics less than 80 km to the north.



203023-B

PLATE XXX. Interbedded argillite (dark) and ash-fall tuff of Yuen Member, Diagonal Mountain, McConnell Creek map-area.

Unlike the typical Smithers Formation, fossils are not abundant in the Yuen Member. In only a few places is there a fauna rich in pelecypods, gastropods, belemnites, and ammonites. Here and there, ammonites are abundant to the exclusion of other fossils. In many sections a monotonous sequence as much as 800 m thick with rare belemnites and one or two solitary ammonites is common. The age of most sections examined is Middle Bajocian. Only on Diagonal Mountain do the lower beds of the member include Toarcian ammonites. Elsewhere, near Omineca River particularly, the underlying Toarcian beds are coarser, poorly sorted, and are typical of the Smithers Formation.

BOWSER LAKE GROUP

The Bowser Lake Group comprises marine and non-marine sediments and minor volcanics of Middle Jurassic (Late Bajocian) to Late Jurassic (Kimmeridgian) age. They were deposited in the Bowser Basin, a successor basin to the volcanogenic Hazelton Trough (Fig. 3C). Its northern and southern boundaries are defined by the Stikine and Skeena arches respectively, and its eastern margin by the Columbian Orogen. The basin apparently was open to the west, but outcrops now terminate against the Coast Plutonic Complex. In this study only the southern, eastern, and northeastern parts of the basin are discussed.

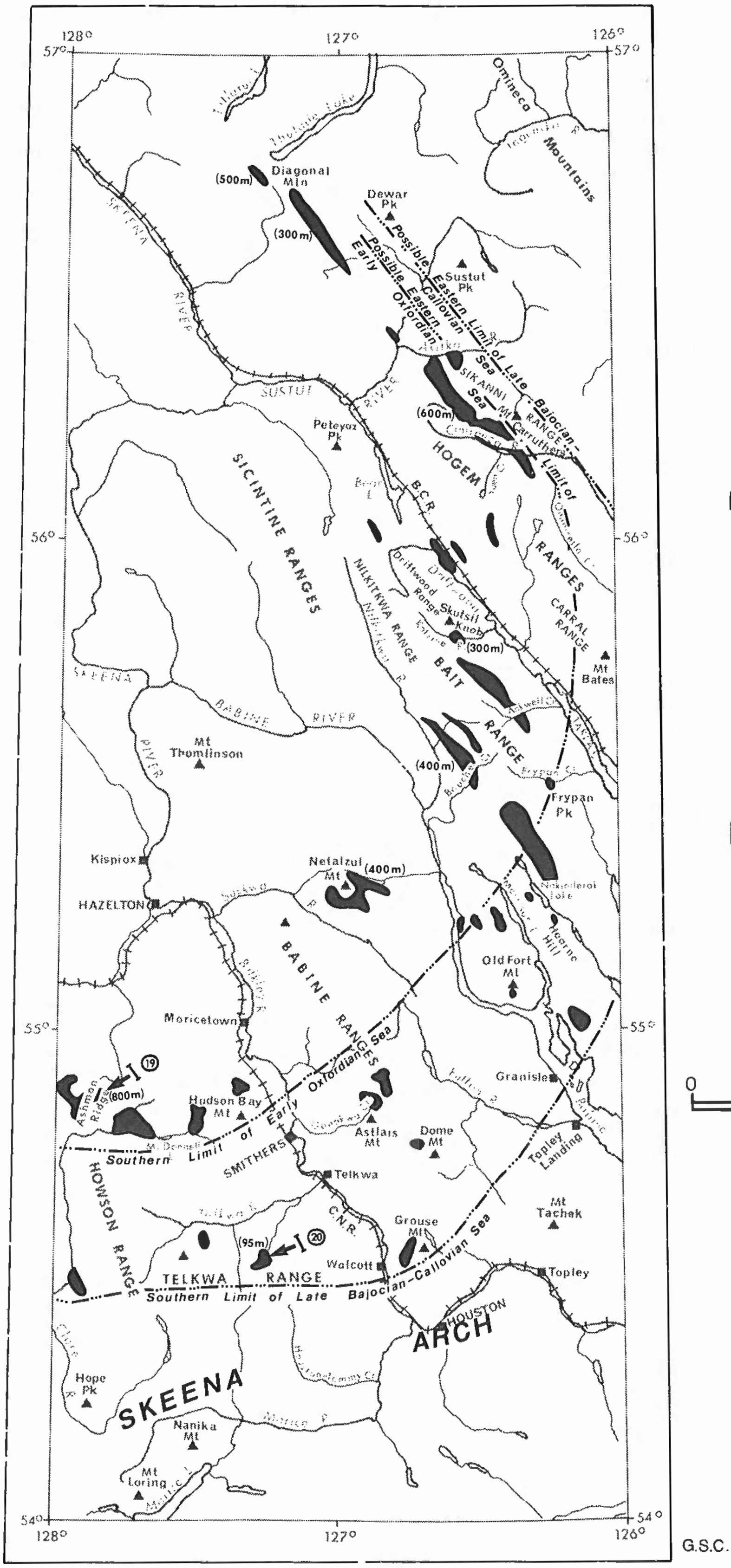
The rocks of Bowser Basin can be subdivided into two or more formations (Fig. 5). The Ashman Formation, of Late Bajocian to Early Oxfordian age, is the most widespread unit of the Bowser Lake Group and is the best known. Other formations or members are currently under study.

Ashman Formation

The Ashman Formation is characteristically dark grey to black shale, feldspathic to quartzose sandstone, greywacke, chert-pebble conglomerate, and greywacke conglomerate (Fig. 10). Minor limy lenses and thin beds of grey limestone are found locally. In the western part of the basin near the Skeena Arch, there are rare, thin beds of tuff or tuffaceous shale, but whether these indicate contemporaneous volcanism has not been proven. In general, the formation is a clastic sedimentary unit with dominant shale and sandstone members and with coarse deltaic facies at the margins of the basin. The sediments are moderately mature, more so than other Jurassic sediments of the area. Chert-pebble conglomerate and quartzose sandstones are relatively common, and well-rounded clasts are typical.

The maximum thickness of the formation is probably 761 m in the type section on Ashman Ridge. It is not possible to demonstrate a complete section anywhere else, but one may exist. A minimum thickness for the formation is difficult to assess, but it seems to be everywhere a thick unit, in excess of 300 m.

The type section is on Ashman Ridge (Pl. XXXI), 40 km west of Smithers, where an essentially unfaulted section is well exposed (Appendix III, Section XIX). There, the formation is almost fully exposed, is of typical lithology,



DISTRIBUTION
of the UPPER
BAJOCIAN TO LOWER OXFORDIAN
ASHMAN FORMATION
of the
BOWSER LAKE GROUP

LEGEND

Ashman Formation

(100 m) Approximate thickness in metres

(19) Stratigraphic sections (Appendix III)

Kilometres
0 60 120

FIGURE 10

203023-C
PLATE XXXI. Well-bedded argillite, siltstone, and greywacke of the Ashman Formation, Ashman Ridge, looking north, Smithers map-area.

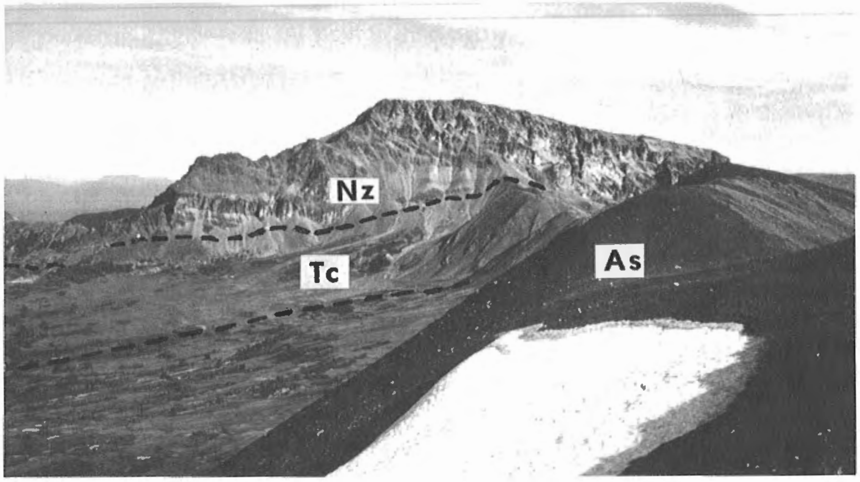
abundantly fossiliferous with all the fossil zones that are recognized anywhere in the basin, and is in observable contact with overlying and underlying formations. Because of its proximity to the basin margin, it has a higher proportion of coarse clastic sediments than would be expected in the centre of the basin. A partial section from Tenas Creek illustrates a highly fossiliferous nearshore assemblage that has been encountered at four or five localities on the north side of the Skeena Arch, and may also have its counterparts on the south side of the arch (Appendix III, Section XX).

Many partial sections of the Ashman Formation have been studied in the Smithers, Hazelton, and McConnell Creek map-areas, but none are as well exposed, as fossiliferous, or as complete as the type section. Commonly, they merely illustrate the sedimentary record for a short span of time. A few will be mentioned to show the facies variations within the formation.

In the Smithers area, one exposure in a railway rock-cut at Walcott, a short Upper Bajocian sequence, comprises shales, sands, fine conglomerate, breccia, and minor limestone lenses with a few ammonites, abundant brachiopods, pelecypods, and gastropods. North of McDonnell Lake, a section of Callovian strata similar to that in Tenas Creek is exposed. One locality on Zymoetz River (54°30′N, 127°56′W), and another in the Telkwa River valley (51°34′N, 127°26′W), display strata that are lithologically similar or identical to part of the Tenas Creek section and have yielded an identical Early Callovian fauna. These three sections represent a nearshore facies flanking the north side of the Skeena Arch. Along Ganokwa Creek north of Astlais Mountain (54°51′N, 126°52.5′W), a thick sequence of black to dark grey shale contains a few Bathonian? and Early Callovian fossils. Dark green lithic sandstones with an abundant pelecypod fauna apparently overlie the shale and may be as young as Middle Callovian; exposures of this facies are northwest of Dome Mountain, at the headwaters of Ganokwa Creek, and on the ridges east of Mount Hyland in the Babine Range.

In the Hazelton area, generally in areas of low relief, Early and Middle Callovian faunas occur sparsely in monotonous sandstone and shale units. A few fossil collections include belemnites, a few ammonites, and, rarely, pelecypods. These rocks are basinal sediments, but no nearshore facies have been recognized to the east, probably because they are obscured by younger sediments. The Upper Callovian and Lower Oxfordian beds are widespread, but because of cover by younger strata, the outcrop distribution follows the margin of the Bowser Basin. These rocks are generally coarse sandstones with abundant woody material, abundant thick-shelled pelecypods, cross-bedded sands, and thin pebble conglomerates that grade rapidly basinward into evenly bedded, black to dark grey shales, and grey to greenish grey fine sands. Although the exposure is limited, the conclusion is that the exposures of these rocks mark Late Callovian and Early Oxfordian nearshore facies of a northwestward regressing sea.

In McConnell Creek map-area, finely laminated black shale and massive black siltstone with rare ammonites and belemnites of Early to Middle Callovian age are widespread in the south half of the area, an extension of a similar facies in the Hazelton map-area. These are overlain by Upper Callovian massive beds of grey-green, coarse siltstone to coarse sandstone that weather buff and are sparingly fossiliferous. Northwestward, near Diagonal Mountain, the Bathonian and/or Upper Bajocian to Lower Oxfordian strata are recognized, and are almost entirely shale and siltstone with a few sandy beds in the upper part. Brief examination of one section in the Spatsizi map-area (104H), farther northwest and on the north side of the Bowser Basin, indicates that the Ashman Formation is readily recognizable there as a thick black shale section with a few interlayered sandstone beds ranging in age from Early Callovian to Early Oxfordian (Appendix III, Section XXI). Chert-pebble conglomerate near the base has a probable northern provenance, and a few sedimentary structures indicate current directions from the north in this part of the Bowser Basin.



203023-D

PLATE XXXII. Exposure of the Bowser Lake Group east of Netalzul Mountain, Hazelton map-area; black shale of Ashman Formation (As) in foreground, in distance, Netalzul volcanics (Nz), overlying sandstone of the Trout Creek (Tc) assemblage.

The relations of the Ashman Formation to overlying and underlying units have been fairly well documented. On Ashman Ridge, the type section is overlain conformably by Late Oxfordian coarse clastics of the Bowser Lake Formation. The relationship is the same in the Hazelton area along Boucher Creek and on Netalzul Mountain (Pl. XXXII). The relation to underlying rocks is not as consistent. On Ashman Ridge, the formation is in structural conformity with the Smithers Formation, and no hiatus is recognized. On Tenas Creek, the Early Callovian beds of the Bowser Lake Formation overlie the Smithers Formation conformably. Along Zymoetz River and on Grouse Mountain southeast of Smithers, Lower Callovian rocks of the Ashman Formation rest directly on the Red Tuff Member. In the Hazelton area, the base is usually covered or in fault contact with older formations, but near Nakinilerak Lake, Upper Bajocian beds apparently rest directly on the Middle Bajocian beds of the Smithers Formation.

Internally, the Ashman Formation appears to be conformable, and in the central part of the basin is probably a continuously deposited, conformable, monotonous, shale–fine sand sequence. The margin of the basin reflects some unstability. Within the formation, there are beds that suggest nonmarine conditions for short periods. There is evidence of erosion, slumping, and channelling, and in the southern part of the basin, in the type section, possible contemporaneous volcanism outside the basin. Sedimentary structures generally suggest transport of material from the south, and a few clasts of plutonic rocks suggest that the Topley Intrusions of Early Jurassic age were being eroded. It is doubtful if the whole formation was fully developed in the outermost parts of the Ashman marine area, particularly the south margin, as evidence indicates that the sea was at its maximum extent in Late Bajocian and Early Callovian time and regressed steadily thereafter. Therefore in Tenas Creek it is probable that Upper Callovian and Lower Oxfordian beds never were deposited.

The age of the formation is precisely defined as ranging from Late Bajocian to the top of the Early Oxfordian. The oldest beds included in the formation have yielded ammonites of Late Bajocian age. The presence in younger beds of a varied fauna confirms as complete a sequence from Early to Late Callovian as is found anywhere in the western Canadian Cordillera. Abundant cardioceratids document the apparent presence of a complete Lower Oxfordian section.

Younger Facies Assemblages of the Bowser Lake Group

With continued uplift of the Skeena Arch and the Pinchi belt, the fine-grained clastics of the Ashman Formation were succeeded by the alluvial-deltaic-delta slope, sedimentary facies of Late Oxfordian to ?Early Kimmeridgian age (Fig. 11). These upper members of the Bowser Lake Group represent a further marine regression that commenced in Callovian time. Local volcanism along the margin of the basin occurred in Late Oxfordian time. Formations and members have not yet been defined, but tentative informal subdivisions are used.

Sandstone, conglomerate, siltstone, and minor coal of the Trout Creek assemblage were deposited conformably above the Ashman Formation. In the south, the contact is abrupt, and the first coarse-grained clastics are marine sandstone and conglomerate with a great abundance and variety of shelly fauna. Upsection, in most places, are nonmarine sandstones with interbeds of siltstone, coal, and pebble and cobble conglomerate up to 50 m thick (Pl. XXXIII). This marine to nonmarine transition is traceable from the Bait Range to Netalzul Mountain, some 30 km. In the McConnell Creek map-area, the nonmarine facies is absent, and the contact with the Ashman Formation is gradational. In the Hazelton area, clasts in the southerly conglomerate include volcanic, granitic, and sedimentary material, whereas those in the north include volcanics, argillite, and chert but no granites. This facies clearly indicates shrinking of the Bowser Basin from the earlier Ashman Formation. Paleocurrent data give a northerly transport direction from the

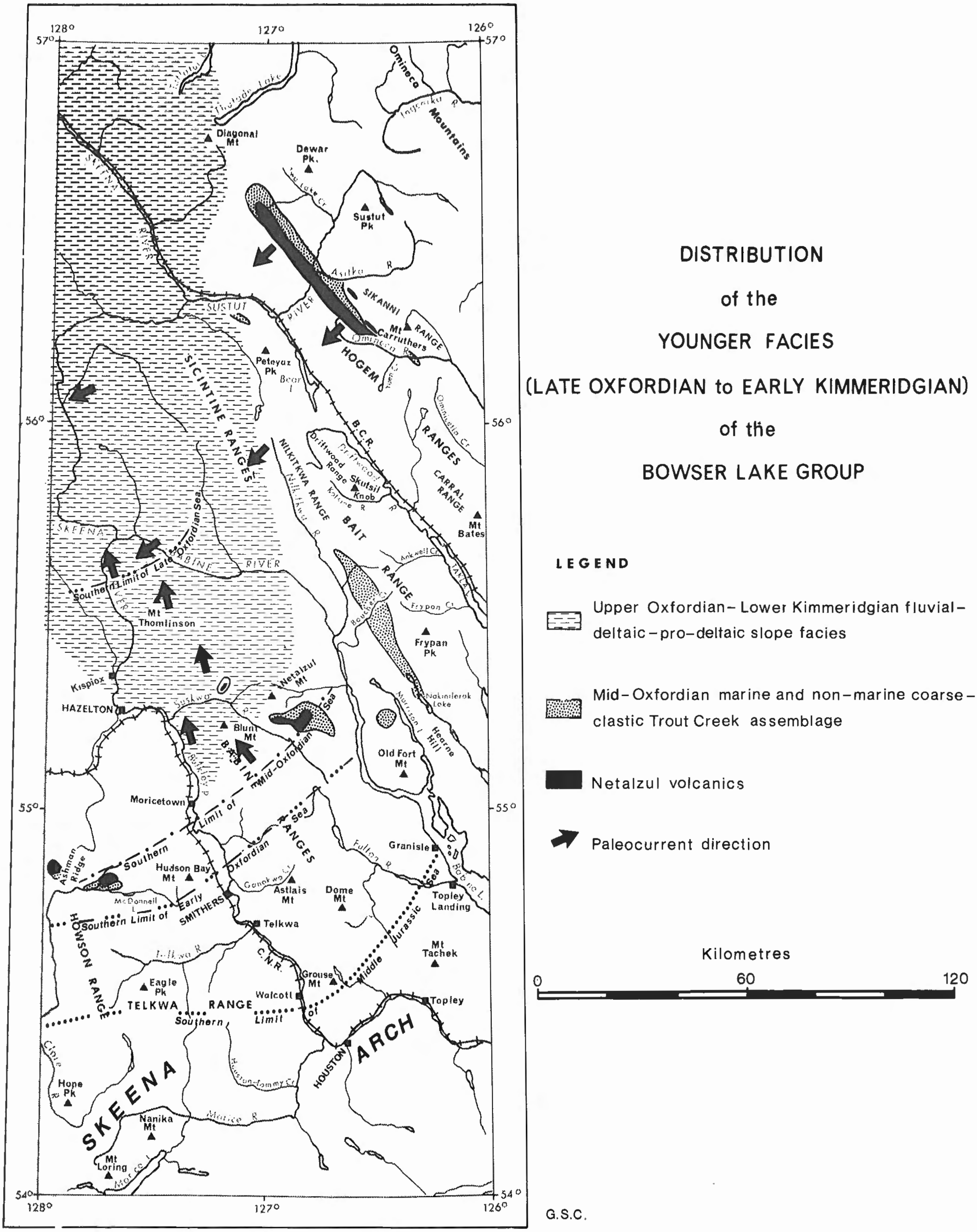

DISTRIBUTION
of the
YOUNGER FACIES
(LATE OXFORDIAN to EARLY KIMMERIDGIAN)
of the
BOWSER LAKE GROUP
LEGEND
Upper Oxfordian-Lower Kimmeridgian fluvial-deltaic-pro-deltaic slope facies
Mid-Oxfordian marine and non-marine coarse-clastic Trout Creek assemblage
Netalzul volcanics
Paleocurrent direction
Kilometres
0
60
120
G.S.C.
128°
127°
126°
57°
56°
55°
54°
Omineca Mountains
Diagonal Mt
Dewar Pk.
Sustut Pk
SUSTUT
SIKANNI RANGE
Mt Carruthers
HOGEM
Peteyaz Pk
SICINTINE RANGES
B.C.R.
RANGES
CARRAL RANGE
Mt Bates
Skutsil Knob
NILKITKWA RANGE
BAIT RANGE
Southern Limit of Late Oxfordian Sea
RIVER
Mt Thomlinson
Frypan Pk
Kispiox
HAZELTON
Netalzul Mt
Blunt Mt
BASIN
Mid-Oxfordian Sea
Old Fort Mt
Moricetown
Southern Limit of Early Oxfordian Sea
RANGES
Granisle
Hudson Bay Mt
Astlais Mt
Dome Mt
Topley Landing
SMITHERS
Southern Limit of Middle Jurassic Sea
Telkwa
HOWSON RANGE
Mt Tachek
C.N.R.
Eagle Pk
Grouse Mt
TELKWA RANGE
Walcott
Topley
HOUSTON
ARCH
SKEENA
Hope Pk
Nanika Mt
Mt Loring

FIGURE 11

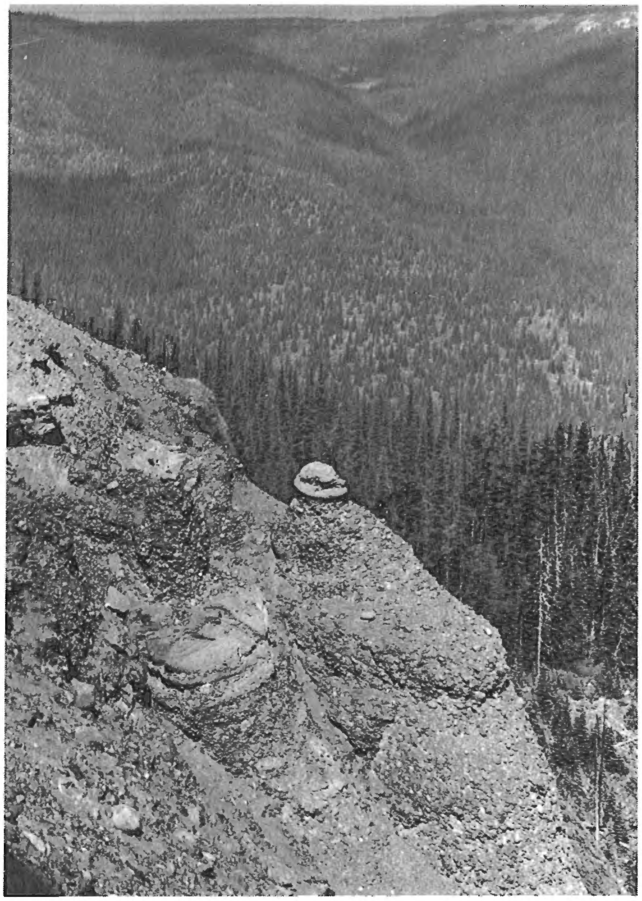


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PLATE XXXIII. Conglomeratic facies of the Trout Creek assemblage, head of Boucher Creek, Hazelton map-area.

Skeena Arch, and a southwesterly transport direction from the Pinchi belt, a situation that persisted to the end of Bowser Lake sedimentation. The unit varies in thickness, up to 300 m in the south and southeast, and thinning basinward. The sediments were deposited in a short interval of time. Sediments below are latest Early Oxfordian and those above are Late Oxfordian, hence a mid-Oxfordian age is indicated.

Overlying and, in part, interbedded with the Trout Creek assemblage are the basaltic and andesitic subaerial Netalzul volcanics. They appear to have formed as isolated piles up to 300 m thick, distributed around the edge of the Bowser sea as defined by the Trout Creek strandline. They are mainly breccias and tuff, but include common, thick-bedded flows and intravolcanic sandstone, conglomerate, and minor coal. The facies in the McConnell Creek map-area is a 50- to 100-m-thick volcanic mudflow fanglomerate that includes many well-preserved but carbonized tree trunks, some in their original positions. They are probably of mid-Oxfordian to earliest Late Oxfordian age.

The youngest strata of the Bowser Lake Group are marine and nonmarine deltaic facies assemblages that underlie most of the southern Bowser Basin. Alluvial, shoreline, and shallow marine facies of conglomerate, sandstone, siltstone, and mudstone dominate, with fine-grained siltstone-shale-limestone distal or delta slope facies found locally on Blunt Mountain and Mount Thomlinson. Alluvial deposits of the Suskwa facies characterize the edge of the basin from the Skeena Arch northward for 30 km where they interfinger with a shoreline coquina facies, marking a new marine edge to the Bowser Basin (Richards and Jeletzky, 1975). This facies interfingers with shallow-water delta-front and prodelta slope facies northward into McConnell Creek map-area, west half (Jeletzky, 1976). Paleocurrent data indicate sediment transport north-northwesterly in the alluvial facies, and a southwesterly direction in the shoreline and delta-front facies, probably indicating marine interference (Richards and Jeletzky, 1975). In the McConnell Creek map-area, the facies of the younger strata are all shallow-water deltaic sandstone, conglomerate, siltstone, and mudstone with sediment transport from a highland to the east-northeast. These form broad facies belts along the east side of the Bowser Basin (Jeletzky, 1976), and can be traced westward 80 km into the Bowser Lake map-area. The lithological assemblages, sedimentary structures, and fauna indicate that this part of the Bowser Basin was shallow during the deposition of the younger strata of the Bowser Lake Group (O. L. Jeletzky, pers. com., 1975).

These rocks show little diversity in fauna, unlike the Ashman Formation and the Trout Creek assemblage. Fauna are common but widely dispersed, and comprise mainly either *Ostrea* coquinas or scattered *Buchia concentrica*. The younger facies of the Bowser Group is probably of Late Oxfordian age, but may include earliest Kimmeridgian. The Skeena Group (Hauterivian to Albian) and the Sustut Group (Late Cretaceous to Eocene) overlie disconformably to unconformably the Bowser Lake Group.

TECTONIC AND DEPOSITIONAL HISTORY OF THE HAZELTON AND BOWSER LAKE GROUPS

Near the close of Late Triassic and ?earliest Jurassic time, the area occupied by the Takla seas was split into two basins by uplift along the easterly trending Stikine Arch and the northerly trending Pinchi belt. To the north and east, the Whitehorse and Quesnel troughs were sites of clastic sedimentation, and to the south and west, the coeval Hazelton Trough was a site of calc-alkaline volcanism and eugeosynclinal sedimentation (Fig. 3B), of which by far the greatest volume is represented by the Late Sinemurian to ?Early Pliensbachian Telkwa Formation. The transition from Takla time to Hazelton time was marked by regional uplift over the entire study area. The Late Triassic basin was entirely marine, whereas the oldest volcanics of the Telkwa Formation were, for the most part, subaerially deposited. Marine clastics of possible Hettangian age, as on Sterrett Island, Babine Lake, may be relics of this diastrophism.

The evolution of the Hazelton Trough involved marine transgressions and regressions in Early to Middle Jurassic time (Fig. 12). Initially the trough was nonmarine, except possibly in its central part (the Nilkitkwa Depression). The history of the Hazelton Group began in Sinemurian time with the eruption of the Telkwa volcanics across the trough,

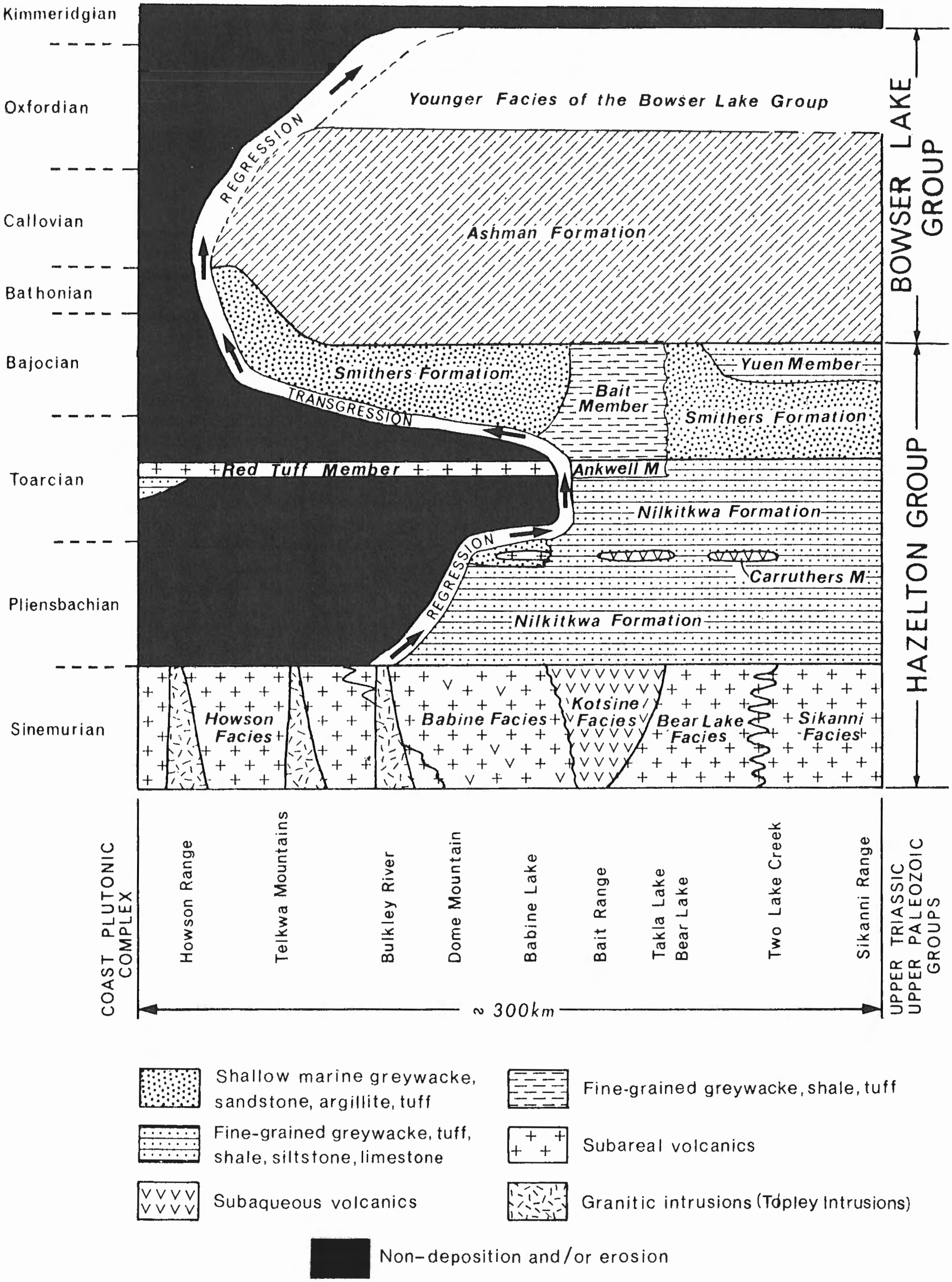

FIGURE 12. Time-stratigraphic cross-section of the Hazelton and Bowser Lake groups between the Coast Plutonic Complex and the Omineca Crystalline Belt.

a westward marine transgression, and a subsequent regression by the end of Telkwa time (Early Pliensbachian?). Calc-alkaline volcanism ceased in the Early Pliensbachian and, from then until Middle Toarcian time, the clastic-tuff assemblage of the Nilkitkwa Formation records a marine regression in the west, a broad submergence in the east, and development of a graben structure within the depression (Fig. 13). This graben development culminated in Middle Toarcian time, coincident with the eruption of a thick pile of alkali-olivine basalt of the Ankwell Member. The trough in subsequent Hazelton time continued to subside *en bloc* east of Babine Valley coincident with, southwest of the depression, a westward transgression of a shallow sea, onlapping and eroding earlier strata. Transgression climaxed in Early Callovian time with uplift of the Skeena Arch, followed by regression and mature sedimentation characteristic of the Bowser Lake Group. The strata of the Hazelton Group represent an island-arc and back-arc, eugeosynclinal, volcanogenic basin, the successor to the Takla Group. This, in turn, evolved to a sedimentary successor basin in which the Bowser Lake Group accumulated.

The Howson, Babine, Kotsine, Bear Lake, and Sikanni facies of the Telkwa Formation represent calc-alkaline volcanism within different environments of deposition. Chemically, the Howson facies is a low-alkali, high-iron calc-alkaline suite, whereas the other facies are more alkalic (Figs. 16, 17, Appendix). These have been referred to the western and eastern blocks, respectively (Fig. 13). The greatest volume of volcanics is to the southwest, in the Howson facies, where in excess of 2500 m of reddish pyroclastic volcanics built up local volcanoes. The locus of volcanism was probably centred over the Topley Intrusions, and the buildup of volcanics over plutons resulted in the formation of an ancestral Skeena Arch. The area, particularly west of Bulkley Valley, was characterized by a volcanic highland around the Howson Range. The surrounding terrane was built up by broad areas of explosive air-fall tuff and breccia, short-lived stream deposits, shallow lake deposits, and intermittent incursions of basalt and ignimbritic flows. The extensive areas of zeolitized rocks surrounding the highland are suggestive of hot spring deposition, and are akin to the geothermal fields of New Zealand (Browne and Ellis, 1970). This nonmarine area sloped gently easterly and northeasterly into a broad, apparently shallow sea in which small islands were scattered, and in which marine and nonmarine volcanics and sediments of the Babine shelf facies

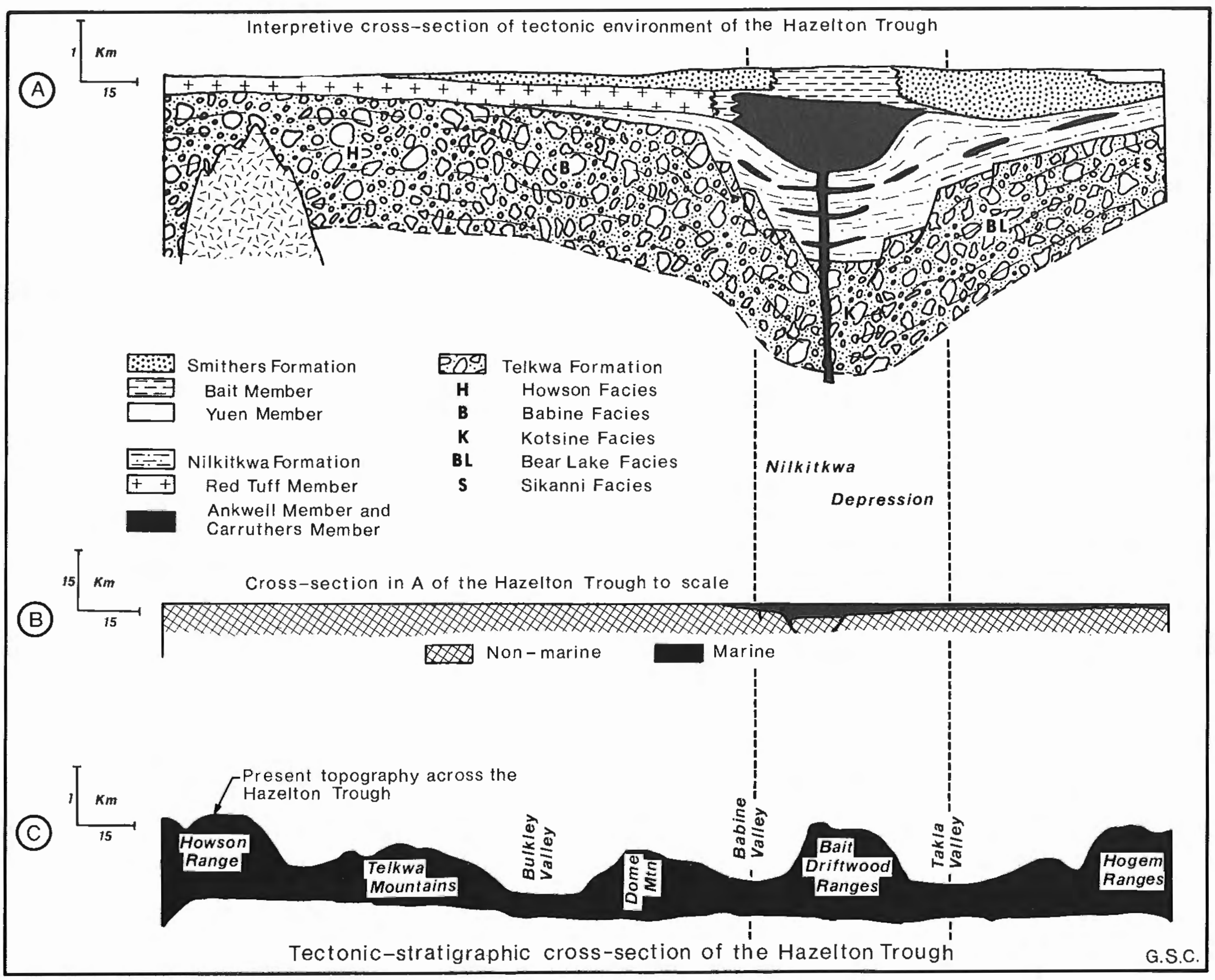

FIGURE 13

were deposited. Together the Howson and Babine facies form a discrete block that extends about 160 km from the Coast Mountains to Babine Lake as an area of subaerially and marine shallow water deposited calc-alkaline volcanism (Fig. 13). Northeasterly, in the Nilkitkwa Depression, these facies pass abruptly into the correlative Kotsine facies, which was erupted into a submarine environment. In the south part of the depression, this marine facies exceeds 1500 m, and thins northward to about 30 m in the Driftwood Range where it rests upon a thick assemblage of reddish volcanics of the Bear Lake facies. Subsidence in the depression during Telkwa time may account for this onlapping of marine strata on nonmarine, and for a northward transgression. The subsidence was confined to the Nilkitkwa Depression, as all the strata of the Bear Lake and Sikanni facies to the northeast are subaerial. The Bear Lake facies is similar in history to the Howson facies but apparently lacked the large volcanic centres. Along the eastern margin of the Hazelton Trough, faulting, probably tensional, along the Pinchi–Two Lake Creek fault system was accompanied by volcanism. There a graben developed, traceable for 80 km, in which the Sikanni facies was deposited. This faulting probably began in Late Triassic (Karnian) time and, in part, controlled the deposition of the Takla Group in the Sustut Peak area (B. N. Church, pers. com., 1975). The southern limit of the facies is marked by a minor shallow marine incursion during Sinemurian time—possibly an easterly onlapping from the Nilkitkwa Depression.

The transition from the Telkwa Formation to the Nilkitkwa Formation is sufficiently abrupt that the base is of the same age, Early Pliensbachian, for some 250 km across the Hazelton Trough. Only the southwestern area, underlain by the Howson facies and the coeval Topley Intrusions, remained emergent after this sudden Early Pliensbachian marine transgression. The Sikanni facies on the northeastern flank of the trough was inundated, but the northeastern limit of the sea is unknown. The seas remained shallow above the Babine shelf facies but deepened abruptly within and east of the Nilkitkwa Depression. From Early Pliensbachian to Middle Toarcian time, pelitic and acidic tuffaceous sediments accumulated to thicknesses of 100 to 150 m above the shelf, thickened to more than 1200 m in the depression, and thinned gradually to about 450 m in the Omineca River area (Fig. 13). The shelf area remained marine in Pliensbachian time, and by Early Toarcian the southern strand was just west of Nilkitkwa Depression in Morrison Lake area where the only probable shallow-water marine sediments of Nilkitkwa Formation were deposited. Acidic volcanism was characteristic of Nilkitkwa time but is undetected west of the depression. Basic volcanism of the Carruthers Member interrupted the fine-grained deposition briefly and locally in latest Pliensbachian time except in the southern part of the depression where basic volcanism continued intermittently, a forerunner of the alkali-olivine basalt Ankwell Member that marks the top of the Nilkitkwa Formation in the depression. There, more than 1000 m of basaltic rocks formed a temporary island. In the depression, the Nilkitkwa Formation, including the Ankwell Member, reached a total thickness of more than 2200 m, an order of magnitude greater than that found to the east and west.

To the west, in the emergent Howson and Babine areas, the formation is represented by the Red Tuff Member, a blanket of nonmarine volcanics up to 300 m thick that interfingers with Nilkitkwa Formation sediments only on the western edge of the Nilkitkwa Depression. The member is primarily air-fall lapilli tuff to the west but eastward includes flows and coarser pyroclastic rocks. This was a Middle Toarcian event and marks the end of accumulation of thick volcanic piles in the Hazelton Group in the study area. However, to the north, the Toodoggone volcanics (Carter, 1972; Gabrielse, 1975) may be of Toarcian and Bajocian age and correlative with the Hazelton Group.

From Middle Toarcian time the history of the Hazelton Group continued with the clastic-tuffaceous sedimentation of the Smithers Formation within the depression and eastward, and a marine transgression from the Nilkitkwa Depression westward across the older Sinemurian Babine shelf facies to onlap the Howson facies in the Smithers map-area. The Smithers Formation generally has coarser sediments, probably indicating shallower seas, except in the Nilkitkwa Depression where the fine clastic sedimentation of the Bait Member continued. In the Omineca River area, the formation attains its greatest thickness, over 1200 m, and thins and becomes finer grained southwestward toward the Nilkitkwa Depression. The westward transgression began in Late Toarcian time with the onlapping of the Bait Member on the volcanics of the Red Tuff Member. Evidence of this is found only in the Morrison Lake and Netalzul Mountain areas. The Bait Member was succeeded in Early Bajocian time by the coarse-grained greywacke assemblages of the typical Smithers Formation. These rocks were deposited by erosion of Telkwa and minor contemporaneous volcanics as the sea advanced and shifted in Bajocian time. A warm and shallow sea is suggested by an abundant, varied, and almost ubiquitous fauna—ammonoids, belemnoids, pelecypods, brachiopods, and corals. The sea reached its maximum advance in Late Bajocian time in the Bulkley Valley–Ashman Ridge region and, although Smithers-type deposition ended over most of the Hazelton Trough at the close of Middle Bajocian time, it continued here through Bathonian and, possibly, into earliest Callovian time. Only in Smithers map-area is the transition from the Hazelton Group to the Bowser Lake Group time-transgressive; elsewhere the top of the volcanogenic Smithers Formation is of Middle Bajocian age, and is abruptly and conformably succeeded by fairly mature sediments of the Ashman Formation. The close of Smithers time marks the end of widespread Mesozoic volcanism and production of typical eugeosynclinal, volcanogenic sediments, and the beginning of deposition of sedimentary rocks derived from erosion of older terranes exposed by the rise of the Skeena Arch and, to the east, by the Pinchi belt.

The Hazelton Group was intimately tied throughout its history to the Nilkitkwa Depression, a tectonic element in which up to 4200 m of marine volcanics and sediments accumulated (Fig. 13). Only in Sinemurian time was it a more or less symmetrical trough. In Early Pliensbachian time the basin was asymmetrical, with a gentle slope shallowing eastward and a steep western slope. This configuration persisted, with modifications to the end of Hazelton time. Transitions into the depression from the shelf area on the west are nowhere recorded in outcrop, but indirect evidence suggests an abrupt and profound deepening, with 500 m of marine sediments and tuffs on the shelf and 2000 m in the depression a short distance east. From Pliensbachian to Bajocian time, the Hazelton Group facies immediately west of the trough (in the Morrison Lake area) consistently were shallow-marine and nonmarine deposits, whereas within the trough they were deep and/or distal marine. Alkali-olivine basaltic volcanism centred on the depression was sporadic throughout early Hazelton time, and culminated in the Middle Toarcian. The subsidence of the depression was apparently controlled by a steeply east-dipping fault, and the structure resembled a half-graben, in which the entire east part of the Hazelton Trough subsided. The fault was probably active throughout Hazelton deposition and, judging from the abrupt thickening of sediments, the downthrow may have exceeded 1000 m. Absence of coarse clastic rocks from the depression suggests low relief and sedimentation at a rate coincident with slow subsidence. The depression remained marine until Oxfordian time, when uplifts associated with development of the Skeena Arch and the Bowser Basin elevated the area to supply detritus to the Bowser Lake Group.

Throughout most of the area, the Ashman Formation rests conformably upon Middle Bajocian strata of the Smithers Formation. Only along the Skeena Arch does this boundary transgress time to earliest Callovian. In earliest Callovian time, the Skeena Arch became an active, positive, tectonic element, dividing the Hazelton Trough into two elements, the Nechako and Bowser basins. Creation of the Bowser Basin was the beginning of a phase of regressive alluvial-deltaic-delta slope sedimentation that characterizes the Bowser Lake Group. Major uplift to the east may not have yet begun. From Callovian to Early Oxfordian time, the southern strandline of the basin migrated northward about 30 km from its maximum extent at the close of Hazelton time. Mid-Oxfordian time was a period of rapid uplift around the southern margin of the basin, and coarse-grained clastic rocks of the Trout Creek assemblage were deposited across the Ashman Formation. Marine regression continued until Kimmeridgian time when the sedimentation ended. Kimmeridgian to Early Cretaceous (Hauterivian?) time was apparently a period of regional uplift, faulting, and erosion that ended with the deposition of the Skeena and Sustut groups on this deformed terrane.

EARLY AND MIDDLE JURASSIC PALEOGEOGRAPHY OF THE CANADIAN CORDILLERA

As the stratigraphic, paleontologic, sedimentologic, and tectonic data accumulate, more detailed models of paleogeography become possible. For all five Mesozoic groups in north-central British Columbia there are available some tentative conceptual models. The best documented picture is for the Hazelton Group. Throughout the western Canadian Cordillera there is a rapidly accumulating wealth of data dealing with paleogeographic aspects of correlative rock-units and contemporary basins. Using Hazelton time (Early and Middle Jurassic) as an example, the paleogeographic model of this time span in the Canadian Cordillera will now be described, emphasizing the different basins of deposition, the facies, and changes within the basins through this time.

The Lower and Middle Jurassic sediments and volcanics of the western Canadian Cordillera were deposited in four recognizable basins of accumulation (Fig. 14), namely the Vancouver Basin on the west, the Hazelton Trough, the Whitehorse-Quesnel Trough and the Fernie Basin on the east. The relation of these basins to one another and the facies will be discussed in turn.

The Fernie Basin, as defined by the Fernie Group, extends from the International Boundary in the south, to the Peace River country in the north, in a band about 1120 km long and about 100 km wide. Although the sediments are typically shales, there is an easterly facies change to sands and coarser sediments (Fig. 15). It is generally believed that in Early Jurassic to Bathonian time in the Fernie Basin there was a shallow sea receiving sediment from a low terrain, to the east and northeast. The westward extension of the basin was removed by erosion, but a direct northwestward connection with the Whitehorse Trough has been postulated (Frebold, 1957; Eisbacher, 1974b). There is good reason to believe that the Fernie Basin and the Whitehorse-Quesnel Trough are merely the eastern and western parts of one open basin which has been separated by the rise of the Omineca Crystalline Belt in Late Jurassic and Cretaceous time, and by subsequent erosion.

The Whitehorse-Quesnel Trough represents an essentially sedimentary area of accumulation in Early Jurassic to Bajocian time superimposed upon a dominantly volcanic Triassic trough. In Early Sinemurian time, volcanism, apparently a last gasp of Triassic volcanism, was active in the central part of the trough between Prince George and Kamloops, and may have been active in a few other isolated places. Around Salmo and Nelson, at the south end of the trough, volcanism was prevalent in Early Toarcian time. Generally, the trough can be considered as a sedimentary basin in Pliensbachian time and subsequently (Fig. 15). In Sinemurian time, argillaceous rocks, greywackes, and conglomerate wedges around high-level latest Triassic plutons are characteristic, but the scant information available gives few clues to the configuration of the western margin of the trough against the uplifted late Paleozoic-Triassic (Pinchi belt) terrane, or the role of this uplifted terrane in Hettangian-Sinemurian time. During Pliensbachian to Middle Bajocian time, late Paleozoic-Triassic terrane shed detritus eastward into the trough as evidenced by the coarse conglomerates in the Quesnel–Prince George area and in the Whitehorse area. In the former area, boulder conglomerate and greywacke lie along the eastern margin of the Cache Creek Group of rocks, and contain boulders derived from the Cache Creek Group and from granitoid bodies within the Cache Creek belt of rocks. Easterly, these coarse clastic wedges grade rapidly to greywacke and shale. The highest units of this sedimentary section (Toarcian and Bajocian beds) are invariably fine greywacke or finely laminated siltstone or mudstone; coarse clastics are totally absent. Although coarse clastic rocks at the base of the section

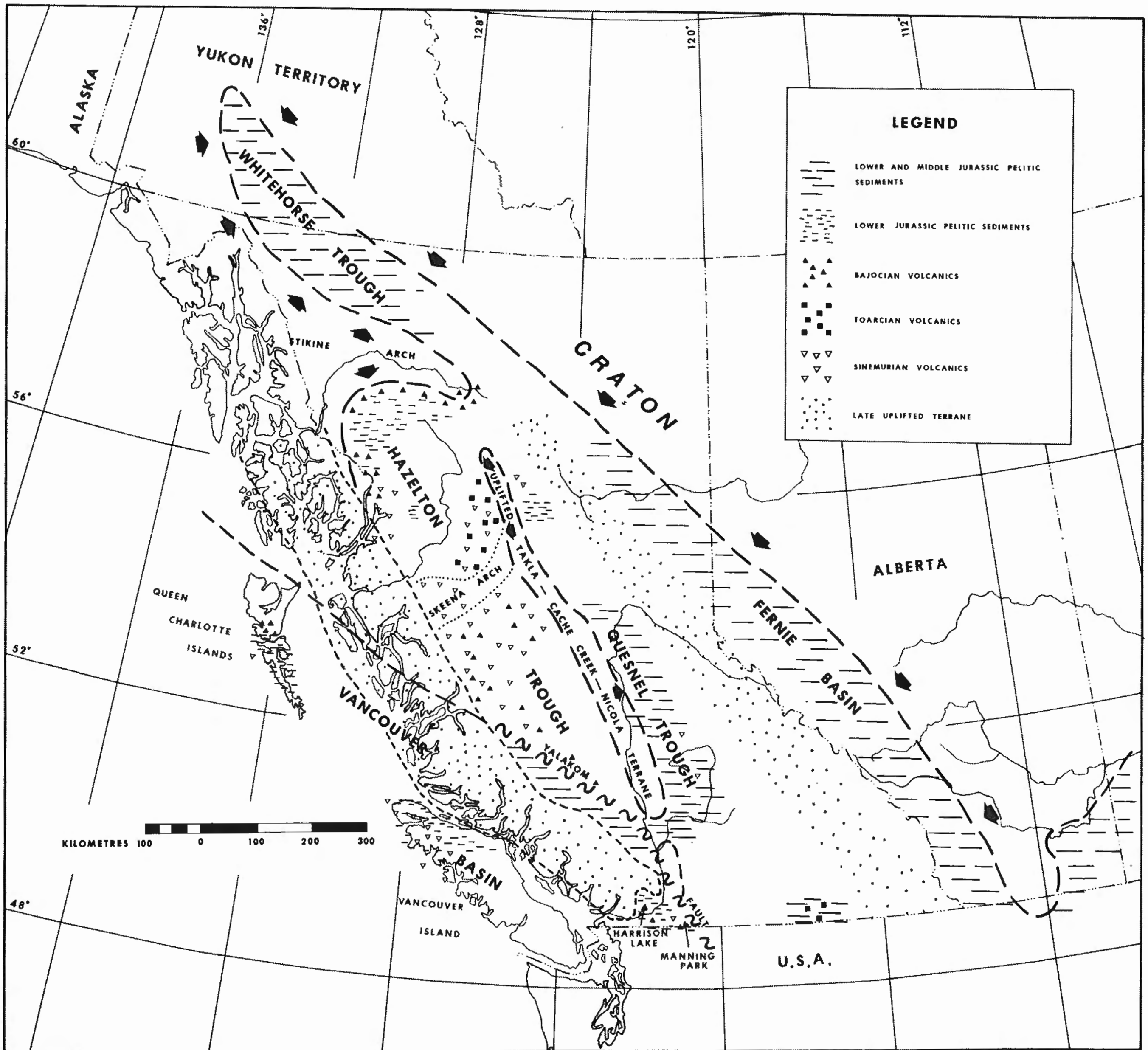

FIGURE 14. Paleogeography of the Early and Middle Jurassic of the Canadian Cordillera.

(Pliensbachian) may be found across the Quesnel Trough, the only evidence for direction transport indicates a westerly source.

The Whitehorse Trough has been described by Wheeler (1961) and Souther (1971), and summarized by Eisbacher (1974b). The northeastern and southwestern margins of the Whitehorse Trough are defined by a proximal granitic-volcanic conglomerate facies that indicates nearby uplifted, probably rugged, source areas, whereas the central outcrop belt is made up of repetitive fine-grained sequences interpreted (Eisbacher, 1974b) as subsea-slope and subsea-fan origin. As in the Quesnel Trough, the highest units in the Laberge Group indicate quiet depositional conditions.

The Whitehorse Trough has provided a good record as a successor basin, and farther south in the Quesnel Trough, the sedimentary record, although fragmentary, suggests similar conditions of tectonic activity and sedimentation except no eastern margin can be recognized. Possibly the eastern margin of the Whitehorse Trough diverges sharply from the western margin and becomes the eastern margin of the Fernie Basin (Fig. 14).

The uplifted Pinchi belt on the west side of the Whitehorse-Quesnel Trough may not have been a continuous barrier preventing direct east–west connections to the Hazelton Trough. Possibly there were gaps in this belt so that, in the vicinity of McConnell Creek map-area, a broad open connection existed, and sediments and volcanics were deposited in places on the Pinchi belt, although they have since been removed by erosion.

The history of the Hazelton Trough has already been

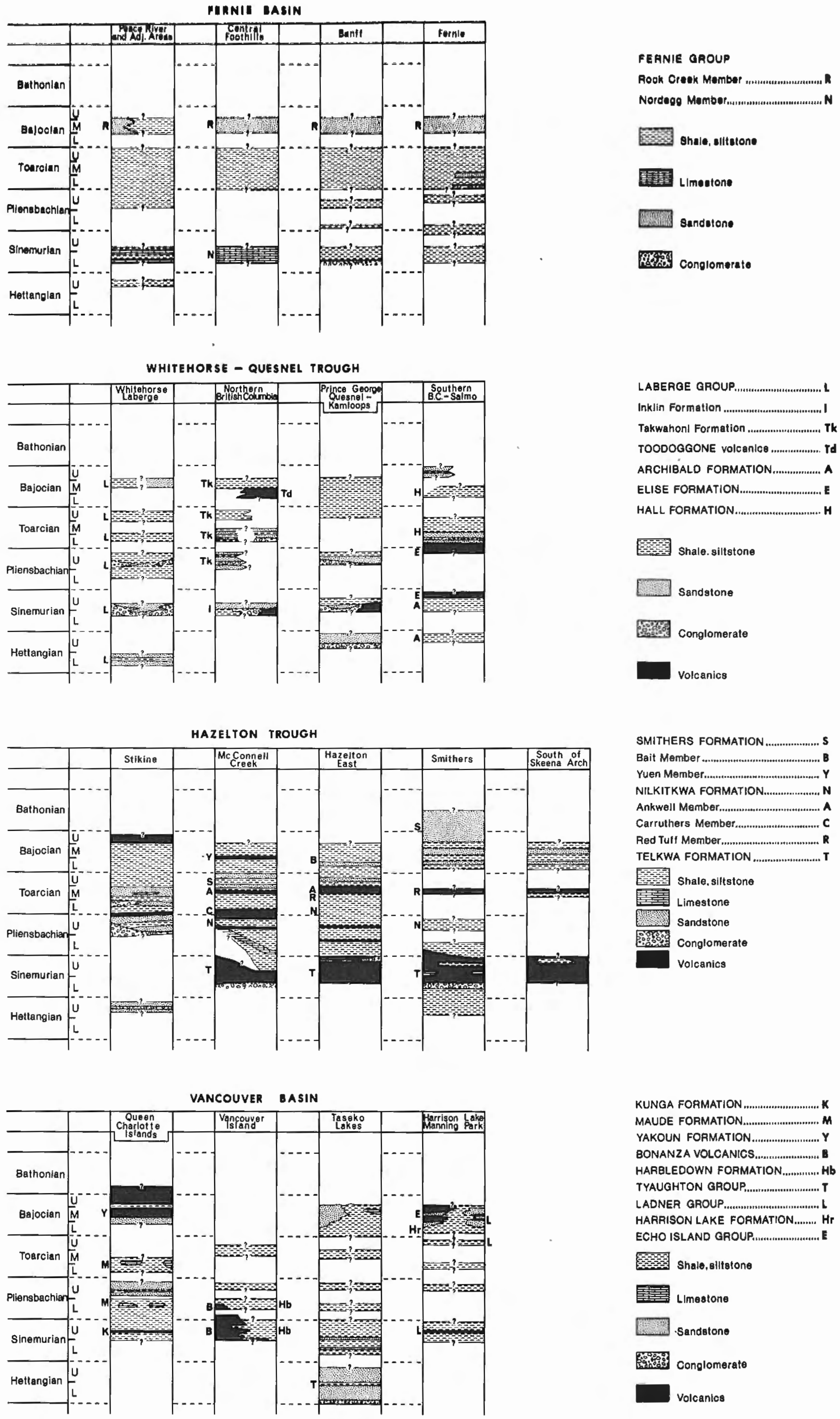

FIGURE 15. Biostratigraphic correlation of the Early and Middle Jurassic of the Canadian Cordillera.

detailed for the northern half; the southern half is poorly known because of Tertiary cover. It essentially lay between the Pinchi belt on the east, the younger Coast Crystalline belt on the west, the Stikine Arch on the north, and was cut off by the Yalakom fault on the south. It was essentially volcanic, with mainly subaerial volcanics on the west and east sides, and subaqueous volcanics in the central part in Early Jurassic time (Fig. 15). As already stated, marine east-west connections with the Whitehorse-Quesnel Trough existed, and western connections with the Pacific Ocean must certainly have existed but are not documented yet. Possible connections are through the present Skeena and Bella Coola valleys. Certainly the last is a probability during Bajocian time (Baer, 1973, p. 29–34). Volcanics of this trough extend southward and are abruptly terminated against the Yalakom fault. The Skeena Arch is a tectonic element that began to rise late in the Early Jurassic, and postdates the rise of the Stikine Arch. The rise of the Skeena Arch marks the end of the major, widespread Jurassic volcanic episodes, and outlines the new basins in which late Middle Jurassic to Upper Jurassic sediments accumulated.

The Yalakom fault is a right-lateral transcurrent fault on which movement ended in Late Cretaceous time, was active throughout Early Cretaceous and Late Jurassic time, and may have been active as early as Late Triassic time. It marks the present eastern limit of the Vancouver Basin. The Vancouver Basin encompasses the Queen Charlotte Islands, Vancouver Island, the eastern flank of the southern Coast Mountains, and Harrison Lake and Manning Park areas. In Early Jurassic time, these areas were part of a single basin of largely sedimentary accumulation. The Coast Plutonic Complex was emplaced later, was uplifted, and all the Jurassic strata were stripped from this complex. Only around the margins of the complex is there any Jurassic lithological record, and this is partly obscured by later sediments and volcanics, displaced by later intrusions, and inundated by the sea on the western side. Nevertheless, the strata of these areas display a remarkable similarity in lithology and paleontology, indicating that the area west of Yalakom fault was part of a single basin in Early Jurassic to Middle Jurassic time (Figs. 14 and 15).

Throughout Early Jurassic time, shale, siltstone, fine sandstone, and minor silty limestone were deposited throughout the Vancouver Basin. Along the western margin, volcanic rocks (Bonanza Volcanics) accumulated on the western part of Vancouver Island (Muller *et al.*, 1974). On Queen Charlotte Islands, a few fine tuff beds are present in a siltstone sequence of identical age. In Manning Park, tuffs are reported from the Ladner Group in sediments of the same age (Late Sinemurian). Except for these three exceptions the basin is sedimentary; the volcanics form a western rim. The fossil record of the four areas, although not well documented, is sufficiently similar to suggest that the areas have a nearly identical faunal succession.

The record of Middle Bajocian time is volcanic rocks on Queen Charlotte Islands (Yakoun Formation), tuffs and breccias at Harrison Lake (Harrison Lake Formation), and in Manning Park (Ladner Group), and possibly unfossiliferous volcanic sequences in Howe Sound (Bowen Island Group); no Bajocian rocks are known on Vancouver Island. The Bajocian rocks along the eastern side of the basin are sedimentary and similar to the Lower Jurassic strata. The Bajocian volcanic belt shifted northeastward (*see* also Jeletzky, 1970, p. 24) from the Early Jurassic site, and probably occupied a position more or less central to the southern Coast Plutonic Complex.

The general trend of elements within this basin lies obliquely across the trend of the Hazelton Trough. Besides detailed evidence for transcurrent movement, the Vancouver Basin differs markedly from the Hazelton Trough where juxtaposed, suggesting that it is an allochthonous block that has moved northwestward along the Yalakom fault and that may have been rotated counter clockwise. The basin predated the Coast Plutonic Complex, as does the Yalakom fault. If the basin is restored to its proper position, the Bonanza Volcanics could well be the southern extension of the Telkwa Formation in the Hazelton Trough; the two units are lithologically, chemically (Figs. 16 and 17), and stratigraphically identical. The Vancouver Basin is the only part of the Canadian Cordilleran Jurassic that appears to have appreciable lateral dislocation; the other basins are in their original positions, relative to one another.

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APPENDIX I

Stage Names from Late Triassic to Late Cretaceous as Used in This Report

CRETACEOUS	UPPER		
	LOWER		Albian Aptian Barremian Hauterivian Valanginian Berriasian
JURASSIC	UPPER		Upper Tithonian Portlandian Kimmeridgian Oxfordian
	MIDDLE	U	Callovian
		M	
		L	
		U	Bathonian
		L	
		U	Bajocian
		M	
		L	
	LOWER	U	Toarcian
		M	
		L	
		U	Pliensbachian
		L	
		U	Sinemurian
		L	
		U	Hettangian
		L	
TRIASSIC	UPPER		Rhaetian
		U	Norian
		M	
		L	
		U	Karnian
		L	

APPENDIX II

Physical Characteristics of Subaerial and Subaqueous Volcanics of the Hazelton Group

Throughout Early Jurassic time, volcanics in the Hazelton Trough were deposited in both marine and nonmarine environments, resulting in genetically related rocks with different physical characteristics. The following table compares physical features of rocks deposited from eruptions into an atmospheric medium to rocks erupted into a subaqueous medium. It is a summation of mineralogical, paleontological, and stratigraphic observations and interpretations that may be used as a guide for mapping the Hazelton Group and is not intended to supply criteria for separating marine from nonmarine rocks, nor is it necessarily applicable to other volcanic terranes. The columns in the table refer only to end member conditions, and all gradations may be expected. They do not necessarily refer to environments of deposition, but only eruption. Subaerial volcanics may be deposited into a marine environment, a situation interpreted for the Telkwa Formation and the Ankwell Member and noted in the Upper Triassic Stuhini (Souther, 1971), Takla (Church, 1974; Monger, 1974, 1976), and Nicola (Preto, *in press*) groups. In this case, the volcanic strata retain many features correlative with the subaerial eruptive suite but are intermixed with marine fauna and sediments. Although red and green colorations are the most obvious difference, no single observation, fact, or criterion is reliable for interpretation of depositional environment.

SUBAERIAL ERUPTED VOLCANICS		SUBMARINE ERUPTED VOLCANICS
Dominantly reddish, maroon, purple; light to dark shades; green and grey common	COLOUR	Dominantly shades of light to dark green, grey common, red rare; weathers brownish, commonly speckled in greens and white
Generally well bedded, planar, and may be laterally extensive, particularly in flows and ignimbrites; beds usually thick (1–50 m) and massive, lamination rare except in rhyolite flows and lacustrine mudstone	BEDDING	Generally massive bedded units whose bedding is difficult to see from a distance; in outcrop may be massive to laminated; beds lenticular on a large scale
Little or no internal sorting, clasts of all sizes intermixed, from blocks to ash; pyroclastic rocks commonly with a fine-grained dense matrix of hematitic mud; fragments generally angular and fragment boundaries usually definable; fragments in pyroclastics may be monomictic or polymictic, usually porphyritic and finely crystalline; basalt and andesite flows massive with subophitic and pilotaxitic texture common, flow top breccia common; acidic rocks with eutaxitic, spherulitic texture, flow banding and massive flows common; accretionary lapilli, flattened pumice, bombs common	INTERNAL STRUCTURE	Tuffs and breccias poorly to moderately sorted, rarely with fine mud matrix, fragments often suspended in dense, white, fine-grained Ca-Al silicate matrix and fine-grained grey limestone; broken pillow breccia common, pillows rare; basalt and andesite fragments usually chilled, finely porphyritic, and amygduloidal, fragment boundaries, particularly in tuff and fine-breccia irregular, diffuse or indistinct; flows rare; acid volcanics range from ash-fall tuff to breccia with spherulitic and flow band texture
Immature sandstone, conglomerate, siltstone, and mudstone with clasts derived from adjacent, contemporaneous volcanics; suite is gradational from unsorted pyroclastics to alluvial sediments and contains lahar and fanglomerate; amount of red matrix decreases with amount of reworking; sediment structures include ripple marks, ripple lamination, cross-beds, scour marks, mudcracks and clastic dykes; thin, laterally extensive limestone may be lacustrine marls; sediment distribution irregular	INTERBEDDED SEDIMENTS	Shale, greywacke, siltstone, limestone and tuffaceous ash, well-bedded; fine laminae may be traceable over great distances; limestone bodies usually lenticular; graded bedding, slump structure, flame structure, rip-up clasts and bioturbation features common; coarse clastics rare, matrix usually fine-grained argillite and/or tuff
Rare in terrestrial deposits; in subaerial erupted volcanics deposited in a marine environment, may contain abundant fauna, including pelecypods, gastropods, brachiopods, corals, and rarer belemnite and ammonite; fauna often concentrated in biohermal reefoid masses; wood and logs common	FAUNA	Common, usually as few isolated ammonites, belemnites, and thin-shelled pelecypods, particularly in interbedded sediments; biohermal reefoid masses common
Abundant and great variety of minerals, including zeolites, prehnite, epidote, albite, chlorite, and K-feldspar; prehnite usually green, commonly with native copper; zeolites in extensive areas particularly as veins, cockscomb, open space and replacements in chaotic sorted pyroclastics; dense, massive units like flows commonly fresh; zeolites common in marine deposited subaerially erupted volcanics	SECONDARY MINERALS	Minerals prehnite, pumpellyite, albite, and chlorite common, zeolites rare except as porphyroblastic replacements of shards in ash-fall tuff and minor veins; epidote common as irregular masses, rare in white cement of tuff and breccia which is composed of prehnite, albite, quartz, calcite, and rare pumpellyite

APPENDIX III

Stratigraphic Sections

SECTION I: TELKWA FORMATION, HOWSON FACIES

Location: Clore River, Smithers Map-area (93L) 54°24′N, 127°W

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
	Top not exposed		
89	Volcanic sandstone, pink, immature, angular fragments to 2 cm	1.0	424.8
88	Crystal tuff, red, medium-grained, feldspathic, minor fine-grained, grey limestone nodules to 2 cm	2.0	423.8
87	Covered	3.0	421.8
86	Breccia, wine-red, medium-grained; clasts fine-grained volcanic and feldspar porphyry	4.5	418.8
85	Covered	5.0	414.3
84	Breccia, pale mauve, glassy fragments to 30 cm	9.0	409.3
83	Covered	4.0	400.3
82	Tuff-breccia, red, medium-grained; clasts mainly pale mauve fine-grained volcanics; 2.5-cm grey limestone, and red lapilli tuff; laumontite cement	7.0	396.3
81	Lapilli tuff, light purple, rubbly weathering, with abundant acid volcanic fragments	12.0	389.3
80	Lapilli tuff, red, crystal-lithic	9.0	377.3
79	Tuff, red, fine- to medium-grained, feldspathic, waterlain, with rare rounded pebbles of volcanic rock	2.0	368.3
78	Covered		
77	Tuffaceous mudstone, dense to rubbly weathering, fine-grained, brick-red, with few medium-grained, angular fragments	1.0	366.3
76	Tuffaceous mudstone, fine-grained, red, with coarse-grained (50 cm) fragments at base	2.0	365.3
75	Volcanic sandstone and conglomerate, red, pebble to cobble, coarse-grained, polymictic; cobbles average 1 cm, maximum to 30 cm	0.6	363.3
74	Tuffaceous siltstone, fine- to medium-grained, reddish, quartz-plagioclase, crystal-lithic, waterlain	1.5	362.7
73	Covered	3.0	361.2
72	Lithic tuff to breccia; at top a light to pale mauve, feldspathic (to 30%), near bottom, matrix becomes dark purple and appears to grade into flow-banded, tough, feldspathic-lithic-vitric ignimbrite	30.0	358.2
71	Covered	2.0	328.2
70	Feldspathic tuff, brick-red, crumbly weathering, fine-grained, minor quartz eyes and 15–60-cm grey limestone mud nodules; fragments increase in size to 3 cm near base	12.0	326.2
69	Quartz-feldspar crystal tuff, fine-grained, brick-red	1.0	314.2
68	Crystal-lithic tuff, red to maroon, fine- to coarse-grained, with minor grey limestone mud nodules	3.0	313.2
67	Breccia, coarse-grained, red	2.0	310.2
66	Lithic tuff to fine breccia, medium- to fine-grained, weakly indurated, crumbly, weathering red to brick-red, fragments increase from 1–3 cm at top to 15 cm toward base	12.0	308.2
65	Lapilli-crystal tuff to fine breccia, dark red, coarse, plagioclase the dominant clast	1.0	296.2
64	Lapilli tuff, brick-red, friable weathering	2.0	295.2
63	Coarse tuff to fine breccia, light pinkish red, with 2-cm red volcanic clasts; minor zeolite alteration	9.0	293.2
62	Tuff, blocky fracturing, massive, red quartz-plagioclase crystal tuff; weakly flow banded, pinkish red to dark red, rubbly weathering, weakly vesicular to chlorite-zeolite amygduloidal lapilli tuff	6.0	284.2
61	Lapilli tuff to fine breccia, dense, red, with abundant, fine-grained, grey limestone mud nodules	8.0	278.2
60	Lapilli tuff, purple, feldspathic	1.0	270.2
59	Breccia, pale reddish pink, weakly flow banded, fine, with purple and red volcanic fragments to 2 cm and quartz-plagioclase crystal clasts	9.0	269.2
58	Covered	3.0	260.2
57	Tuffaceous mudstones, 1–15-cm beds, poorly exposed, red	3.0	257.2
56	Lithic lapilli tuff to fine breccia, dark red, plagioclase (30–40%), locally slightly vesicular	9.0	254.2
55	Tuff, dense, brittle, dark red, fine-grained	1.0	245.2
54	Quartz-plagioclase-lithic lapilli tuff, blocky fracturing, red, weakly flow banded and vesicular	8.0	244.2

SECTION I—*continued*

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
53	Volcanic sandstone, feldspathic, red, with red, muddy matrix	0.3	236.2
52	Mudstone and siltstone, thin-bedded, red, mudcracks	0.3	235.9
51	Tuff, dense, brittle, fine-grained, red, with fine-grained grey limestone nodules	3.0	235.6
50	Feldspathic tuff, fine-grained, inverse gradient with abundant plagioclase clasts at the top and uncommon toward base	0.6	232.6
49	Tuffaceous mudstone, fine-bedded, red	1.0	232.0
48	Feldspathic tuff, finely graded beds, waterlain, feldspar concentrations mark the base of each layer	0.3	231.0
47	Lapilli tuff to fine breccia, fine-grained, red, with grey limestone nodules	1.0	230.7
46	Tuffaceous siltstone, fine- to medium-grained, waterlain, with thin laminations of tuffaceous mudstone	1.0	229.7
45	Lapilli tuff, well-bedded (25–150 cm), red to brick-red, feldspathic-lithic, moderately indurated to friable	5.0	228.7
44	Volcanic sandstone, purple, immature, medium- to coarse-grained, pebbly, feldspathic	0.3	223.7
43	Tuff, fine- to medium-grained, red to purple, waterlain	1.0	223.4
42	Breccia, brick-red, medium-grained, fragments of all red volcanics, top of member 1–3-cm clasts, increasing to 15 cm toward base	7.0	222.4
41	Breccia, red to maroon, medium- to fine-grained	6.0	215.4
40	Covered	4.0	209.4
39	Flow-banded acidic breccia, light purple, minor epidote	3.0	205.4
38	Tuff, dense, brittle, medium- to fine-grained, reddish purple	3.0	202.4
37	Volcanic sandstone, fine-grained, pale green	1.0	199.4
36	Plagioclase-lithic tuff, fine-grained, well-bedded to laminated, waterlain; locally with fine-grained, grey limestone nodules	9.0	198.4
35	Covered	2.0	189.4
34	Plagioclase-lithic lapilli tuff, fine- to medium-grained, purplish red	2.0	187.4
33	Acid tuff, beige-weathering, conchoidal fracturing, glassy, bottom 10 cm rich in fine-grained limy clots and lithic clasts	2.0	185.4
32	Siltstone and mudstone, thin-bedded (3–30 cm), fine-grained, red to purple, waterlain quartz-plagioclase-lithic, tuffaceous	2.5	183.4
31	Volcanic sandstone, immature, thin-bedded, fine-grained, purple-red	0.6	180.9
30	Plagioclase-quartz-lithic tuff to lapilli tuff, fine- to medium-grained, thin-bedded (15–60 cm), red to maroon, weakly indurated to crumbly weathering	6.0	180.3
29	Feldspathic-lithic lapilli tuff to breccia, fine- to medium-grained, massive to medium-bedded, moderate to weakly indurated	11.0	174.3
28	Breccia, pinkish red, feldspathic–lithic, fine-grained, with 1–15-cm, fine-grained, grey limestone nodules	2.0	163.3
27	Covered	3.0	161.3
26	Crystal-lithic tuff and tuffaceous mudstone, fine-grained, fine- to medium-bedded, red to brick-red	4.0	158.3
25	Breccia, medium-grained, red	2.0	154.3
24	Covered	2.0	152.3
23	Purple breccia, tough, massive, medium-grained; small grey limestone clots common, locally amygduloidal with calcite and chlorite fillings; clasts average 5 cm, maximum to 30 cm	8.0	150.3
22	Sandstone, poorly sorted, purple, volcaniclastic, medium-grained	0.3	142.3
21	Purple breccia, friable, weakly indurated, clasts up to 15 cm	1.2	142.0
20	Lapilli tuff and breccia, dense to weakly indurated, medium- to fine-grained, purple to red quartz-plagioclase-lithic fine limestone nodules common	9.0	140.8
19	Siltstone, thin-bedded, purple-red, waterlain, volcaniclastic	0.3	131.8
18	Tuffaceous siltstone, well-bedded, locally graded, purple, plagioclase	1.5	131.5
17	Quartz-plagioclase-green lithic lapilli tuff, fissile, well-bedded (15–90 cm)	8.0	130.0
16	Covered	3.0	122.0
15	Breccia, massive bedded, moderately indurated, red, medium-grained	4.0	119.0
14	Plagioclase-lithic tuff, finely bedded, purple, minor limestone nodules	3.0	115.0
13	Breccia, massive, brittle, highly fractured, dark to light purple, fine-grained	6.0	112.0
12	Covered	7.0	106.0
11	Breccia, massive, dark purple, medium-grained; calcite veins common	5.0	99.0
10	Lapilli tuff to fine breccia, red to purple, moderately indurated	3.0	94.0
9	Covered	9.0	91.0
8	Lapilli tuff and fine breccia, purple to dark red	4.0	82.0
7	Mudstone, brownish purple, medium-grained, tuffaceous	2.0	78.0
6	Mudstone, rusty, wine-red, friable, crystal-lithic, fine-grained, lapilli tuffaceous	4.0	76.0
5	Feldspathic-lithic tuff, blocky fracturing, amygduloidal, greenish; clay-altered pumice fragments common	1.0	72.0

SECTION I—*continued*

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
4	Crystal-lithic lapilli tuff to fine breccia, well-bedded (30–150 cm), coarsely fractured, spheroidal weathering, moderately indurated, red, maroon to brick-red; minor, 2–15-cm, intercalated, fine-grained, red, tuffaceous mudstone and siltstone	14.0	71.0
3	Lithic lapilli tuff, massive bedded, coarsely jointed, red, plagioclase-rich	6.0	57.0
2	Feldspathic acidic tuff, massive bedded, grey to light mauve, dense, tough, resistant; grades downward into dense, massive, grey to mauve, crystal-lithic, massive, acidic, lapilli tuff	45.0	51.0
1	Lapilli tuff, well-bedded, red to purple, crystal-lithic, moderately indurated	6.0	6.0
	Fault		
	Base not exposed		

SECTION II: TELKWA FORMATION, HOWSON FACIES
Location: Loljuh Creek, Smithers Map-area (93L) 54°24′N, 127°13′W

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
	Top not exposed		
25	Basalt-andesite flows, massive bedded (2–4 m), dark grey; tops amygduloidal and brecciated	15.0	126.9
24	Tuffaceous red mudstone	1.5	111.9
23	Flows, massive, grey to blue-grey, hematitic; three flows present, with flow top breccias; locally amygduloidal; cavities and pods filled with prehnite and epidote; laumontite veins common	9.0	110.4
22	Mudstone, brittle, red, tuffaceous	3.0	101.4
21	Basalt-andesite flow, dark grey to reddish grey, fine-grained, dense, with fine-grained, reddish hematitic mafic microphenocrysts, top highly amygduloidal and locally brecciated; fillings and veins of prehnite, calcite, and chalcocite	4.5	98.4
20	Mudstone and siltstone, laminated, red, lithic, tuffaceous	3.0	93.9
19	Breccia, fine- to coarse-grained, light weathering, zeolite-cemented, unwelded, chaotic, with angular polymictic volcanic fragments to 50 cm	7.0	90.9
18	Mudstone, thin, laminated (6 mm–3 cm), red, tuffaceous	0.6	83.9
17	Ash tuff, fine, light green, friable	0.3	83.3
16	Mudstone and siltstone, fine-bedded, red to maroon, tuffaceous	2.0	83.0
15	Basalt-andesite flow, dark grey, massive bedded, hematitic, mafic; chalcedonic veins common	3.0	81.0
14	Dark grey flow, amygduloidal epidote-quartz and flow top breccia	5.0	78.0
13	Mudstone, red, fine-bedded, tuffaceous	5.0	73.0
12	Basalt-andesite flows, massive bedded (1.5–4 m), dark grey; fine microphenocrysts of mafics oxidized to hematitic pseudomorphs; locally highly amygduloidal either along flow tops or central to flow, with zeolite or prehnite-epidote fillings	18.0	68.0
11	Thin-bedded to laminated tuffaceous mudstone and lithic lapilli tuff	1.0	50.0
10	Feldspar porphyry flow, green to greenish grey	6.0	49.0
9	Thin-bedded (30–60 cm) to laminated, red, fine-grained feldspathic-crystal tuff, crystal-lithic lapilli tuff, and tuffaceous mudstone	7.0	43.0
8	Volcanic breccia, medium- to fine-grained, chaotic, polymictic clasts 1–3 cm set in a light coloured, bleached, zeolitic matrix	4.0	36.0
7	Lapilli tuff, dense to brittle, well-bedded, fine-grained, red	1.0	32.0
6	Lithic-vitric tuff, light maroon to pinkish, medium- to fine-grained, moderately welded and moderately indurated; contains 3–30-cm, flattened, altered pumice fragments; little or no evidence of internal flow structure	5.0	31.0
5	Tuff and breccia, red, medium-grained, lithic-vitric lapilli tuff to fine breccia with green, clay-altered, flattened pumice fragments	3.0	26.0
4	Lapilli tuff, dense, brittle, medium- to fine-grained, red; minor light grey, fine-grained, limestone nodules or clasts	2.0	23.0
3	Lapilli tuff to breccia, medium- to fine-grained, dense, red	4.0	21.0
2	Tuff and breccia, red to maroon, medium-grained (1–10 cm), polymictic, volcanic breccia with flattened pumice fragments, red lapilli tuff, vesicular volcanic and pahoehoe clasts and crystal fragments, with little or no sorting or flow structure	8.0	17.0
1	Tuff and breccia, moderate to poorly indurated, light to medium red, medium- to fine-grained, polymictic, lithic-vitric tuff; fine- to medium-grained breccia with both flattened and unflattened pumice fragments	9.0	9.0
	Base not exposed		

SECTION III: TELKWA FORMATION, HOWSON FACIES

Location: Ashman Ridge, Smithers Map-area (93L) 40 km west of Smithers 54°50′N, 127°51′W

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
	(Overlain by RED TUFF MEMBER, NILKITKWA FORMATION)		
23	Crystal-lapilli tuff, well-bedded, fine- to medium-grained, reddish, minor basalt flows	15.0	344.0
22	Tuff and breccia, red to maroon, fine-grained lithic tuff, lapilli tuff and fine- to medium-grained breccia (fragments to 60 cm), minor brown-weathering basalt-andesite flows	20.0	329.0
21	Tuff, well-bedded (30–120 cm), red, brick-red to maroon fine tuff to fine-grained lithic tuff	15.0	309.0
20	Breccia, well-bedded, rubbly, pale greenish grey basaltic-andesite	6.0	294.0
19	Fossiliferous limestone, grey, fine-grained, outcropping as elongate, discontinuous lenses 30–150 m along strike. GSC loc. 85399. *Asteroceras* sp., *Arctoasteroceras* sp.	1.5	288.0
18	Breccia, fine- to medium-grained, pale greenish to purplish; fragments mainly altered, green feldspar porphyries	7.5	286.5
17	Tuff and tuffaceous shale, finely bedded (5–60 cm), red to maroon, fine-grained lithic tuff, crystal-lithic lapilli tuff, and tuffaceous mudstone and siltstone	75.0	279.0
16	Lithic lapilli tuff to fine-grained breccia, massive bedded, pale mauve to pink, flow banded, siliceous, crystal (K-feldspar)	30.0	204.0
15	Tuff and breccia, interbedded, fine-bedded (30–90 cm), brittle to friable red tuff and lapilli tuff; thin- to thick-bedded (30 cm–3 m), medium- to fine-grained, red, maroon, and purple breccias with red tuff, rhyolite, and feldspar porphyry fragments to 30 cm; 1–3-m, bedded, fine-grained, grey to purple amygduloidal basalt-andesite flows and minor siliceous fine-grained tuff	45.0	174.0
14	Crystal-lithic lapilli tuff, fine-grained, massive, siliceous, red and mauve	6.0	129.0
13	Interbedded red to maroon lapilli tuff and 60–150-cm beds of feldspar porphyry flow	9.0	123.0
12	Crystal-lithic tuff, fine- to coarse-bedded (30 cm–3 m), pale mauve to red, siliceous	45.0	114.0
11	Lithic lapilli tuff, massive bedded, brick-red	3.0	69.0
10	Interbedded purple to mauve feldspar porphyry, and dark green, amygduloidal basaltic flow	7.5	66.0
9	Interbedded red to brick-red lithic lapilli tuff and 1.5-m massive bedded feldspar porphyry flow	15.0	58.5
8	Feldspar porphyry flow, red, massive	3.0	43.5
7	Lithic lapilli tuff, well-bedded (30–90 cm), fine- to medium-grained, red	9.0	40.5
6	Lithic lapilli tuff to fine breccia, coarse-grained, red; fragments chaotic sorted 3–15 cm	1.5	31.5
5	Lithic-vitric lapilli tuff, fine-grained, brittle, siliceous	3.0	30.0
4	Basalt-andesite flow, grey-green, amygduloidal, oxymafic	3.0	27.0
3	Lithic-crystal lapilli tuff, well-bedded, fine-grained, red to maroon	15.0	24.0
2	Siliceous tuff, fine-grained, grey to pale mauve	3.0	9.0
1	Lapilli tuffs, fine-grained, brittle to friable, red	6.0	6.0
	Base not exposed		

SECTION IV: TELKWA FORMATION, KOTSINE FACIES, AND BEAR LAKE FACIES

Location: Driftwood Range, Hazelton Map-area (93M) 55°50′N, 126°40′W

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
	(Overlain by NILKITKWA FORMATION)		
	Kotsine Facies		
8	Breccias, tuffs, and flows, green aquagene volcanic breccias and tuffs, few interlayered amygduloidal flows and lime-cemented volcanic breccias; most common member is a massive bedded (3–6 cm) calcite-quartz-prehnite cemented green lapilli tuff and fine- to medium-grained volcanic breccia	75.0	475.0
	Bear Lake Facies		
7	Lapilli tuff, fine breccia and grey to reddish grey basalt flows; interbedded red, maroon to purple	60.0	400.0
6	Interlayered basalt flows and red lapilli tuff and breccias; flows 3–6 m thick, pyroclastics dominate	30.0	340.0
5	Dense red tuff, lapilli tuff, and fine breccia, massive bedded, reddish, intermediate composition	70.0	310.0

SECTION IV—*continued*

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
4	Tuff, flows, and breccias, interbedded, massive (1–9 m) amygduloidal basalt flows, flow breccia, and red to purple lapilli tuff and fine- to medium-grained breccia; toward base, green basaltic agglomerate-breccia and minor lahar composed of angular red volcanic clasts in a finer grained green, altered matrix	30.0	240.0
3	Top dominantly composed of basalt and andesite flows, interbedded with few red, dense to lapilli tuff; basal 30-m-thick agglomerate with few clasts to 12 cm diameter, and interbedded red tuff and hard, intraformational volcanic sandstone; minor, thin (6 cm) limestone lenses with abundant included volcanic fragments and few pelecypods	60.0	210.0
2	Tuffs and flows, interbedded, coarsely to massively bedded, red lapilli tuffs overlying a section of 3–9-m-thick, massive bedded basalt flows; many are amygduloidal and few show well-developed flow top breccia	60.0	150.0
1	Massive bedded, light red to pink to mauve acid breccias and flows, many showing flow banding, and interbedded, dense, massive crystal-lithic welded tuffs	90.0	90.0
	Base not exposed		

SECTION V: TELKWA FORMATION, BEAR LAKE FACIES

Location: East of Motase Lake, McConnell Creek Map-area (94D) 55°03′N, 126°52′W

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
	Top not exposed		
25	Mudstone and tuff, fine-bedded (0.3–0.6 m), red, tuffaceous mudstone and crystal-lithic lapilli tuff	6.0	201.0
24	Grey basalt with flow top breccia; veins and fillings of epidote, potash feldspar, and zeolite	6.0	195.0
23	Breccia, angular clasts to 0.6 m, dominantly of red amygduloidal basalt-andesite, cavities filled with calcite	12.2	189.0
22	Conglomerate and sandstone, interbedded volcanic sharpstone conglomerate, fanglomerate, volcanic sandstone, siltstone, and lapilli tuff; minor fine-grained pumice breccia	12.2	176.8
21	Tuff and breccia, finely bedded to medium-bedded (15 cm–1.5 m), well-bedded, waterlain pumice lapilli tuff and fine breccia	9.2	164.6
20	Breccia, massive bedded, reddish polymictic andesite-dacite breccia	1.8	155.4
19	Mudstone and tuff, finely bedded to medium-bedded, reddish tuffaceous lapilli mudstone, tuff; minor medium-grained sandstone	9.2	153.6
18	Massive bedded, poorly sorted lahar, angular to subrounded volcanic clasts to 0.6 m in chaotic-sorted reddish tuffaceous siltstone and mudstone	4.6	144.4
17	Siltstone and mudstone, well-bedded (0.3–0.6 m) tuffaceous siltstone, mudstone, minor sandstone, and pebble conglomerate	7.6	139.8
16	Breccia, polymictic, medium-grained	4.5	132.2
15	Tuff and breccia, interbedded, red, pumice-lithic-lapilli tuff and fine breccia; grey feldspar porphyry	12.2	127.7
14	Basalt, grey amygduloidal	3.0	115.5
13	Tuff, red, fine-grained lapilli-crystal tuff grading upward into medium- to coarse-grained lapilli tuff	0.6	112.5
12	Breccia, medium- to coarse-grained, feldspathic andesite breccia with epidote-quartz-potash feldspar alteration	7.6	111.9
11	Mudstone, rubbly weathering, fine-grained, lapilli, tuffaceous	0.9	104.3
10	Basalt, grey to reddish grey	3.1	103.4
9	Breccia, well-bedded (15 cm–1 m), red, lapilli tuff and fine-grained breccia	9.2	100.3
8	Andesite, massive to amygduloidal	7.6	91.1
7	Rhyolite, massive, dense, mauve	12.2	83.5
6	Breccia and tuff, red to purple, feldspar porphyry	7.6	71.3
5	Andesite, grey to reddish, amygduloidal	6.0	63.7
4	Volcanic sandstone, reddish, feldspathic; minor cross-bedding	1.5	57.7
3	Tuff and breccia, reddish to light purple, feldspathic; quartz veins common	4.6	56.2
2	Porphyry and tuff, dense, massive to interbedded, pink to grey siliceous feldspar porphyry; massive red ash tuff; a few 1.5-m basalt interlayers	6.0	51.6
1	Basalt and breccia, grey, black, purple and red olivine basalt, aphanitic basalt, feldspar porphyry flow, and flow breccia; minor 0.6–1.8-m interbeds of red lapilli tuff	45.6	45.6
	Base not exposed		

SECTION VI: TELKWA FORMATION, SIKANNI FACIES

Location: Mount Bates, Hazelton Map-area (93M) 55°45′N, 126°02′W

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
	Top not exposed		
7	Volcanic breccia, well-indurated, purple-maroon	9.0	216.0
6	Volcanic sandstone, siltstone, and minor mudstone, rapidly alternating, purple-maroon, poorly sorted, well-bedded (30 cm–1 m), polymictic, rare 30–60-cm-thick beds of purple, moderately indurated volcanic breccia and lapilli tuff	30.0	207.0
5	Polymictic conglomerate, coarse-grained; clasts to 8 cm, subangular, dominantly big bladed feldspar porphyry, green tuff, green volcanic, and rare augite porphyry, granitic textured quartz-feldspar porphyry and vein quartz	9.0	177.0
4	Interbedded reddish to greenish volcanic-granitic cobble conglomerate, sandstone, and siltstone; clasts in conglomerate rounded to subangular, with maximum diameter to 20 cm; base of section marked by resistant member of purple feldspar porphyry breccia	18.0	168.0
3	Red to maroon, coarse-grained lapilli tuff to fine-grained breccia	45.0	150.0
2	Interbedded red lapilli tuff, volcaniclastic sandstone, siltstone, and minor volcanic breccia and conglomerate	45.0	105.0
1	Recessive, poorly exposed, interbedded (30 cm–1 m beds), maroon to purple lapilli tuffs and volcaniclastic sandstone; minor interbeds of predominantly volcaniclastic conglomerate with well-rounded clasts to 10 cm	60.0	60.0
	Base not exposed		

SECTION VII: TELKWA FORMATION, BEAR LAKE FACIES

Location: South of Dewar Peak, McConnell Creek Map-area (94D) 56°38′N, 126°48′W

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
	Top not exposed		
11	Four upward fining volcanic mud-flow conglomerate cycles; units of pebble to cobble mud-flow lahar composed of well-rounded feldspar porphyry clasts in a matrix of feldspathic sand and red mud; grades upward to fine-grained mudstone or feldspathic lapilli tuffaceous mudstone; minor interbedded olivine basalt flows	90.0	207.0
10	Interlayered cobble (to 0.6 m) fanglomerate units grading upward to fine mudstone, laminated near tops, rarely cross-bedded and with mudcracks; conglomeratic units to 6 m; coarse-grained, sandy members altered preferentially to epidote	30.0	117.0
9	Interlayered (0.15–1.8 m) sequence of medium-grained feldspathic-pebble volcanic sandstone and thin-bedded to laminated, waterlain pyroclastics with common pumice fragments; selective replacement of sandstone by epidote; mudstone rip-up clasts common	30.0	87.0
8	Mudstone, red, massive lithic or lithic-lapilli	3.0	57.0
7	Sandstone, interbedded green, medium-grained, feldspathic-lithic sandstone grading upward to thin mudstone	3.0	54.0
6	Waterlain, crystal-lithic lapilli tuff, graded to poorly sorted; may be well laminated; rare fine- to medium-grained breccia; minor, red, laminated mudstone; scour bases common	15.0	51.0
5	Coarse-grained, feldspar porphyry cobble mud-flow conglomerate, clasts to 0.6 m	3.0	36.0
4	Pebble-mudflow conglomerate to volcanic grit in beds 0.3 to 1.8 m thick, grades upward to 2.5–15.0-cm red siltstone-mudstone; scour bases present	6.0	33.0
3	Red tuffaceous mudstone and feldspathic-volcanic grit; minor cross-bedding	6.0	27.0
2	Cyclic sequence (1.5–3.0 m beds) of poorly sorted, feldspar porphyry, dacite porphyry pebble sandstone and mud-flow conglomerate; each unit grading upward to 0.63–30.8-cm-thick laminated red siltstone and mudstone	12.0	21.0
1	Feldspar porphyry-dacite porphyry pebble and cobble fanglomerate with clasts in poorly sorted red, feldspathic grit; grades into laminated sandstone, siltstone, and mudstone at top	9.0	9.0

SECTION VIII: NILKITKWA FORMATION TYPE SECTION

Location: Southern Nilkitkwa Range, Hazelton Map-area (93M) 55°55′N, 126°50′W

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
	(Overlain by ANKWELL FORMATION)		
18	Greywacke, dark to medium grey, rusty weathering, fine-grained, interbeds of buff ash-fall tuffs	15.0	615.0
17	Siltstone and greywacke, light rusty weathering, grey-brown to dark grey-brown; lighter units siliceous and resistant, darker are recessive; some 30–60-cm beds of buff-weathering, recessive ash tuffs; *Dactylioceras, Peronoceras* (GSC loc. 90987, 90988, 90990)	45.0	600.0
16	Rhyolite, dense, cream to buff, bleached	6.0	555.0
15	Greywacke, resistant, light to dark grey, partly siliceous, fine-grained, well-bedded, with thin 2–30-cm siltstone interbeds; calcite concretions common; 1–2-m acidic tuff and fine breccia interbeds; *Prodactylioceras* sp.	90.0	549.0
14	Greywacke and gritty argillite, dark grey to black, recessive, fine-grained	60.0	459.0
13	Greywacke, resistant, massive, light grey, fine- to medium-grained; minor 30–150-cm beds of acidic fine-grained breccia; minor black shale	60.0	399.0
12	Tuffaceous greywacke, medium blue-grey to dark grey, rusty weathering, resistant feldspathic-volcanic, laminated to massive, small-scale slump features, and graded bedding; *Uptonia* cf. *U. dayiceratoides* (GSC loc. 90986)	60.0	239.0
11	Greywacke, medium grey, resistant to recessive, 30- to 150-cm beds, fine-grained	30.0	179.0
10	Fine siltstone, medium grey to black, finely bedded (15–60 cm)	18.0	149.0
9	Argillite, platy black argillite, laminated argillite, and limy argillite	6.0	131.0
8	Argillite, brittle black and dark grey, silty	6.0	125.0
7	Limestone, dull grey, fine-grained	2.0	119.0
6	Siltstone, brittle, grey, tuffaceous, fine-grained	4.0	117.0
5	Black argillite, *Uptonia* cf. *U. dayiceratoides* (GSC loc. 90989)	3.0	113.0
4	Diabase, medium- to coarse-grained, prehnite-pumpellyite-bearing, altered	50.0	110.0
3	Argillite, well-bedded, rusty weathering, black to dark grey, limy in part; minor small limestone concretions; *Crucilobiceras* sp., *Tropidoceras* sp	30.0	60.0
2	Tuffaceous argillite and siltstone, massive, resistant, laminated grey and blue-grey; abundant 1–60-cm limy nodules	15.0	30.0
1	Argillite and greywacke, rusty black argillite, hard, grey, pyritic argillite and tuffaceous fine-grained greywacke; ?*Crucilobiceras*	15.0	15.0
	(Underlain by TELKWA FORMATION)		

SECTION IX: NILKITKWA FORMATION

Location: Southern Bait Range, Hazelton Map-area (93M) 55°35′N, 126°23′W

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
	(Overlain by ANKWELL FORMATION)		
34	Greywacke, fine-grained, medium grey, silicified, resistant, tuffaceous, in (1–3 m) beds; recessive medium to dark grey greywacke and minor argillite; one 4-m-thick, medium- to fine-grained green-grey volcanic breccia	60.0	946.0
33	Massive, resistant, medium grey-green, medium-grained greywacke and recessive tuffaceous greywacke; acidic tuff and argillite with minor, thin limestone lenses	4.0	886.0
32	Recessive, interbedded greywacke, tuff, and argillite	18.0	882.0
31	Argillite, well-bedded, dark grey, with tuffaceous laminae, monotonous, planar bedded in lower 30 m; sediments grade rapidly upward into 1–3-m bedded, structureless, medium grey-green, medium-grained greywacke and siltstone with minor shale partings; tuffs increase upward, forming thick beds (3–4 m) but are more indurated and siliceous than the greywackes	90.0	864.0
30	Flows, massive, resistant, green, augite-porphyry, amygduloidal	18.0	774.0
	Fault		
29	Interbedded, fine-grained tuff, cream to light grey rhyolite, lithic tuff, argillite, and massive, pale green, volcanic breccia	45.0	756.0
28	Black argillite	6.0	711.0
27	Rhyolite, massive, light grey, light rusty brown-weathering, more or less resistant	21.0	705.0
26	Massive, light coloured acid to intermediate volcanic breccia and crystal tuff	21.0	684.0
25	Argillite, black, laminated argillite and silty argillite; minor subaqueous greenish volcanic breccia	30.0	663.0

SECTION IX—*continued*

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
24	Resistant rhyolite	9.0	633.0
23	Laminated black argillite, *Harpoceras, Eleganticeras*	4.0	624.0
22	Rhyolite, light rusty weathering, resistant, light coloured	6.0	620.0
21	Laminated black and dark grey argillite, some laminated, gritty, feldspathic, fine-grained greywacke, and fine-grained intermediate volcanic breccia; some 1–3-m beds of light coloured, in part spherulitic, rhyolite	30.0	614.0
20	Rhyolite, massive, bluff-forming, locally spherulitic	8.0	584.0
19	Argillite, light to medium grey, siliceous, laminated, tuffaceous	18.0	576.0
18	Massive, light coloured, fine-grained acidic-intermediate volcanic tuffs	60.0	558.0
17	Argillite, interbedded, poorly laminated, with crystal-lithic laminae; a thick (15 m) unit of medium-grained feldspathic-lithic greywacke included	36.0	498.0
16	Argillite, dark grey, laminated to thin-bedded, silicified, with scattered crystal-lithic fragments; minor fine-grained greywacke	21.0	462.0
15	Argillite, rusty weathering, recessive	2.0	441.0
14	White, limonitic stained, rhyolite-acidic flow and tuffs	24.0	439.0
13	Augite porphyry, light to medium grey-green	12.0	415.0
12	Greywacke, fine-grained, massive bedded	15.0	403.0
11	Laminated argillite	1.0	388.0
10	Volcanic greywacke, light medium grey, thick-bedded, massive, resistant, medium-grained	24.0	387.0
9	Breccia, light green, calcite-quartz with or without prehnite cemented, fine-grained, andesitic	3.0	363.0
8	Laminated argillite with sporadic intervals of grey to khaki, fine- to medium-grained greywacke	75.0	360.0
7	Argillite, dark grey to light grey, plane laminated; minor flame structure, load casts and small-scale ripples; in places rip-up argillite chips and volcanic fragments along the laminations; included is a 15-m bed of pale green, calcite-quartz-cemented, fine- to medium-grained andesitic breccia	90.0	285.0
6	Argillite, dark grey to black, plane laminated with 15–30-cm limestone concretions; interbeds of whitish to light grey crystal-lithic tuff and gritty tuff and infrequent light coloured, dense, massive acidic tuff	60.0	195.0
5	Tuff and argillite, light grey, fine-bedded silica tuff and very fine grained, light grey argillite with interlaminations of feldspathic grit or crystal-lithic tuff	15.0	135.0
4	Covered, may be interbedded light coloured acidic tuff and dark argillite	90.0	120.0
3	Rhyolite, light coloured, flow laminated	3.0	30.0
2	Siltstone, dark grey to black, rusty weathering, fine-bedded and laminated, recessive, planar bedded	15.0	27.0
1	Tuff, white to cream, rusty weathering, massive, flow laminated, acidic crystal tuff	12.0	12.0
	Base not exposed		

SECTION X: NILKITKWA FORMATION

Location: North of Omineca River, McConnell Creek Map-area (94D) 56°13′N, 126°21′W

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
	(Overlain by SMITHERS FORMATION)		
29	Breccia-conglomerate, poorly sorted, volcanic clasts	0.3	632.3
28	Sandstone and siltstone interbedded, sandstone in 15–25-cm beds, plane bedded, massive, no grading, blue-grey to grey on fresh surface, weathers pale greenish grey; siltstone, rubbly, 2.5–7.5 cm thick, rarely thicker, fine- to coarse-grained, weathers rusty brown and concretionary; contains *Hildaites, Protogrammoceras, Dactylioceras*	20.0	632.0
	Possible fault		
27	Sandstone and tuff interbedded, waterlain, limy in part; dark grey, grey, blue-grey on fresh surface, weathers light grey, green-brown; in beds 0.3–0.6 m thick with fine shale partings 2.5–5.0 cm; rock finely laminated in places; contains *Dactylioceras, Protogrammoceras? Hildaites,* aptychi, belemnoids	29.0	612.0
	Fault of unknown displacement		
26	Limy sandstone, finely laminated, dark red on fresh surface, weathers grey-buff	7.5	583.0
25	Covered	6.0	575.5

SECTION X—*continued*

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
24	Rubbly grey siltstone	4.5	569.5
23	Limy sandstone as in unit 26	7.5	565.0
22	Interbedded sands and siltstone, 45-cm-thick beds of sandstone separated by 10-cm bands of siltstone; contains harpoceratid ammonites	13.5	557.5
21	Grey, fine limestone with sandy partings	1.5	544.0
20	Fine sandstone and siltstone, buff-weathering, limy in part; plane laminated bedding in beds 0.15 to 0.3 m thick with fine-grained thin laminations between large concretions scattered at random; pelecypod coquina at top including *Weyla acutiplicata* and *Inoceramus* sp., 9.0 m from top of unit an ammonite—*Paltarpites*?	16.5	542.5
19	Breccia-conglomerate and tuffaceous sandstone, purplish green, reddish on fresh surface; generally well bedded in massive beds over 6.0 m; grades from sand size at top to 2.5-cm pebbles and 20-cm clasts in breccia at base; all greenish volcanic clasts; spheroidal weathering in places	60+	526.0
	Fault		
18	Volcanic breccia and tuff, red-brown, grey, greenish grey; spheroidal weathering; well layered in beds 3.0–4.5 m thick (breccias), 30–60 cm (tuff), poorly sorted; lower contact gradational and conformable	90.0	466.0
17	Sandstone and siltstone, plane laminated in bands 30–60 cm thick; buff-coloured but greenish at top near volcanics; concretionary, blocky joints or slabby, tuffaceous, finely laminated in places; contains abundant poorly preserved fossils *Weyla acutiplicata*, *Plagiostoma*, pectinids, a few ammonoids	10.0	376.0
16	Siltstone and sandstone, sandier toward base, thin siltstone bands to 2.5 cm; greenish toward base, grade into bedded tuff and breccia, transition is gradual	5.0	366.0
15	Volcanic conglomerate, light green-weathering, dark green on fresh surface; coarsely bedded fine breccia conglomerate with repeated layers 2.5 cm thick of single pebbles; clasts are all green volcanics; laumontite abundant	24.0	361.0
	Gap of unknown thickness		
14	Volcanic breccia and tuff, brown-weathering, rubbly	16.0	337.0
13	Volcanic conglomerate, green, rubbly, coarse, poorly sorted	7.0	321.0
12	Tuff and tuffaceous sandstone, buff-weathering, green on fresh surface	12.0	314.0
11	Volcanic breccia, green, coarse	6.0	302.0
10	Sandstone, tuff, and siltstone; brown-weathering, well-bedded, not laminated; a few cream-coloured beds; beds 7.5–45 cm thick; abundantly fossiliferous with brachiopods near the top and *Leptaleoceras*, *Protogrammoceras*, *Fuciniceras*? and belemnoids; near base of unit are *Arieticeras*, *Amaltheus*, *Protogrammoceras*? and other unidentified ammonites	32.0	296.0
9	Tuffaceous siltstone, grey and light grey-weathering; abundant small pelecypods and *Fanninoceras* sp.	43.0	264.0
8	Green volcanic breccia with 2.5-cm fragments	10.0	221.0
7	Tuffaceous siltstone, fine-bedded, brittle, shingle fracture, light, siliceous, weathers brown to cream coloured, some beds are siliceous fine tuffs; near top are small pelecypods, about 10 m from top is *Uptonia*, and 5 m below are *Tropidoceras actaeon*, *Acanthopleuroceras*? *Crucilobiceras pacificum*, and *Weyla*	116.0	211.0
6	Sandstone, brown-weathering, banded, limy	21.0	95.0
5	Limy sandstone, grey-weathering	7.0	74.0
4	Sandstone and siltstone, rubbly, brown-weathering	30.0	67.0
3	Limy siltstone, grey-weathering, black on fresh surface	3.0	37.0
2	Tuff and siltstone interbedded	28.0	34.0
1	Sandstone and massive tuff	6.0	6.0
	(Underlain by SIKANNI FACIES, TELKWA FORMATION)		

SECTION XI: NILKITKWA FORMATION

Location: Two Lake Creek, McConnell Creek Map-area (94D) 56°39′N, 126°58′W

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
	Top not exposed		
14	Siltstone, fine-grained, dark grey to grey, rarely laminated to beds 15–25 cm thick; breaks in large slabs parallel to bedding; locally are abundant ammonite faunas including *Arieticeras*, *Fuciniceras*	45.0	379.0
13	Volcanic breccia, fragments to 7.5 cm, unsorted, reddish green feldspathic fragments in a greenish matrix	30.0	334.0
12	Silty tuff, greenish weathering, grey on fresh surface, finely banded and sorted	30.0	304.0

SECTION XI—*continued*

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
11	Tuff, waterlain, bedded, rusty weathering	15.0	274.0
10	Siltstone, brittle, partly tuffaceous, brown-weathering	7.5	259.0
9	Sandstone, limy, brown-weathering, resistant	2.0	251.5
8	Glauconitic sandstone, bright green, weathers grey-green, medium sand size, well sorted, interbedded with thin siltstone bands, pea-size conglomerate-breccia, sandstone is resistant	22.5	249.5
7	Siltstone, brown-weathering, grey on fresh surface, rubbly talus, brittle	37.5	227.0
6	Tuff, silty, finely banded with up to 0.6-cm, fine, red tuff bands and a few black silt interbeds	10.5	189.5
5	Black siltstone, carbonaceous, finely banded on weathered surface, massive on fresh; flaggy jointing 2.5–15.0 cm thick; rare ammonites—*Amaltheus, Protogrammoceras*	62.0	179.0
4	Siltstone, soft, black to dark grey with flaggy to thin shaly fracture; a few sand interbeds and tuff or volcanic breccia; laminated in places; are ammonites—*Amaltheus, Arieticeras, Protogrammoceras, Fuciniceras*	42.0	117.0
3	Sandy siltstone, laminated, shingle fracture, brittle	7.5	75.0
2	Siltstone, black, massive, soft, carbonaceous, sooty; *Amaltheus, Arieticeras, Fuciniceras*	37.5	67.5
1	Sandstone and limy sandstone, coquinoid lenses in places with *Weyla* sp., coarse pelecypods, corals, gastropods, belemnites, and ammonites—*Uptonia, Acanthopleuroceras, Prodactylioceras*	30.0	30.0
	(Underlain by SIKANNI FACIES, TELKWA FORMATION)		

SECTION XII: NILKITKWA FORMATION, ANKWELL MEMBER

Location: Head of Ankwell Creek, Hazelton Map-area (93M) 55°37′N, 126°30′W

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
	(Overlain by BAIT MEMBER)		
13	Sandstone and greywacke, lithic-feldspathic, light green to grey, well-bedded (30 cm–3 m); finely laminated, green, aquagene tuff	30.0	885.0
12	Volcanic breccia, fine-grained, green (1–5-cm clasts); locally breccias form in pockets between pillow-like structures	60.0	855.0
11	Sandstone, tuff, breccia, interbedded, light green volcanogenic sandstone, and siltstone, fine green aquagene tuff, and fine (15-cm clasts) breccia cemented by calcite, quartz, and prehnite, minor limestone lenses and pods, some to 3 by 6 m thick, with abundant fauna; *Peronoceras, Phymatoceras* (GSC loc. 89613)	60.0	795.0
10	Tuff and breccia, thin- to thick-bedded (15 cm–6 m), green aquagene tuff and breccia; breccias massive with calcite-quartz-prehnite cement; agglomerate composed of rounded to angular, amygduloidal, green andesitic volcanics, some blocks to 3 m in diameter, most 1–15 cm; fine-grained, grey limestone pods, commonly with rounded and angular 6-mm–15-cm clasts of green, amygduloidal andesitic volcanic; minor green to grey volcanic sandstone and siltstone; broken shell fragments common	150.0	735.0
9	Tuff, breccia, and flows, massive, bedded (1–10 m), interbedded red and green andesitic tuff and breccias; fine-grained, purplish to reddish, 1–6-m-thick basalt flows; red to maroon tuffaceous mudstone and lapilli tuff; interbedded, fine-grained, dense, massive, light to pale green basaltic to andesitic flows or breccias	150.0	585.0
8	Tuff and breccia, massive, cliff-forming, fine-grained (1–10-cm clasts), brown-weathering green breccias; minor calcite-cemented green aquagene tuff and breccia; minor purplish feldspar porphyry and red volcanic mudstone and sandstone and reddish to purple fine-grained basalt flows; minor 30–150-cm limestone pods	60.0	435.0
7	Fine-grained, dense, thin-bedded acidic tuff and tuffaceous siltstone	15.0	375.0
6	Thick-bedded (6–9 m), pale grey-weathering, greenish amygduloidal flows	30.0	360.0
5	Breccias, massive, medium-grained, green, amygduloidal	30.0	330.0
4	Flows, purplish grey and purplish green, amygduloidal	15.0	300.0
3	Siltstone and greywacke, recessive, poorly exposed, tuffaceous	45.0	285.0
2	Breccias, thick- to medium-bedded, green, fine- to medium-grained; some calcite cemented	90.0	240.0
1	Breccia, monotonous, dark grey-green augite porphyry and andesitic to basaltic fine- to coarse-grained; calcite-quartz-prehnite cemented breccia; interbeds of dark grey feldspathic greywacke, laminated aquagene tuff, tuffaceous siltstone, and sandstone; pockets of shelly fauna	150.0	150.0
	(Underlain by NILKITKWA FORMATION)		

SECTION XIII: SMITHERS FORMATION

Location: Ashman Ridge, Smithers Map-area (93L), 40 km west of Smithers, B.C. 54°50′N, 127°51′W

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
	(Overlain by ASHMAN FORMATION)		
8	Finely banded, uniform thickness of beds (0.15–1.9-cm thick), interbedded, dark grey and pink, fine-grained siliceous rock, probably a tuff; blocky fracture, in places large (1 m) limestone concretions, near base of beds are coarser, darker grey with no pink beds and are fossiliferous; 45 m above base, ammonoids were collected; "*Kheraiceras*" sp.	102.0	298.8
7	Volcanic tuff with tuffaceous greywacke, dull grey, greenish grey with coquinoid beds and lenses; *Gryphaea*, *Arctocephalites* (*Cranocephalites*) sp. (GSC loc. 85437)	42.0	196.8
6	Greywacke and tuff, dull grey, greenish grey, hard, mainly resistant, some limy beds, some coquinoid lenses, abundant fossils	9.0	154.8
5	Tuff, fine, white ash bed	0.3	145.8
4	Greywacke and tuff, grey to greenish grey, hard fractured, fossiliferous, fine banded at base; *Holcophylloceras costisparsum* Imlay, *Zemistephanus richardsoni* (Whiteaves) (GSC loc. 85405)	13.5	145.5
3	Tuff and fine-bedded breccia; grey, hard, siliceous rock, breaks with sharp fracture, very fossiliferous; *Zemistephanus* (GSC loc. 85368)	31.5	132.0
2	Tuff, greenish grey, weathering light grey to light greenish grey; hard, compact, siliceous, *Teloceras*, stephanoceratids (GSC loc. 85427)	31.5	100.5
1	Tuff, grey-weathering, hard, siliceous, compact, generally lighter colour than overlying units, generally fine grained becoming sandier toward base; fossiliferous throughout; *Sonninia* and an abundant ornate pelecypod fauna (GSC loc. 85412, 85385, 85381)	63.0	63.0
	(Underlain by RED TUFF MEMBER, NILKITKWA FORMATION)		

SECTION XIV: SMITHERS FORMATION

Location: Tenas Creek, Telkwa Range, Smithers Map-area (93L) 54°31.5′N, 127°14′W

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
	(Overlain by ASHMAN FORMATION)		
6	Sandstone, bright green, thick-bedded, medium- to coarse-grained, moderately well sorted, white quartz feldspar and lithic grains subrounded to angular in a green glauconitic matrix; no fossils in situ	9.4	36.7
5	Sandstone, bright blue-green, medium-grained, poorly bedded, glauconitic, highly fossiliferous; *Epizigzagiceras evolutum*, *Arctocephalites* (*Cranocephalites*) *costidensus*, *A.*? *multicostatus*, *Parareineckia* cf. *P. shelikofana*, *Cobbanites talkeetnanus*, *Oppelia*, *Morrisiceras*? *dubium* (GSC loc. 88570, 85444, 85380)	7.6	27.3
4	Sandstone, bright green, medium-grained; *Megasphaeroceras* (GSC loc. 88568)	6.1	19.7
3	Sandstone, bright green, medium-grained, glauconitic, locally very fossiliferous; *Megasphaeroceras*? aff. *M. rotundum*, *Epizigzagiceras crassicostatum*, *Cobbanites* (GSC loc. 88567)	4.4	13.6
2	Sandstone, bright green, medium-grained, unevenly bedded with thin coquinoid beds and lenses, glauconitic; *Epizigzagiceras crassicostatum*, *Megasphaeroceras*? *Zemistephanus* (GSC loc. 88566, 85408)	1.6	9.2
1	Sandstone, bright green, medium- to coarse-grained, feldspathic, glauconitic; base is very coarse and feldspathic; pelecypods and gastropods are common	7.6	7.6
	(Underlain by RED TUFF MEMBER)		

SECTION XV: SMITHERS FORMATION AND BAIT MEMBER

Location: South end of Netalzul Mountain, Hazelton Map-area (93M) 55°13′N, 126°50′W

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
	Top not exposed		
14	Greywacke, fine- to medium-grained, light brown to grey, rusty weathering; in 15–60-cm-thick beds; partings and interbeds of light blue-grey, fissile siltstone 1 to 10 cm thick, recessive; abundant pelecypod fauna with fragments of stephanoceratids in lower 30 m	75.0	852.0
13	Greywacke and siltstone interbedded, fine- to medium-grained; *Chondroceras* and stephanoceratid ammonites (GSC loc. 91123)	15.0	777.0
12	Greywacke and tuff interbedded, fine-grained, feldspathic, light grey to light brown-weathering greywacke and light grey to khaki-brown-weathering acid tuffs; contains fragmentary stephanoceratids	45.0	762.0
11	Greywacke, fine-grained, grey, rusty weathering; minor limestone concretions, thin grit and sharpstone pebble conglomerate in lower part of unit; bedding mostly 15–60 cm thick, more or less planar and even; *Stemmatoceras*, *Zemistephanus* cf. *Z. richardsoni* (Whiteaves) (GSC loc. 91076)	75.0	717.0
10	Greywacke, massive, resistant, thick-bedded, fine- to medium-grained	10.0	642.0
9	Greywacke, fine- to medium-grained, thin-bedded, grey, rusty weathering	12.0	632.0
8	Greywacke, fine-grained, grey, rusty brown-weathering; minor, gritty, brittle argillite interbeds; minor limestone concretions	60.0	620.0
7	Greywacke, upper half of unit is rusty, rubbly weathering, medium-grained, with minor limestone concretions, mainly crudely plane or even-bedded; lower half of unit rusty and rubbly to spheroidal weathering, medium-grained, carbonaceous fragments and bioturbation markings common; *Sonninia*	60.0	560.0
6	Greywacke and siltstone, recessive, rusty brown to grey-weathering, argillaceous, fine grained with abundant carbonaceous plant fragments and some burrowing features; minor limestone concretions	45.0	500.0
5	Greywacke and siltstone like unit 4 with minor 15–60-cm-thick interbeds of medium-grained, light khaki-brown to grey, well-sorted volcaniclastic sandstone toward base of section; *Sonninia* sp., perisphinctids (GSC loc. 91082)	150.0	455.0
4	Greywacke and siltstone as in unit 3 becoming more calcareous down section, weathers rusty purple-pink to buff and becoming plane laminated with a platy fracture	80.0	305.0
3	Sandstone, buff-weathering, plane laminated, rounded to spheroidal weathering, platy fracturing to massive, fine- to coarse-grained calcareous cement, volcaniclastic; fresh surfaces show green coloration due to glauconitic cement; coquinas of thick-shelled pelecypods in massive sandstone beds interspersed through section at 10–20-m intervals; *Tmetoceras* sp. (GSC loc. 91098)	200.0	225.0
	BAIT MEMBER		
2	Black argillite and siltstone, finely bedded; minor thin black limestone and acid tuff	20.0	25.0
1	Sandstone and siltstone, grey-weathering, massive bedded; few pelecypod coquinas	5.0	5.0
	(Underlain by NILKITKWA FORMATION, RED TUFF MEMBER)		

SECTION XVI: SMITHERS FORMATION, BAIT MEMBER

Location: Frypan Creek, Hazelton Map-area (93M) 55°30′N, 126°16′W

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
	Top not exposed		
21	Siltstone and argillite, dark grey to black siliceous siltstone and gritty argillite; stephanoceratid or ootoitid; *Oppelia*? (GSC loc. 91067)	30.0	396.5
	Fault		
20	Greywacke, light grey, medium-grained, feldspathic, 30-cm–1-m beds	60.0	366.5
19	Siltstone, moderately resistant, laminated, light grey, somewhat flaggy; minor 30–60-cm greywacke beds	7.0	306.5
18	Siltstone, black to dark grey, flaggy weathering, local, thin, 1–5-mm laminations; 3–30-cm, grey limestone pods common; *Posidonomya* (GSC loc. 89645)	13.0	299.5
17	Greywacke, light grey, medium-grained	2.0	286.5

SECTION XVI—*continued*

Unit	Description	Thickness (metres) of unit	above base
16	Siltstone, black, dark grey, flaggy weathering, laminated; a few 1–5-cm shale beds between 60-cm beds of siltstone; *Tmetoceras* (GSC loc. 89626)	15.0	284.5
15	Greywacke, hard, resistant, light grey, medium-grained	3.0	269.5
14	Siltstone, black to dark grey, flaggy weathering, laminated, 30–60-cm beds intercalated with 5 cm of black, soft-weathering shale	6.0	266.5
13	Siltstone, black to dark grey, flaggy to fissile, laminated; minor soft shale partings; *Posidonomya*	24.0	261.5
12	Greywacke, hard, siliceous, light grey	1.5	237.5
11	Siltstone, dark to medium grey, platy, laminated	18.0	236.0
10	Siltstone, dark grey, silicified, resistant, hard, tuffaceous; *Posidonomya*	12.0	218.0
9	Siltstone and greywacke, fine-bedded (2–15 cm), indurated, light grey, silicified, tuffaceous siltstone and fine-grained, medium grey greywacke (15–30-cm beds)	45.0	206.0
8	Limestone, dull grey, fine-grained	2.0	161.0
7	Siltstone, light to medium grey, fine-bedded (15–30 cm), more or less resistant, planar banded; *Haugia* (GSC loc. 91157)	45.0	159.0
6	Siltstone, light to medium grey, recessive, bioturbation features; *Haugia, Dicoelites* (GSC loc. 91138)	15.0	114.0
5	Siltstone, resistant 30-cm-thick beds to massive beds, structureless; with dark grey interbedded 30–60-cm, medium-grained greywacke; minor small carbonate concretions; *Dicoelites*?	15.0	99.0
4	Siltstone, recessive, dark grey; minor, thin (15 cm), fine-grained resistant greywacke; minor limestone concretions; *Dicoelites*	9.0	84.0
3	Greywacke, light brown-weathering, medium- to coarse-grained, lithic-feldspar	3.0	75.0
2	Shale, recessive, dark grey, gritty argillite and siltstone; minor (1–2 m) beds of fine- to medium-grained greywacke	12.0	72.0
1	Shale, dark grey to black, fissile to pencil fractured, plane laminated to massive gritty argillite and siltstone; some black sooty carbonaceous siltstone, small concretions; minor thin lithographic limestone, minor silicic tuff, and thin-bedded volcanic sandstone at base; *Haugia* (GSC loc. 91138)	60.0	60.0
	(Underlain by ANKWELL MEMBER)		

SECTION XVII: SMITHERS FORMATION AND YUEN MEMBER (units 22 and 23)

Location: North of Omineca River, McConnell Creek Map-area (94D)
56°12′N, 126°22′W

Unit	Description	Thickness (metres) of unit	above base
	(Overlain by ASHMAN FORMATION, BOWSER LAKE GROUP)		
18	Fine siltstone-argillite, in band 7.5–15 cm thick with shaly parting; limy and lime concretions near top, fine rubble fracture	450.0	1103.7
17	Siltstone and argillite, in beds 15–27 cm thick, in places finely laminated; dark grey, weathering grey, buff, or brown; a few white-weathering tuff bands 2.5–27 cm thick; blocky fracture; contains a few poor sonninids and *Witchellia*	330.0	653.7
16	Conglomerate, grey-weathering, clasts to 0.63 cm of green volcanic rock	3.6	323.7
15	Sandstone, buff-weathering	4.5	320.1
14	Sandstone, grey-weathering, hard, in beds 15–25 cm thick; contains belemnites	6.6	315.6
13	Sandstone, dark grey, weathering brown, some shaly interbeds; *Grammoceras*	7.5	309.0
12	Grit and fine conglomerate, dark grey, weathering light greyish green, speckled, massive beds, polymictic but mainly volcanic clasts 0.15–0.63 cm with scattered pebbles to 1.3 cm thick, subrounded	6.0	301.5
11	Covered	45.0	295.5
10	Sandstone, grey, weathering to buff; 2.5–5-cm-thick beds, fine- to medium-grained, not graded, concretionary in places	57.0	250.5
9	Green glauconitic sandstone, medium- to coarse-grained; pelecypods, gastropods, belemnites, ammonites—*Collina*? *Pseudolioceras*?	7.5	193.5
8	Conglomerate and breccia, greenish weathering, poorly sorted, volcanic clasts to 30 cm, average 5–7.5 cm or less, recessive	9.0	186.0
7	Light buff to rusty tuff	4.5	177.0
6	Green tuff, bedded, weathers buff to brown, white, or, in places, bright green, contains belemnites	6.0	172.5
5	Grit and fine pebble conglomerate, buff-weathering, grit mainly quartz clasts; conglomerate is polymictic, unsorted clasts to 0.63 cm diameter	3.0	166.5

SECTION XVII—*continued*

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
4	Sandstone, buff-weathering from grey-buff, greenish grey on fresh surface; in beds 0.3–0.6 m thick with blocky fracture; *Phymatoceras, Haugia, Polyplectus,* dactylioceratid	52.5	163.5
3	Limy sandstone and sandy limestone, grey-weathering, dark grey limy sandstone and laminated limestone; contains belemnites	48.0	111.0
2	Sandstone and siltstone, weathers brown and buff-brown from drab brown on fresh surface; forms rubbly talus in fine beds a few centimetres thick; generally fine; glauconitic sands near the base; belemnites and ammonites—*Phymatoceras, Dactylioceras*	52.5	63.0
1	Sandstone, dark green, weathering to bright green or light green; probably glauconitic; fairly soft, breaks to rubbly scree; not graded but uniform throughout; in beds 2.5–30 cm thick; ammonites—*Dactylioceras*? *Peronoceras, Phymatoceras,* and *Posidonomya*	10.5	10.5
	(Underlain by NILKITKWA FORMATION)		

SECTION XVIII: SMITHERS FORMATION, YUEN MEMBER

Location: Diagonal Mountain, McConnell Creek Map-area (94D)
56°42′N, 126°57′W

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
	(Overlain by ASHMAN FORMATION)		
2	Siltstone, dark grey to grey, weathering buff to drab grey, in beds 5–15 cm thick, finely banded in places, minor grey tuffaceous bands, well-indurated, rubbly talus; not graded, uniform texture; abundant ammonites—*Stephanoceras* and other stephanoceratids	90±	240+
1	Siltstone and tuff, hard, grey to dark grey siltstone, fine-grained, uniform, finely laminated in places, much like unit 2 but bands are coarser; interbedded with fine siliceous grey to greenish grey ash-fall tuff that weathers reddish brown, bands of tuff are 1–25 cm thick and comprise 50% by volume of exposed section but at various levels one or the other rock-type may predominate; rock is hard, brittle, breaks in rectangular blocks on smooth surfaces; sonninid ammonites are near the top of unit and *Dactylioceras* occurs low in unit	150+	150+
	Base not exposed		

SECTION XIX: ASHMAN FORMATION TYPE SECTION

Location: Ashman Ridge, 40 km west of Smithers, Smithers Map-area (93L)
54°50′N, 127°51′W

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
	Undifferentiated beds of Bowser Lake Group		
24	Shale, massive, black, a few thin sandy beds; grey limestone concretions to 15 cm in upper 2 m of unit containing thin-shelled pelecypods; about 23 m from top small pelecypods, *Pleuromya* (GSC loc. 85425), near the base ammonites were found: *Cardioceras* (*Cardioceras*) cf. *C.* (*C.*) *lilloetense* Reeside, *Cardioceras* (*Subvertebriceras*) cf. *C.* (*S.*) *canadense* (Whiteaves) (GSC loc. 85442)	55.0	659.0
23	Grey ash-like arenite and subangular conglomerate, contains belemnites and a few pelecypods	12.0	604.0
22	Grey crumbly shale, fairly massive, contains a few small pelecypods (GSC loc. 85395)	10.0	592.0
21	Grey gritty arenite or sandy tuff?, white angular specks or fragments scattered throughout	0.5	582.0
20	Grey shale similar to unit 23, recessive	6.0	581.5

SECTION XIX—*continued*

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
19	Cross-bedded sandstone, evenly bedded sandstone, shaly sandstone and fine gritty to pebbly conglomerate, weathers brown and light buff, blue-grey on fresh surface, well-consolidated, resistant unit	23.0	575.5
18	Shale, brown-weathering, recessive, contains *Cardioceras* (*Scarburgiceras*) *martini* Reeside (GSC loc. 85428)	5.0	552.5
17	Sandstone, brown and grey-weathering, some cross-bedding, minor limy interbeds, concretionary, wood fragments common; many interbeds lenticular and pinching out abruptly, thin shale beds up to 5 cm interbedded here and there	23.0	547.5
16	Interbedded shale and sandstone with minor conglomerate, shale predominates at top, sandstone in middle and conglomerate at base; conglomerate has lithic pebbles well rounded to 2 cm diameter; unit is fairly evenly bedded in beds about 30 cm thick; weathers buff, light-buff on fresh surface	9.0	524.5
15	Dark brown-weathering shale or siltstone, fairly massive but concretionary and limy in places, friable and recessive	44.0	515.5
14	Siliceous mudstone, grey on fresh surface, weathers white, few thin interbeds of sandstone, individual beds are 30 to 60 cm thick and weather to form a ribbed surface; belemnite holes are abundant; *Cardioceras* (*Scarburgiceras*) *martini* Reeside (GSC loc. 85439)	45.0	471.5
13	Evenly bedded, fine conglomerate or grit becoming sandier and somewhat concretionary near base; belemnite holes persist throughout	16.0	426.5
12	Mudstone, brown, uniform, brittle, well-preserved ammonites; *Quenstedtoceras* (*Lamberticeras*) *henrici* Douville, *Quenstedtoceras* (*Lamberticeras*) *henrici* Douville var. *brasili* Douville, *Quenstedtoceras* (*Lamberticeras*) *intermissum* Buckman (GSC loc. 85376)	13.8	410.5
11	Interbedded sandstone, minor shale, and conglomerate, some cross-bedding in the sandstone, a few concretions, and belemnites, some limy sandstone bands weather white giving rock a ribbed appearance	59.0	396.7
10	White-weathering, coarse arkose with wood fragments scattered throughout, some cross-bedding, fairly soft (kaolinitic?), possibly nonmarine	21.0	337.7
9	Conglomerate and sandstone, the top 90 cm is composed of a few beds of conglomerate of which one bed is coarse boulder conglomerate with clasts to 23 cm diameter; remainder of unit fairly massive brown-grey greywacke without prominent bedding and rare conglomerate lenses; a few trigoniids (GSC loc. 85406)	38.0	316.7
8	Finely banded greywacke with interlayered arkosic beds, bands up to 5 cm thick; softer beds weather out, unit shaly near base with minor fine conglomeratic beds	18.0	278.7
7	Massively bedded sandstone and fine pebbly sandstone, pebbles to 1 cm diameter scattered throughout unit, limy in some beds with a few concretions, unit finely banded, cross-bedded, and coarsens near base	27.0	260.7
6	Feldspathic sandstone, well-bedded, minor thin beds of shale, individual beds to 5 cm thick	20.5	253.7
5	Spotted sandstone	2.7	213.2
4	Grey-brown sandstone	10.5	210.5
3	Brown-weathering, brown sandstone with limy concretions in places; *Pseudocadoceras* cf. *P. grewingki* (Ponpeckji) *Pseudocadoceras* cf. *P. crassicostotum* Imlay, *Cadoceras* (*Stenocadoceras*) sp. indet., belemnoids, pelecypods, gastropods	62.0	200.0
2	Interbedded white-weathering arkose and brownish sandstone in beds 60–90 cm thick with limy concretions	10.5	138.0
1	Well-bedded and banded siliceous argillites in beds about 30 cm thick with bands of fine siliceous mudstone or shale interbedded; a few sandy interbeds; belemnite moulds abundant at top of unit, about 67.5 m below top of unit *Kepplerites* sp. and *Cobbanites* sp. were collected (GSC loc. 85413)	127.5	127.5
	(Underlain by SMITHERS FORMATION)		

SECTION XX: ASHMAN FORMATION

Location: Tenas Creek, Telkwa Range, Smithers Map-area (93L) 54°31′N, 127°14′W

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
	Top not exposed		
15	Green to greenish brown glauconitic sandstone, poorly sorted with coquinoid lenses and thin beds, much woody material throughout, fine pebble conglomerate at base consisting of pea size (0.5 cm) pebbles of a feldspathic plutonic rock; fossils abundant *Lilloettia* spp.; "*Xenocephalites*" sp. *Kepplerites* sp. (rare), *Parareineckia* sp., *Cobbanites* sp., *Lytoceras*? sp. perisphinctids, pelecypods, gastropods, belemnites, bryozoa, corals (GSC loc. 85456).......	10.5+	71.2+
14	Light green, coarse sandstone, white to cream-weathering, fine, hard sandstone, brittle with a platy fracture; *Kepplerites* spp. (abundant), *Lilloettia* spp., cadoceratid?, pelecypods (GSC locs. 85461, 85453)......................	1.5	60.7
	Gap of unknown extent		
13	Sandstone, medium- to coarse-grained, friable, feldspathic, dark grey and speckled to dark green, weathers yellowish grey, thin irregular bedding; *Lilloettia* sp., *Kepplerites* sp. *Rhynchonella* sp., belemnites (GSC locs. 85454, 85455)..	6.0	59.2
12	Red-brown-weathering greenish sandstone, similar to unit 13 and may be partly or entirely equivalent as unit is not in stratigraphic continuity and the contact is covered; *Lilloettia* spp., *Kepplerites* sp., *Xenocephalites* sp., "*Kheraiceras*" sp. (GSC loc. 85451)..	7.5+	53.2
11	Interbedded dark green sandstone, grey shale, light green sandstone, weathers grey to red-brown; *Lilloettia* spp., *Kepplerites* spp., "*Kheraiceras*" sp., *Cosmoceras* sp., *Xenocephalites* sp.?, *Cobbanites* sp. (GSC loc. 85457)...........	10.0±	45.7
10	Section interrupted by a dyke 3 to 5 m thick............................		
9	Sandstone, fine- to medium-grained, tuffaceous, hard, dark grey, well-bedded, 7–30-cm-thick beds, weathers spheroidally, brick-red; "*Kheraiceras*" sp., *Kepplerites* spp., *Cobbanites* sp. (GSC loc. 85460).........................	3.0	35.7
8	Sandstone, fine- to medium-grained, tuffaceous, hard, dark grey, well-bedded, 7–30-cm-thick beds, beds are separated by 3–1.2-cm partings of siltstone and poorly consolidated sand; "*Kheraiceras*" sp., *Kepplerites* sp., *Xenocephalites*? sp., *Cobbanites* sp., *Lilloettia* spp., pelecypods, belemnites (GSC loc. 85458)..	9.0	32.7
7	Interbedded sandstone and siltstone, green to dark grey, weathering red-brown; "*Kheraiceras*" spp., *Cosmoceras* sp., pelecypods (GSC loc. 85397)..........	2.4	23.7
6	Covered...	2.1	21.3
5	Interbedded green sandstone and fine conglomerate, spotted, minor light grey, hard siltstone; 2.5–30-cm-thick, even beds with transecting "worm trails" about 1.5 cm wide composed of fine, white sand; "*Kheraiceras*" sp. *Parareineckia* sp., pelecypods (GSC loc. 85462)...............................	3.6	19.2
4	Red-weathering spotted light green sandstone, interbedded with light grey hard siltstone, evenly bedded; *Lilloettia*? sp., "*Kheraiceras*" sp., *Gowericeras* sp., *Cosmoceras*? sp., *Cobbanites* sp., *Parareineckia*, pelecypods, belemnites (GSC loc. 85392)...	3.0	15.6
3	Greenish weathering spotted sandstone, medium-grained, hard, thin, irregular bedding; "*Kheraiceras*" sp., *Oppelia* (*Oxycerites*)? sp., *Gowericeras* sp., *Cobbanites* sp., *Parareineckia* sp., pelecypods (GSC loc. 85396)............	4.5	12.6
2	Sandstone, light green-grey, spotted, medium-grained, hard; abundant fossils, "*Kheraiceras*" sp., perisphinctids, pelecypods ammonites are up to 20 cm diameter (GSC loc. 85410)...	2.1	8.1
1	Sandstone, light green-grey, spotted, medium- to coarse-grained, fine, irregularly bedded, nearly fissile to nearly massive, weathers red-brown; "*Kheraiceras*" sp., *Gowericeras* sp., perisphinctids, pelecypods, belemnites (GSC locs. 85390, 85413)..	6.0	6.0
	(Underlain by SMITHERS FORMATION)		

SECTION XXI: ASHMAN FORMATION, BOWSER LAKE GROUP

Location: 18 km southeast of Cold Fish Lake 57°30′N, 128°34′W

Unit	Description	Thickness (metres) of unit	Thickness (metres) above base
	Undifferentiated beds of Bowser Lake Group		
10	Black concretionary siltstone with minor sandstone, siltstone is dark grey to black, massive without lamination, ironstone concretions abundant with belemnites and a few thin pelecypods, rare limestone concretions with belemnites; sandstone is grey weathering, dark grey weathering rusty in beds 3.0 to 4.5 m thick; about three main bands of siltstone each about 30 m thick and sand units about 20 m thick interbedded	200.0±	678.0±
9	Interbedded sandstone and siltstone, sandstone weathers grey, rusty brown, white, fawn in beds 0.6–3.0 m thick; much woody material and one fossil leaf, one bed with abundant pelecypods and ammonites—*Partschiceras pacificum*—near top	60.0+	478.0
8	Friable shale, dark grey to black, soft and sooty, minor, thin, rusty-weathering sand layers poorly defined; a few ammonites—cadoceratid	30.0+	418.0
7	Coarse sandstone, grey-weathering, blocky fracture, rare pebbles scattered throughout	30.0+	388.0
6	Shale and siltstone, near top of unit black shale with fine sandy layers to 10 cm thick, rusty weathering; grades abruptly to massive, black, soft shale, carbonaceous, no obvious beds or laminations	60.0+	358.0
	Fault		
5	Coarse sandstone, grey-weathering greenish sandstone, rusty sandstone, fine-grained, massive, fossiliferous in places, ammonites—*Lilloettia, Kepplerites*, perisphinctid ammonite	30.0+	298.0
4	Shale and siltstone with minor sandstone as in unit 6	85.0+	268.0
3	Massive chert-pebble conglomerate beds, pebbles of grey and black chert and red jasper closely packed; lenticular bodies and a few large cross-beds indicating a northerly source	33.0+	183.0
2	Shale as in unit 6 with *Lilloettia*	60.0+	150.0
1	Sandstone, mostly grey sandstone with thin chert-pebble conglomerate lenses, minor grey siltstone; conglomerate pebbles closely packed or scattered in sand	90.0+	90.0
	Volcanics similar to Toodoggone volcanics		

APPENDIX IV

Typical Marine Fossil Fauna Collected from the Hazelton and Bowser Lake Groups in the Smithers, Hazelton, and McConnell Creek Map-areas

The Hazelton and Bowser Lake groups have yielded numerous fossil collections, rich in numbers and varieties. With few exceptions the ammonoid faunas have been the most useful in assigning a stratigraphic age, but even these are not fully understood. Many gastropods, pelecypods, brachiopods, and corals, although generally of lesser stratigraphic value, are commonly good indicators of depositional environment. Much remains to be learned about these faunas.

Credit for identification of and research on our collections must be shared with several colleagues. T. P. Poulton spent several seasons with the writers in the field collecting and studying trigoniid faunas in these areas and in other parts of the Cordillera; his assistance and advice is greatly appreciated. J. A. Jeletzky identified several belemnoids and pelecypod faunas from the Jurassic strata, as well as the Cretaceous faunas not reported here. Most of the identifications, particularly of ammonites, must be credited to Hans Frebold, who devoted much time and effort to research and identification of forms new to these areas. He patiently assisted the writers in their field identifications, and coauthored two short papers on faunas from these map-areas (Frebold and Tipper, 1973, 1975) with the senior author. The assistance of these co-workers greatly eased our task.

The following are incomplete lists of fossils that can commonly be expected in the various Jurassic groups, formations, and members in the study area. Many identifications are tentative, many are field identifications, and much work remains to be done. These lists will serve to illustrate the variety and probable genera and species to be expected in the different units.

HAZELTON GROUP

Telkwa Formation

Howson facies

Cephalopoda
- *Arctoasteroceras* cf. *A. jeletzkyi* Frebold
- *Asteroceras* sp. indet.
- *Nautilus* sp.
- belemnoids (rare)

Pelecypoda
- *Weyla* sp. aff. *W. alata* von Buch
- *Weyla* sp. aff. *W. acutiplicata* (Meek)
- *Weyla* sp.
- *Cardinia* sp. indet.
- *Pholadomya*? sp.
- *Astarte* sp. indet.
- *Ostrea* sp. indet.
- *Pecten* sp. indet.
- *Pinna*? sp. indet.
- *Trigonia* sp.
- *Gryphaea*? sp. indet.
- *Lima*? sp.
- *Modiolus*? indet.

Brachiopoda
- "Terebratula" sp.
- "Rhynchonella" sp.

Miscellaneous
- gastropods—several unidentified genera
- corals—unidentified and common

Babine facies

Cephalopoda (probably more than one faunal zone)
- *Arctoasteroceras jeletzkyi* Frebold
- *Echioceras* sp.
- *Melanippites* sp.
- *Arnioceras* sp.

Pelecypoda
- *Pleuromya* sp.
- *Cardinia* sp.
- *Weyla* spp.
- *Pecten* sp.
- *Gervillia* sp.
- *Pinna* sp.
- *Lima* (*Plagiostoma*?) sp.

Miscellaneous
- terebratulid brachiopods
- gastropods—unidentified
- corals

Kotsine facies

Cephalopoda
- *Leptechioceras* sp.

Pelecypoda
- *Weyla acutiplicata* (Meek)
- *Trigonia* sp.
- *Modiolus* sp.

Miscellaneous
- gastropods
- corals

Sikanni facies

Cephalopoda
- indeterminate ammonite ?*Asteroceras* sp.

Pelecypoda
- *Weyla acutiplicata* (Meek)
- *Pecten* sp.
- *Trigonia* sp.
- other trigoniids, pectenids

Miscellaneous
- indeterminate corals and gastropods

Nilkitkwa Formation

Cephalopoda
- Lower Pliensbachian ammonites
  - *Crucilopiceras* sp. cf. *C.* pacificum Frebold
  - *Crucilobiceras* sp. aff. *C. mouterdei* Frebold
  - *Acanthopleuroceras*? sp.
  - *Tropidoceras actaeon* (d'Orbigny)
  - *Uptonia* aff. *U. dayiceratoides* Mouterde
  - *Prodactylioceras* sp.
  - *Platypleuroceras* sp.
  - *Coeloceras*? sp.

Hazelton Group (cont.)

Upper Pliensbachian ammonites
Arieticeras algovianum (Oppel)
Arieticeras cf. *A ruthense* (Reynes)
Leptaleoceras pseudoradians (Reynes)
Fanninoceras kunae McLearn
Amaltheus stokesi (J. Sowerbyi)
Paltarpites spp.
Becheiceras? sp.
Fuciniceras sp.
Protogrammoceras? sp.

Toarcian ammonites
Harpoceras exaratum Young and Bird
? *Mercaticeras* sp.
Eleganticeras sp.
? *Tiltoniceras* sp.
Harpoceroides sp.
Dactylioceras sp. indet.
Dactylioceras (*Orthodactylites*) sp.
Dactylioceras (*Dactylioceras*) sp.
Protogrammoceras sp.
Phymatoceras sp.
Haugia sp.

nautiloids present in all stages
belemnoids abundant in Toarcian beds but rare in Pliensbachian

Pelecypoda
Weyla acutiplicata (Meek) } only in Pliensbachian beds
Weyla dufrenoyi (d'Orbigny) } only in Pliensbachian beds
Weyla spp. } only in Pliensbachian beds
Posidonomya sp. (rare in Pliensbachian)
Trigonia sp.
Oxytoma sp.
Ostrea sp.
Entolium sp.
Modiolus sp.
Astarte sp.
Pecten sp.
many undetermined pelecypods

Miscellaneous
corals—common but not abundant
gastropods—abundant and varied
crinoid columnals—particularly in Upper Pliensbachian beds
rhynchonellid brachiopods

Ankwell Member

Cephalopoda
Peronoceras sp.
Phymatoceras sp.

Pelecypoda
Myophorella sp.
Trigonia sp.
Ctenostreon sp.
Camptonectes sp.
Pholadomya sp.
Ostrea sp.
Modiolus sp.
Pleuromya sp.
Astarte sp.
Pinna sp.
Gryphaea sp.
pectenids, nuculids, other ornate pelecypods

Miscellaneous
corals, gastropods (particularly *Turritella*-like forms), crinoid columnals, rhynchonellid brachiopods

Red Tuff Member

one indeterminate ammonite
rhynchonellid brachiopods
high-spired *Turritella*-like gastropods
several pelecypods such as *Lima* sp. and large coarse-shelled forms

Smithers Formation

Cephalopoda
Bathonian ammonites (only in Smithers map-area)
Arctocephalites (*Cranocephalites*) *costidensus* Imlay
Arctocephalites ? *multicostatus* Frebold
Arctocephalites (*Cranocephalites*) sp. aff *A.* (*C.*) *pompeckji* (Madsen)
Parareineckia cf. *P. shelikofana* (Imlay)
Parareineckia cf. *P. hickersonensis* Imlay
Cobbanites talkeetnanus var. *densicostata* Frebold
Cobbanites talkeetnanus Imlay
Morrisiceras ? *dubium* Frebold
Oppelia sp.

Upper (?) Bajocian ammonites
Megasphaeroceras ? aff. *M. rotundum* Imlay
Epizigzagiceras crassicostatum Frebold
Cobbanites talkeetnanus Imlay var. *densicostata*
Cobbanites talkeetnanus Imlay
Zemistephanus sp. indet.
Oppelia (*Oxycerites*) sp. indet.
Oppelia (*Oxycerites*) cf. *O.* (*O.*) *kellumi* Imlay

Middle Bajocian ammonites (Humphresianum, Sowerbyi, and Sauzei Zones)
Stephanoceras sensu lato sp. indet.
Teloceras dowlingi McLearn
Zemistephanus richardsoni (Whiteaves)
Zemistephanus sp. cf. *Z richardsoni* (Whiteaves)
Holcophylloceras costisparsum Imlay
Stemmatoceras sp.
Graphoceras sp.
Arkelloceras sp.
Bradfordia sp. cf. *B. costidensa* Imlay
Bradfordia ? sp. aff. *B.* ? *caribouensis* Imlay
Fontannesia spp.
Pseudotoites ? sp. indet.
Pelecodites aff. *P. pelecus* Buckman
Witchellia sp.
Docidoceras (*Pseudocidoceras*) cf. *D. widebayense* Westermann
Eudmetoceras sp. cf. *E. klimakomphalum* Vacek
Sonninia sp. indet. aff. *S. tuxedniensis* Imlay
Sonninia sp. indet.
Guhsania bella McLearn
Guhsania sp. cf. *G. bella* McLearn
Chondroceras sp. cf. *C. defontii* (McLearn)
Otoites sp.
Oppelia sp.
Oedania ? sp.

Lower Bajocian ammonites
Tmetoceras scissum (Benecke)
Tmetoceras sp.
Graphoceras ? sp.
ammonite, new genus and species
nautiloid, common but not abundant
belemnoids, abundant throughout

Upper and Middle Toarcian ammonites
Haugia sp.
Phlyseogrammoceras sp.
Grammoceras sp.
Dumortieria ? sp.
Catulloceras ? sp.

Hazelton Group (cont.)

Pelecypoda
Gryphaea sp.
Inoceramus (*Retroceramus*) sp. indet.
Pleuromya sp. indet. aff. *P. subcompressa* (Meek)
Pleuromya sp.
Pinna sp. aff. *P. kingi* Meek
Pinna sp.
Pecten sp.
Gervillia sp.
Lima tizglensis McLearn
Ctenostreon gikshanensis sp. McLearn
Ostrea sp. cf. *O. weegeti* McLearn
Ostrea sp.
Astarte sp.
Oxytoma submcconnelli McLearn
Oxytoma sp.
Perna weelaupensis McLearn
Perna sp.
Posidonomya sp. (L. Bajocian and Toarcian only)
Trigonia sp.
Vaugonia sp.
Myophorella sp. cf. *M. dawsoni* (Whiteaves)
Myophorella sp.
Idonearca sp. cf. *I. haguei* (Stanton)
Idonearca sp.
Camptonectes sp. aff. *C. platessiformis* White
Camptonectes sp.
Modiolus sp.
Parallelodon sp. indet.

Miscellaneous
terebratullid and rhynchonellid brachiopods
many genera and species of gastropods
rare corals
rare fragments of crabs

Bait Member

Cephalopoda
Phymatoceras sp.
Haugia sp.
Sonninia sp.
Otoites sp.
Tmetoceras sp. cf. *T. scissum* (Benecke)
Dumortieria sp.
belemnites—*Dicoelites*? sp.

Pelecypoda
Posidonomya sp.
Myophorella sp.
Trigonia sp.
Ctenostreon sp.
Pholadomya sp.
Oxytoma sp.

Miscellaneous
terebratullid brachiopods
star-shaped crinoid columnals
gastropods—varied

Yuen Member

Cephalopoda
Sonninia sp.
Witchellia sp.
Stephanoceras sp.
Dactylioceras sp.
belemnites

Miscellaneous
rare thin-shelled pelecypods

BOWSER LAKE GROUP

Ashman Formation

Cephalopoda
Callovian ammonites (Lower and? Middle)
"*Kheraiceras*" sp. cf. *K. abruptum* Imlay
"*Kheraiceras*" *abruptum* Imlay
"*Kheraiceras*" sp. cf. *K. intermedium* Imlay
"*Kheraiceras*" sp. cf. *K. martini* Imlay
Kepplerites (*Seymourites*) sp. cf. *K. ingrahami* McLearn
Kepplerites sp. cf. *K. alticostatus* Imlay
Kepplerites sp. aff. *K. ingrahami* McLearn
Kepplerites sp. aff. *K. tychonis* Ravn and *K. multus* (McLearn)
Gowericeras costidensum Imlay
Gowericeras sp.
Kosmoceras sp. cf. *K. zortmanense* Imlay
Kosmoceras sp. cf. *K. alaskanum* Imlay
Lilloettia lilloetensis Crickmay
Lilloettia sp. cf. *L. lilloetense* Crickmay
Lilloettia buckmani (Crickmay)
Lilloettia sp. cf. *L. milleri* Imlay
Lilloettia sp. aff. *L. mertonyarwoodi* Crickmay
Lilloettia sp. aff. *L. stantoni* Imlay
Lilloettia tipperi Frebold
Parareineckia sp. aff. *P. shelikofana* Imlay
Parareineckia sp. cf. *P. hickersonensis* Imlay
Xenocephalites hebetus Imlay
Xenocephalites sp. cf. *X. hebetus* Imlay
Xenocephalites sp. cf. *X. bearpawensis* Imlay
Cobbanites sp. cf. *C. talkeetnanus* Imlay
Cobbanites sp. cf. *C. engleri* (Frebold)
Pseudocadoceras sp.
Paracadoceras sp.
Cadoceras ? sp.
Gulielmiceras ? sp.
Grossouvria ? sp.
Arctocephalites ? sp.
Procerites ? sp.
Phylloceras (*Macrophylloceras*) *grossicostatum* Imlay
Lytoceras sp.
perisphinctid ammonites

Callovian ammonites (Middle)
Cadoceras (*Stenocadoceras*?) sp. indet.
Pseudocadoceras sp. cf. *P. grewingki* (Pompeckji)
Pseudocadoceras sp. cf. *P. crassicostatum* Imlay

Callovian ammonites (Upper)
Quenstedtoceras (*Lamberticeras*) *henrici* Douville
Quenstedtoceras (*Lamberticeras*) *intermissum* Buckman
Phylloceras (*Partschiceras*) *pacificum* Frebold and Tipper
Binatisphinctes? sp.
perisphinctid ammonites

Lower Oxfordian ammonites
Phylloceras (*Partschiceras*) *pacificum* Frebold and Tipper
Cardioceras (*Cardioceras*) sp. cf. *C.* (*C.*) *lillooetense* Reeside
Cardioceras (*Subvertibriceras*) sp. cf. *C.* (*S.*) *canadense* (Whiteaves)
Cardioceras (*Scarburgiceras*) *martini* Reeside
Cardioceras (*Scarburgiceras*) sp. cf. *C.* (*S.*) *wyomingense* Reeside
Cardioceras (*Scarburgiceras*) sp. cf. *C.* (*S.*) *cordiforme* (Meek and Hayden)

Bowser Lake Group (cont.)

Pelecypoda

mainly Late Bajocian to Early Callovian

Inoceramus sp. cf. *I. obliquiformis* McLearn
Idonearca haguei (Stanton)
Oxytoma sp. cf. *O. blairmorensis* McLearn
Oxytoma sp.
Pleuromya obtusiporata McLearn
Pleuromya sp. cf. *P. obtusiporata* McLearn
Pleuromya sp. cf. *P. subcompressa* var. *carlottensis* Whiteaves
Pleuromya subcompressa (Meek)
Gryphaea impressimarginata McLearn
Myophorella sp.
Gervillia sp.
Pinna sp.
Pecten sp.
Astarte sp. cf. *A. packardi* (White)
Cucullaea sp.
Perna sp.
Ostrea sp.
Lima sp.
Modiolus sp.

Lower Oxfordian forms

Gryphaea sp.
Parallelodon sp.
Oxytoma sp.
Pleuromya sp.
Pinna sp.
Cucullaea sp.
?*Ostrea* sp.
Gervillia sp.
Buchia concentrica (Sowerby) (only in transitional beds at top)

Miscellaneous

gastropods—many genera and species
terebratulids and rhynchonellids—common crabs

Trout Creek assemblage

Cardioceras sp.
Pachyteuthis sp.
Cylindroteuthis sp.
Oxytoma sp.
Pinna sp.
Astarte sp.
Gervillia sp.
Inoceramus sp.
Pleuromya sp.
Psilomya sp.
"*Heterotrigonia*" sp. ex gr. *doroshini*
gastropods

Upper Bowser Lake Group assemblage

Amoeboceras sp.
?*Rasenia* sp.
?*Vertebriceras* sp.
Cylindroteuthis sp.
Buchia n. sp. ex aff. *B. concentrica* (Sowerby)
Buchia concentrica (Sowerby)
Buchia cf. *B. mosquensis* (Buch)
Echinotis sp.
large pectenids

APPENDIX V

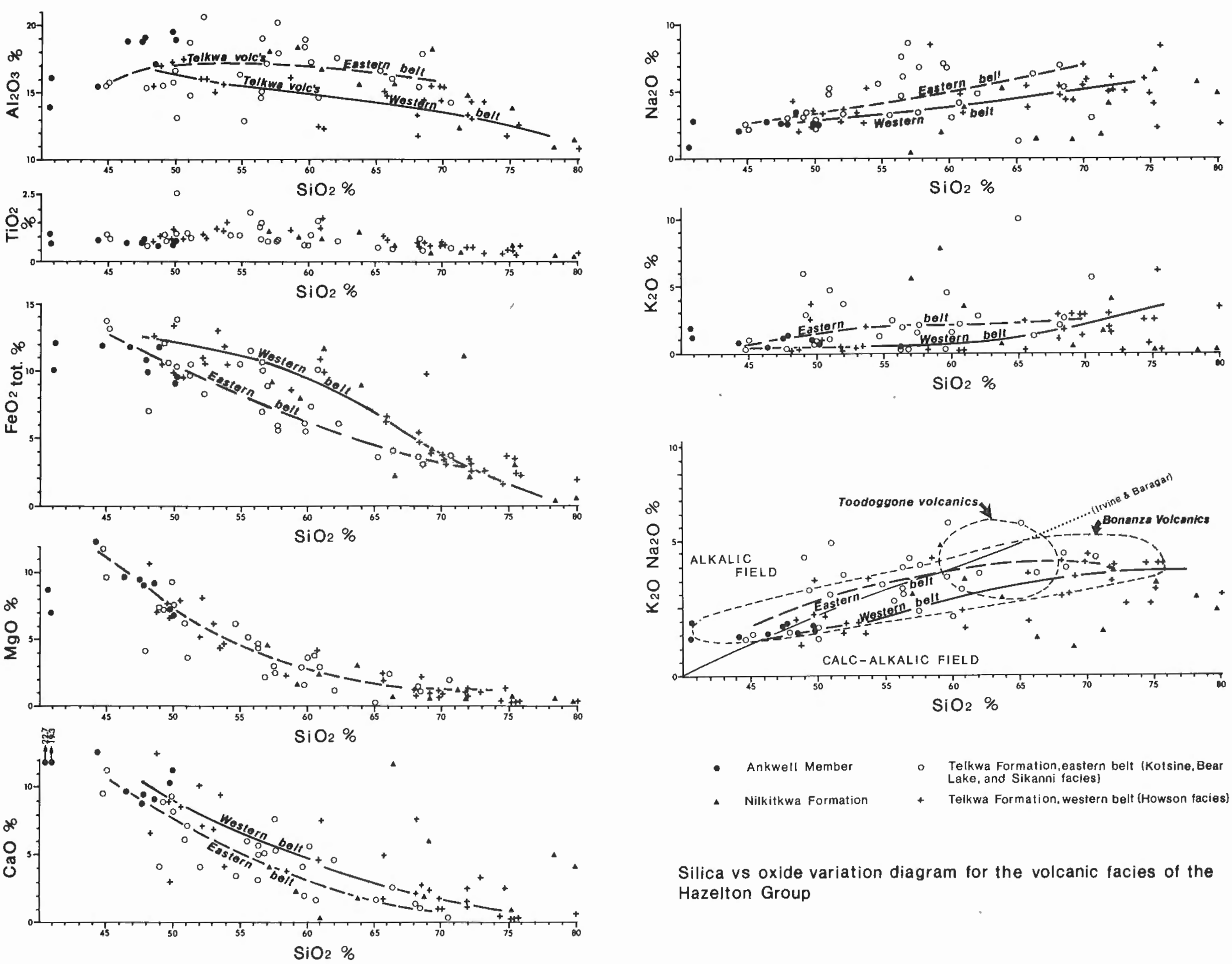
Chemical Analyses of the Hazelton Group

Chemical analyses of the volcanics of the Hazelton Group show trends typical of calc-alkaline volcanic terranes (Figs. 16 and 17). They are presented here for data completeness and for comparison with Mesozoic volcanic suites in the Canadian Cordillera (*see* also Souther, *in press*).

The chemistry of the Telkwa Formation volcanics is typical of a calc-alkaline basalt to rhyolite assemblage. Two distinctive suites can be separated chemically from rocks that are physically identical (except for the Kotsine facies) in the field, a western belt represented by the Howson facies, and an eastern belt, by the Kotsine, Bear Lake, and Sikanni facies. There are no data for the Babine facies, but intuitively the facies can probably be correlated with the Howson. Distinctions between the eastern and western belts are subtle and are shown as average trends in Figures 16 and 17. Using Irvine and Baragar's chemical classification of volcanic rocks (1971), the western belt comprises 28 per cent rhyolite, 22 per cent dacite, 18 per cent andesite, and 32 per cent basalt, and the eastern belt 8 per cent rhyolite, 7 per cent dacite, 30 per cent andesite, and 55 per cent basalt. Although these differences undoubtedly involve a sampling problem, they illustrate the more acidic composition of the western suite of the Telkwa Formation compared to the eastern one. A major distinction results also in a comparison of the basalts from the two belts. Two of thirteen basalt samples from the Howson facies show alkaline affinities, whereas seven of the eleven from the eastern belt were alkalic. The $Na_2O + K_2O$ vs SiO_2 plot (Fig. 16H) shows the more alkaline nature of the eastern suite. The dividing line between the two belts is probably west of the Nilkitkwa Depression.

Of eight analyses from the clastic-tuff facies of the Nilkitkwa Formation, seven are dacite and rhyolite. All are ash-fall tuffs, probably with appreciable additions of silt. As the tuffs are composed of shards altered to laumontite, analcite, and heulandite?, it is probable that their chemistry has been modified during diagenesis. These ash-fall tuffs typify the intermittent volcanism of the Nilkitkwa Formation, postdating the calc-alkaline Telkwa volcanism and preceding the brief Red Tuff, Ankwell, and Carruthers eruptions. Analyses of the tuffaceous beds of Smithers Formation would probably show a similarity to the Nilkitkwa tuffs.

Of the three members of the Nilkitkwa Formation, only the Ankwell Member has been analyzed. Petrographically, the Carruthers Member is basaltic, and the Red Tuff member, rhyolitic to



Silica vs oxide variation diagram for the volcanic facies of the Hazelton Group

FIGURE 16

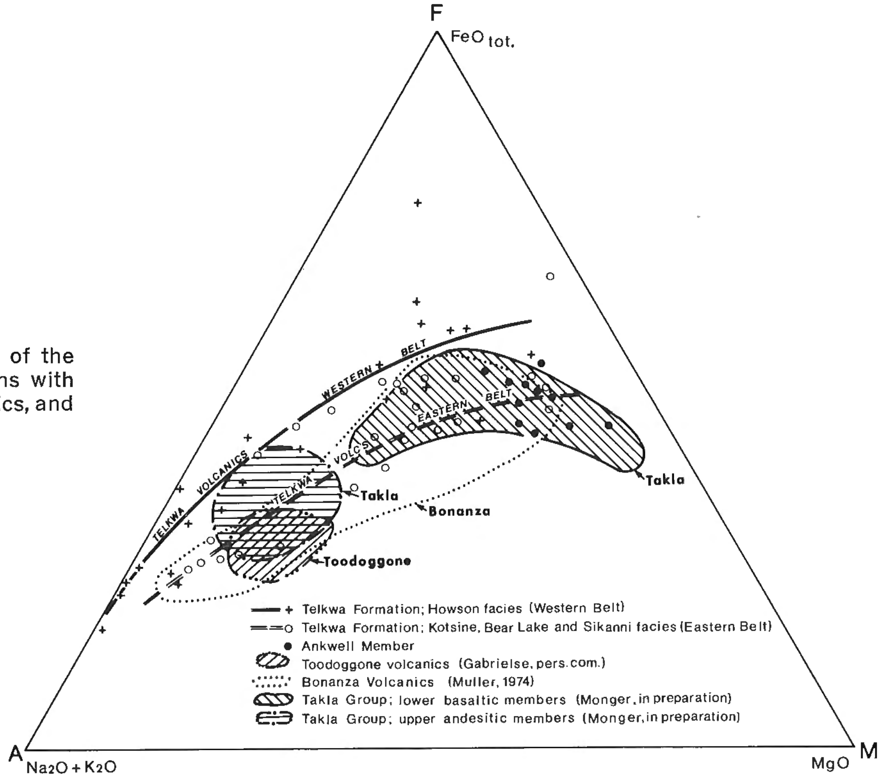


FIGURE 17

AFM plot of the volcanic facies of the Hazelton Group and comparisons with the Takla Group, Bonanza Volcanics, and the Toodoggone volcanics.

basaltic. The Ankwell Member is entirely basaltic; seven of twelve analyses are alkalic, four are calc-alkaline high alumina, and one is tholeiitic. The alkalic suite includes mainly the greenish aquagene tuff and breccia with common calcite-quartz-prehnite-albite secondary cement, whereas the calc-alkaline high alumina basalts are subaerial flows with minor alteration. If the chemical and mineralogical differences between the two suites are controlled by deuteric reactions in a marine environment versus minimal reactions in an atmospheric environment, then the original composition of the Ankwell volcanics was probably a calc-alkaline rather than an alkaline series.

The Telkwa Formation and the Bonanza Volcanics of the Vancouver Basin (Muller *et al.*, 1974) are chemically indistinguishable (Figs. 16H and 17). The Toodoggone volcanics are a suite of mainly acidic to intermediate volcanics, probably correlative with part of the Hazelton Group, that do not show the basalt to rhyolite trend typical of the Telkwa Formation; the acidic tuffaceous rocks of the Smithers Formation are probably a correlative facies. The bulk of the Takla Group volcanics are basalts and basaltic andesites, with no intermediate and acidic types (Fig. 17), although the uppermost assemblages in the Sustut–Dewar Peak region tend to be andesitic and are only distinguishable from the Telkwa Formation with great difficulty (Church, 1974; Monger, *in press*).

Telkwa Formation

Howson facies

	316	317	318	319	320	321	322	323	325	326
SiO_2	68.51	67.03	50.56	71.03	46.43	52.83	52.18	45.07	48.65	70.07
Al_2O_3	15.18	15.02	16.04	14.24	16.12	15.48	14.86	14.41	16.82	13.85
TiO_2	.52	.53	1.37	.48	.85	1.12	1.21	.73	.80	.27
Fe_2O_3	3.64	3.62	6.47	2.72	8.01	4.31	4.44	6.71	5.23	2.14
FeO	.30	.40	3.90	.00	2.60	7.70	8.80	5.70	4.40	.50
MnO	.14	.14	.40	.30	.19	.22	.37	.33	.18	.10
MgO	.62	.90	4.24	.73	6.73	4.30	5.92	9.99	7.51	.87
CaO	.86	2.21	3.85	1.03	11.84	9.18	6.65	6.08	8.20	3.12
Na_2O	5.24	4.18	4.88	6.02	1.79	2.54	3.34	3.93	3.22	4.84
K_2O	3.00	2.91	1.96	2.11	.37	.64	.54	.06	1.06	.32
P_2O_5	.16	.16	.27	.11	.21	.19	.20	.18	.19	.08
CO_2	.74	1.38	2.11	.41	.02	.00	.00	1.82	.06	.00
H_2O	1.40	1.50	3.20	.80	3.70	1.40	.90	3.90	2.90	3.40
S	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
Cr_2O_3	.04	.05	.07	.04	.06	.08	.05	.10	.07	.05
TOTAL	100.36	100.05	99.35	100.04	98.93	100.02	99.48	99.05	99.29	99.62

	328	329	330	331	333	334	335	336	337	339
SiO_2	48.29	71.40	69.05	79.07	73.55	63.70	70.88	65.83	67.93	75.34
Al_2O_3	14.84	13.22	15.26	10.73	11.62	11.00	13.23	12.94	14.04	12.66
TiO_2	.83	.52	.60	.24	.37	.54	.48	.65	.61	.52
Fe_2O_3	7.49	2.74	1.15	1.92	2.95	3.90	3.37	5.54	3.72	2.42
FeO	3.00	.60	1.90	.10	.80	.80	.30	.10	.00	.00
MnO	.26	.16	.16	.09	.12	.22	.15	.20	.15	.06
MgO	7.38	1.22	.78	.19	1.29	.69	.88	1.19	1.07	.04
CaO	6.57	2.44	.88	.52	2.37	7.01	1.38	1.97	1.59	.17
Na_2O	3.18	4.98	5.66	2.59	4.71	4.42	4.80	5.20	6.69	8.32
K_2O	.37	1.96	3.13	3.36	.55	1.14	3.13	3.03	1.45	.03
P_2O_5	.21	.13	.13	.06	.08	.11	.13	.17	.13	.09
CO_2	.00	.00	.00	.15	.21	5.34	.37	2.39	1.69	.00
H_2O	6.50	.80	1.10	1.10	1.00	.90	.80	.70	.80	.60
S	.03	.02	.02	.05	.02	.02	.02	.02	.02	.02
Cr_2O_3	.07	.05	.06	.04	.07	.04	.05	.06	.04	.06
TOTAL	99.04	100.24	99.88	100.21	99.73	99.83	99.96	99.99	99.92	100.33

	340	341	342	343	344	345	348	349	350	352
SiO_2	59.71	58.51	50.05	62.58	64.20	47.22	74.06	74.35	75.32	55.12
Al_2O_3	12.07	11.98	15.27	14.27	14.81	16.38	14.03	13.46	12.48	15.21
TiO_2	1.61	1.18	.94	.76	.80	.78	.33	.24	.21	1.06
Fe_2O_3	6.23	9.18	6.00	5.66	5.65	5.16	3.62	1.50	2.46	7.64
FeO	4.00	2.10	4.90	1.10	1.00	4.70	.00	.10	.00	1.10
MnO	.23	.19	.18	.16	.20	.17	.08	.04	.07	.17
MgO	2.80	3.98	4.92	2.17	2.03	7.22	.05	.23	.04	2.13
CaO	7.31	4.28	9.66	4.63	1.57	8.50	.06	.31	.04	3.36
Na_2O	3.31	4.60	2.56	3.43	5.21	2.23	3.94	5.82	2.20	7.92
K_2O	.08	.07	.48	.38	2.22	2.49	2.43	2.39	6.15	.30
P_2O_5	.68	.27	.16	.21	.25	.18	.06	.05	.05	.28
CO_2	.00	1.38	.00	.00	.00	1.36	.00	.00	.00	1.25
H_2O	1.90	2.20	4.00	4.00	2.40	3.30	1.70	.60	.60	4.60
S	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
Cr_2O_3	.04	.07	.05	.05	.06	.07	.04	.05	.07	.05
TOTAL	99.98	100.01	99.19	99.41	100.41	99.78	100.43	99.15	99.71	100.22

	354	355
SiO_2	47.49	67.19
Al_2O_3	16.52	14.15
TiO_2	1.16	.67
Fe_2O_3	8.15	1.75
FeO	5.40	3.10
MnO	.53	.16
MgO	6.30	2.14
CaO	2.83	2.63
Na_2O	3.30	4.24
K_2O	3.56	1.92
P_2O_5	.21	.20
CO_2	1.11	.20
H_2O	3.20	1.10
S	.03	.02
Cr_2O_3	.05	.05
TOTAL	99.83	99.51

Howson facies

316 siliceous, feldspar-quartz eye porphyry (Howson Range)
317 feldspar porphyry-crystal vitric tuff (Tsai Creek)
318 amygduloidal crowded feldspar porphyry, quartz, calcite, chlorite in amygdules (Ashman Ridge)
319 dense, weakly flow banded plagioclase crystal-red lithic lapilli tuff (Clore River)
320 amygduloidal olivine basalt, calcite in amygdules (McDonnell Lake)
321 massive, fresh, subophitic basalt (Nanika Mountain)
322 saussuritized, fine-grained, subophitic basalt (Mount Loring)
323 oxyhornblende, feldspathic, amygduloidal andesite, epidote, calcite, chlorite in amygdules (Houston Tommy Creek)
325 fine-grained, fresh, olivine basalt, olivine to iddingsite (Sunsets Creek)
326 poorly sorted, intraformational pebble conglomerate, laumontite cement (Sunsets Creek)
328 fine-grained lithic breccia, feldspar porphyry clasts, laumontite cement (McDonnell Lake)
329 polymictic, vitric-crystal-lithic, siliceous lapilli tuff (Howson Range)
330 massive, dense, flow-banded, siliceous feldspar porphyry (northern Howson Range)
331 massive, light pink rhyolitic breccia (northern Howson Range)
333 finely flow banded, lithic-vitric ash-flow tuff (Howson Range)
334 fine-grained, silty red tuffaceous mudstone (Clore River)
335 light coloured, massive ash-flow vitric-lithic-crystal tuff
336 dense, pale grey, siliceous, fine-grained lapilli tuff (Ashman Ridge)
337 weakly flow layered, pale mauve, welded crystal-lithic tuff (Howson Range)
339 fine-grained, pale mauve, weakly flow laminated crystal-lithic-vitric tuff (McDonnell Lake)
340 brick-red, even-grained, lapilli-tuffaceous mudstone (Howson Range)
341 brick-red, scoriaceous, fine-grained feldspathic andesite, epidote, and chlorite in amygdules (Telkwa Range)
342 highly amygduloidal, fine-grained basalt-andesite, epidote, quartz, prehnite, and chlorite in amygdules (Nanika Mountain)
343 stratified volcanic breccia cemented by laumontite (Sunsets Creek)
344 dark, purplish grey, glassy feldspar porphyry (Sunsets Creek)
345 massive, fresh olivine basalt, olivine to iddingsite (Sunsets Creek)
348 light coloured vitric-crystal lithic unwelded ash-flow tuff (Telkwa River)
349 dense, delicately flow laminated vitric-crystal ash-flow tuff (Clore River)
350 dense, light purple rhyolite dome (Clore River)
352 chaotic sorted, dense, polymictic lithic breccia (Nanika Mountain)
354 massive amygduloidal feldspar porphyry, amygdules quartz, k-feldspar, chlorite (Hope Peak)
355 dense, glassy, feldspar porphyry lapilli tuff-breccia (Poplar Mountain)

Kotsine facies

	365	366	367	372	380	383	386
SiO_2	40.49	42.39	53.58	57.32	54.62	51.70	47.19
Al_2O_3	13.93	14.72	13.90	13.86	14.62	12.02	15.65
TiO_2	.89	.77	1.27	1.43	1.32	1.73	.96
Fe_2O_3	5.56	6.20	5.60	7.16	3.13	5.77	3.79
FeO	7.40	6.80	5.00	3.20	6.80	5.50	6.30
MnO	.24	.66	.38	.20	.15	.17	.18
MgO	10.60	9.00	4.26	3.59	4.43	4.72	8.77
CaO	8.52	10.54	4.59	1.55	5.40	5.49	8.68
Na_2O	2.21	1.90	4.36	3.92	5.87	2.95	2.01
K_2O	.28	1.03	1.74	2.03	.17	2.29	.62
P_2O_5	.14	.10	.26	.37	.27	.49	.19
CO_2	2.53	.00	.75	.09	.03	1.67	.00
H_2O	6.00	5.20	3.90	4.40	2.20	4.20	4.70
S	.03	.03	.15	.03	.03	.12	.05
Cr_2O_3	.11	.07	.06	.05	.07	.07	.10
TOTAL	98.93	99.40	99.80	99.20	99.10	98.91	99.18

Bear Lake facies

	356	357	358	359	360	361	371	393	394
SiO_2	63.26	54.27	69.34	46.27	51.99	46.29	45.35	45.60	41.52
Al_2O_3	16.34	16.44	14.03	14.74	15.51	14.72	13.15	11.90	13.21
TiO_2	.46	.70	.42	.73	.85	.91	1.04	2.42	.53
Fe_2O_3	3.85	7.71	2.03	6.85	6.92	11.41	10.21	4.86	6.73
FeO	.00	.80	1.80	3.70	3.70	1.10	.10	8.20	.20
MnO	.08	.20	.08	.37	.37	.68	.34	.13	.30
MgO	.17	2.09	1.80	6.85	5.79	6.86	3.21	6.90	3.63
CaO	1.67	4.88	.27	8.26	3.19	3.90	6.29	7.47	17.65
Na_2O	1.22	8.09	2.97	3.30	5.23	2.65	4.61	2.50	2.47
K_2O	9.85	.27	5.58	2.60	1.19	5.60	4.15	.69	.32
P_2O_5	.24	.18	.11	.17	.28	.21	.34	.22	.14
CO_2	1.10	2.90	.01	1.78	1.38	2.03	10.62	3.92	10.10
H_2O	1.10	1.30	1.40	3.50	3.20	3.20	.70	4.20	3.20
S	.02	.02	.02	.03	.03	.03	.02	.28	.02
Cr_2O_3	.07	.04	.05	.08	.04	.07	.07	.06	.05
TOTAL	99.43	99.89	99.89	99.22	99.67	99.66	100.20	99.34	100.08

Kotsine facies

365 medium-grained aquagene tuff, calcite-prehnite cement (head of Kotsine River)
366 very dense, fine-grained green tuff (head of Kotsine River)
367 brown-weathering, medium-sorted, polymictic aquagene lapilli tuff (Nilkitkwa Range)
372 polymictic-acidic-basaltic clast fine-grained breccia (Frypan Peak)
380 dense, massive, fine-grained, spotted green tuff, chilled basalt, albite, chlorite, prehnite (Frypan Peak)
383 fine-grained peperite volcanic breccia, prehnite, calcite, albite cement (Mount Teegee)
386 interlaminate green aquagene tuff and fine breccia (northern Bait Range)

Bear Lake facies

356 light purple, siliceous feldspar porphyry (Iktlaki Peak)
357 dense, fine-grained crystal-lithic lapilli tuff (Mount Bates)
358 light mauve, flow-banded crystal-vitric ash-flow tuff (Skutsil Knob)
359 massive, fresh olivine basalt, amygdules of quartz, prehnite, k-feldspar (Skutsil Knob)
360 massive, poorly sorted lithic lapilli tuff (northern Driftwood Range)
361 massive, fresh olivine basalt (Skutsil Knob)
371 dense, brick-red, calcite cemented lithic-lapilli tuff (northern Driftwood Range)
393 dense, fine-grained, massive, greenish basalt-andesite (Iktlaki Peak)
394 friable red lithic lapilli tuff, laumontite cement (Mount Bates)

Nilkitkwa Formation

Ash-fall tuffs

	362	363	368	370	373	374
SiO_2	59.84	76.75	74.07	67.95	74.24	59.81
Al_2O_3	13.22	9.99	9.36	10.82	12.69	13.57
TiO_2	.64	.20	.22	.35	.54	1.11
Fe_2O_3	.00	.00	.02	3.47	.11	2.33
FeO	2.00	.40	.30	7.50	2.80	6.30
MnO	.12	.03	.03	.10	.05	.20
MgO	.55	.04	.09	1.53	.53	2.79
CaO	10.55	3.96	4.85	.14	.95	1.84
Na_2O	1.24	4.60	5.42	1.70	6.49	4.79
K_2O	1.25	.02	.04	1.52	.21	.65
P_2O_5	.20	.06	.06	.09	.11	.23
CO_2	4.22	3.08	3.28	.00	.35	.05
H_2O	5.50	1.20	2.00	3.80	.70	5.10
S	.40	.04	.05	.02	.03	.18
Cr_2O_3	.07	.04	.07	.05	.05	.07
TOTAL	99.81	100.40	99.86	99.06	99.84	99.02

	375	376	377	378	379
SiO_2	54.28	64.29	59.59	52.01	70.40
Al_2O_3	16.11	16.05	15.23	15.14	13.41
TiO_2	1.11	.32	.80	.78	.49
Fe_2O_3	3.03	2.58	3.21	.00	.70
FeO	6.00	1.60	8.60	7.00	1.60
MnO	.32	.08	.10	.16	.09
MgO	4.28	.58	2.40	1.34	.53
CaO	3.94	5.59	.35	1.99	2.49
Na_2O	.38	1.29	3.59	1.62	3.95
K_2O	5.40	.57	3.51	6.93	3.92
P_2O_5	.21	.10	.22	.26	.16
CO_2	.00	.01	.00	9.97	1.38
H_2O	4.30	6.60	1.90	2.00	.50
S	.03	.03	.02	.56	.04
Cr_2O_3	.05	.05	.07	.04	.05
TOTAL	99.44	99.72	99.59	99.80	99.70

362 laminated, laumontized, ash-fall vitric tuff (Kotsine River)
363 dense, porcelaneous, thick-bedded, fine ash-fall tuff (Nilkitkwa Range)
368 dense, glassy, massive feldspar porphyry tuff (Nilkitkwa Range)
370 porcelaneous, cherty, creamy grey ash tuff (Ankwell Creek)
373 brittle, dull grey, very fine grained cherty tuff (Nilkitkwa Range)
374 spotted, analcite altered, argillaceous ash-fall tuff (Nilkitkwa Range)
375 coarsely spotted, laumontized ash-fall vitric tuff (Nilkitkwa Range)
376 chalky, laumontized ash-fall vitric tuff (Nilkitkwa Range)
377 dense, poorly sorted, siliceous clast lithic tuff (Ankwell Creek)
378 brittle, dull grey, very fine grained cherty tuff (Kotsine River)
379 light coloured, cherty, lithic lapilli tuff (Nilkitkwa Range)

Ankwell Member

	381	382	384	385	387	388
SiO_2	44.36	32.86	41.47	35.19	34.58	48.33
Al_2O_3	16.91	11.35	13.44	12.94	12.61	17.19
TiO_2	.70	.60	.77	.63	.85	.77
Fe_2O_3	3.83	5.40	5.66	5.01	5.25	3.60
FeO	7.90	4.70	6.10	6.00	7.50	6.10
MnO	.29	.19	.21	.19	.34	.19
MgO	9.20	6.69	11.58	6.12	11.81	6.41
CaO	9.15	21.96	11.80	16.53	14.03	11.00
Na_2O	2.48	1.68	1.80	2.30	1.28	2.09
K_2O	.55	.18	.91	1.18	.44	.72
P_2O_5	.14	.19	.15	.19	.22	.17
CO_2	.72	8.58	3.22	7.89	4.43	.33
H_2O	3.00	5.10	1.80	4.90	5.90	2.20
S	.04	.03	.04	.04	.03	.03
Cr_2O_3	.07	.08	.07	.06	.07	.09
TOTAL	99.34	99.61	99.03	99.18	99.35	99.21

	389	390	391	392	369
SiO_2	49.18	45.78	45.91	45.96	36.80
Al_2O_3	18.20	17.07	15.10	17.25	11.52
TiO_2	.69	.73	.64	.78	1.00
Fe_2O_3	5.93	4.79	9.87	5.19	4.02
FeO	3.70	6.20	2.30	5.00	5.60
MnO	.17	.19	.16	.19	.48
MgO	7.17	9.05	8.69	8.73	7.92
CaO	10.28	8.55	8.53	9.08	20.55
Na_2O	2.39	2.39	3.14	2.39	.69
K_2O	.83	1.27	.04	1.43	1.80
P_2O_5	.20	.18	.13	.22	.20
CO_2	.00	.00	.00	.05	4.68
H_2O	1.60	3.30	4.40	3.20	4.10
S	.02	.03	.03	.02	.04
Cr_2O_3	.08	.08	.09	.09	.08
TOTAL	100.44	99.62	99.02	99.57	99.48

Toarcian diabases

	309	310	311
SiO_2	51.85	47.71	47.11
Al_2O_3	13.81	12.85	16.70
TiO_2	2.31	1.87	.90
Fe_2O_3	4.70	5.76	3.75
FeO	9.10	13.10	6.70
MnO	.33	.46	.20
MgO	4.34	4.13	4.84
CaO	4.93	5.28	10.47
Na_2O	5.12	3.35	3.52
K_2O	.55	.06	.64
P_2O_5	.25	.31	.18
CO_2	.00	.06	.00
H_2O	2.20	4.00	4.10
S	.02	.08	.03
Cr_2O_3	.07	.05	.07
TOTAL	99.57	99.09	99.20

Ankwell Member

381 massive, fine-grained, grey-green amygduloidal basalt, amygdules with chlorite, calcite, and prehnite (southern Bait Range)

382 chaotic green breccia,with amygduloidal chilled basalt clasts in matrix of calcite and prehnite (northwest of Frypan Peak)

384 lithic-lapilli, green aquagene tuff, clasts chilled basalt, prehnite-quartz-calcite-albite cement (north of head of Ankwell Creek)

385 well-bedded to laminated green aquagene tuff and fine breccia, prehnite-albite-calcite-quartz matrix (southern Bait Range)

387 dark green, amygduloidal basalt breccia (head of Frypan Creek)

388 massive, subconchoidal, ophitic basalt (southern Bait Range)

389 dense, feldspar porphyry (southern Bait Range)

390 dense, massive, fresh, ophitic olivine basalt (southern Bait Range)

391 massive, reddish purple feldspar-olivine porphyry subaerial basalt (southern Bait Range)

392 dense, fine-grained dark purple basalt, epidote stringers (southern Bait Range)

369 medium-grained, green lithic-lapilli tuff, calcite-prehnite cement (Nilkitkwa Range)

Toarcian diabases

309 coarse-grained gabbro (Frypan Peak)

310 coarse-grained, fresh diabase (Nilkitkwa Range)

311 coarse-grained prehnite-pumpellyite diabase (Nilkitkwa Range)