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PERMIAN ROCKS OF THE CACHE CREEK GROUP IN THE MARBLE RANGE, CLINTON AREA, BRITISH COLUMBIA

H.P. TRETTIN

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PERMIAN ROCKS, OF THE CACHE CREEK GROUP, IN THE MARBLE RANGE, CLINTON AREA, BRITISH COLUMBIA

Abstract

A major outcrop area of Carboniferous to Middle(?) Triassic strata between the Fraser and Thompson Rivers is divisible into three belts. The eastern belt includes the type area of the original lower Cache Creek Group and the central belt that of upper Cache Creek Group or Marble Canyon Formation. Strata of the western belt previously assigned by the writer to Division I of the Pavilion Group are restored to the Cache Creek Group as mapped by G.M. Dawson.

The study area provides more insight into the stratigraphy and structure of the central belt than the type area of the Marble Canyon Formation. Five successive lithological units are distinguished. Map-unit 1 comprises incompletely metamorphosed basalt, underlain by thin units of limestone and chert. Map-unit 2 consists of well-bedded limestone (mostly wackestone) with some marble and dolostone, all containing stringers of chert. The poorly exposed map-unit 3 includes lithic arenite, pelite, chert, and thin units of volcanic and carbonate rocks. Map-unit 4 is characterized by massive limestone (mostly wackestone). Map-unit 5 is similar to map-unit 3.

Map-units 2 and 4 both contain fusulinacean faunas of probable early Guadalupian (Wordian) age. Lithology, fossils and structure suggest that map-units 4 and 5 constitute a major thrust sheet that repeats and overrides map-units 2 and 3. If so, the Marble Canyon Formation consists of a single limestone body divisible into two facies (map-units 2 and 4).

The presumed early thrust faulting was followed by the formation of fairly extensive folds in map-units 2 and 4 that are upright or overturned to the northeast. The folds are offset by faults with both vertical and horizontal displacements. A poorly exposed, broad, northwestward-plunging anticlinorium could be younger than the other folds.

Résumé

Une importante zone d'affleurements, contenant des strates dont l'âge varie du Carbonifère au Trias moyen(?), et située entre le fleuve Fraser et la rivière Thompson, peut être subdivisée en trois zones. La zone est comprend la localité-type du groupe inférieur de Cache Creek d'origine et la zone centrale, contient soit la localité-type du group supérieur de Cache Creek, soit la formation de Marble Canyon. On a de nouveau placé dans le groupe de Cache Creek, comme cartographié par G.M. Dawson, les strates antérieurement attribuées par l'auteur de cet article à la division I du groupe de Pavilion.

La zone étudiée nous donne un aperçu plus clair de la stratigraphie et de la structure de la zone centrale, que la localité-type de la formation de Marble Canyon. On distingue cinq unités lithologiques successives. La coupure de carte 1 contient des basaltes incomplètement métamorphisés supportés par de minces unités de calcaire et de chert; la coupure de carte 2 contient des calcaires bien lités (surtout des wackestones) avec un peu de marbre et de dolomite, qui sont tous parcourus par des veinules de chert. Sur la coupure de carte 3, où les affleurements sont bien moins nets, on rencontre des arénites lithques, des pélites, des cherts et de minces unités de roches volcaniques et carbonatées. Sur la coupure de carte 4, on trouve principalement des calcaires massifs (surtout des wackestones). La coupure de carte 5 est semblable à la coupure de carte 3.

Les secteurs 2 et 4 contiennent des faunes de Fusulinacés, d'âge probablement guadalupien inférieur (Wordien). La lithologie, les fossiles et la structure semblent indiquer que les coupures de carte 4 et 5 englobent une vaste nappe de charriage, qui se répète et chevauche les secteurs 2 et 3. Si cette hypothèse s'avère exacte, la formation de Marble Canyon serait donc formée d'une seule masse calcaire qui se subdiviserait en deux faciès (secteurs 2 et 4).

Le chevauchement initial postulé aurait donc été suivi de plis assez étendus dans les secteurs 2 et 4 et qui sont, soit droits ou renversés vers le nord-est; en outre les plis sont décalés par des failles à décrochements horizontaux et verticaux. Un vaste anticlinorium qui plonge vers le nord-est et forme un affleurement restreint est peut-être plus jeune que les autres plissements.

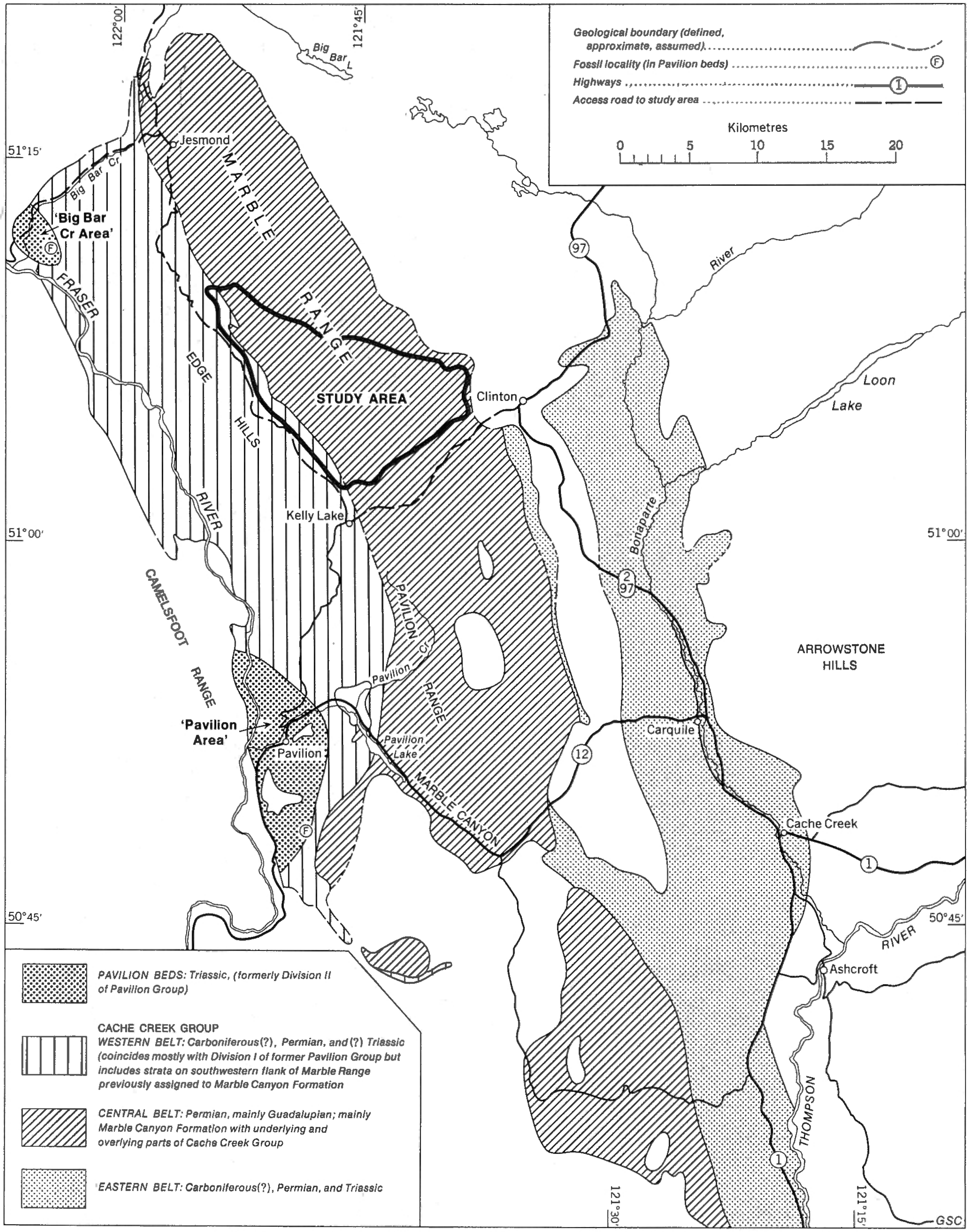


FIGURE 1. *Major outcrop belts of Carboniferous to Triassic strata between Fraser and Thompson Rivers and location of study area.*

PERMIAN ROCKS, OF THE CACHE CREEK GROUP, IN THE MARBLE RANGE, CLINTON AREA, BRITISH COLUMBIA

INTRODUCTION

The Cache Creek Group is one of earliest defined and most extensive units of the Canadian Cordillera and important for the interpretation of its tectonic history. In 1957 and 1958 the writer (Trettin, 1961) studied an area along the Fraser River Valley that included parts of the Cache Creek Group close to its type area. It soon became apparent, however, that this thesis work required revisions. The main purpose of this paper is to clarify to some extent the stratigraphy and structure of the Marble Canyon Formation and of underlying and overlying parts of the Cache Creek Group. The contributions to these problems are based on 17 days of field work in the Marble Range between 1964 and 1974. The paper also revises the stratigraphy of strata previously assigned by the writer to the Pavilion Group, and the brief comments on that subject are based on two days of field work with J.W.H. Monger in 1978.

The fossil identifications were made by C.A. Ross (Western Washington University, Bellingham), E.W. Bamber (Geological Survey of Canada, Calgary), B.L. Mamet (Université de Montréal) and M.B. Rafek (University of Saskatchewan, Saskatoon). W.R. Danner (University of British Columbia, Vancouver) has given unpublished information and advice through the years.

The study area in the Marble Range, with highest elevations of about 2200 m, is accessible from a road leading from Clinton to Canoe Creek via Kelly Lake and Jesmond (Fig. 1). It is characterized by steep limestone ridges and intervening slopes and valleys covered with softwood forest and meadows.

REGIONAL GEOLOGICAL SETTING AND STRATIGRAPHIC FRAMEWORK

The Cache Creek Group was established by Selwyn (1872) close to the present study area as a reconnaissance unit composed of a lower part of presumed Carboniferous age and an upper part of presumed Cretaceous or Eocene age. Subsequent work (e.g. Armstrong, 1949; Aitken, 1959) has shown that it is a distinctive rock unit that is widely exposed in the Intermontane Belt between the Yukon border and latitude 50°N, but concepts of its age, internal stratigraphy and significance have changed. As presently understood (Monger, 1977), it is a structurally complex assemblage of thinly interstratified radiolarian chert and pelite, basalt, and carbonate rocks with lesser amounts of arenite, that ranges in age from Early Mississippian to Middle or Late Triassic. The oldest known stratigraphic unit in the Intermontane Belt, it probably was deposited in an ocean or marginal oceanic basin, the basement of which is represented by alpine-type ultramafic bodies such as the Nahlin body of the Atlin Terrane (Aitken, 1959; Monger, 1975; Terry, 1977). The structural complexity of the group is due to a long and complex history that may have included subduction beneath a Late Triassic-Early Jurassic magmatic arc represented in the Ashcroft area by the Nicola Group and the Guichon Creek Batholith (Travers, 1978).

The type area of the Cache Creek Group lies in an outcrop area between the Fraser and Thompson Rivers (Fig. 1) that is in fault contact with surrounding Upper Triassic to Cretaceous strata and locally unconformably overlain by upper Miocene-Pliocene sediments and plateau basalts. The upper Paleozoic to Cretaceous succession is intruded by granitic plutons of Mesozoic age. The Cache Creek Group is here divisible into three northwesterly trending belts, first mapped by Dawson (1895a, b), that differ in lithology and physiography. The study area lies mainly in the central belt but includes a narrow adjacent part of the western belt.

The eastern belt includes the type area of the lower Cache Creek Group, which extends along the old Cariboo Highway from Spences Bridge to Clinton. This belt is underlain by volcanic rocks, limestone, chert and pelite with minor amounts of arenite and small bodies of serpentinized ultramafic rocks (Duffel and McTaggart, 1952; Campbell and Tipper, 1971; Travers, 1978). The stratigraphy and structures are poorly known. The oldest fusulinids, Middle Pennsylvanian in age (W.R. Danner, pers. com., 1978), were found at Meadow Lake, north of the Marble Range (north of the area shown in Fig. 1). Strata east of Clinton have yielded fusulinids of Permian, Wolfcampian and late Leonardian or early Guadalupian age, the youngest fusulinids being older than the *Yabeina* fauna of the Marble Canyon Formation (Campbell and Tipper, 1971).

Little is known about the age of the strata in the southern part of the eastern belt (Ashcroft map-area), except that a pelecypod and radiolarians of Triassic, probably Ladinian or Karnian age, have recently been found near the settlement of Cache Creek (Travers, 1978).

The central belt is characterized by prominent, ridge-forming limestones, but also includes poorly exposed chert, pelite, and volcanic rocks. Selwyn (1872) referred to these rocks as the upper Cache Creek Group, Dawson (1895a, b) as the Marble Canyon limestones or the upper member of the Cache Creek Formation, and Duffel and McTaggart (1952) as the Marble Canyon Formation (of the Cache Creek Group), the term accepted by subsequent workers. Duffel and McTaggart designated Marble Canyon and Pavilion Mountains as the type area but did not describe a type section.

Fusulinaceans from the Marble Canyon have been studied since the earliest geological investigations, but concepts of their age and affinity have changed with time (cf. Selwyn, 1872; Dawson, 1895a; Dunbar, 1932 and in Duffel and McTaggart, 1952; Thompson and Wheeler, 1942; Thompson et al., 1950; Skinner and Wilde, 1966). C.A. Ross, who has identified similar faunas from the Marble Range for Campbell and Tipper (1971) and for this report, places them in the upper part of the Assemblage Zone of *Neoschwagerina* (Assemblage Zone of *Neoschwagerina margaritae*) in agreement with Dunbar (1932). The fauna is late Akasakan in terms of the Japanese nomenclature, and probably early Guadalupian (Wordian) in terms of the Texan nomenclature (Ross and Nassichuk, 1970; cf. Fig. 3).

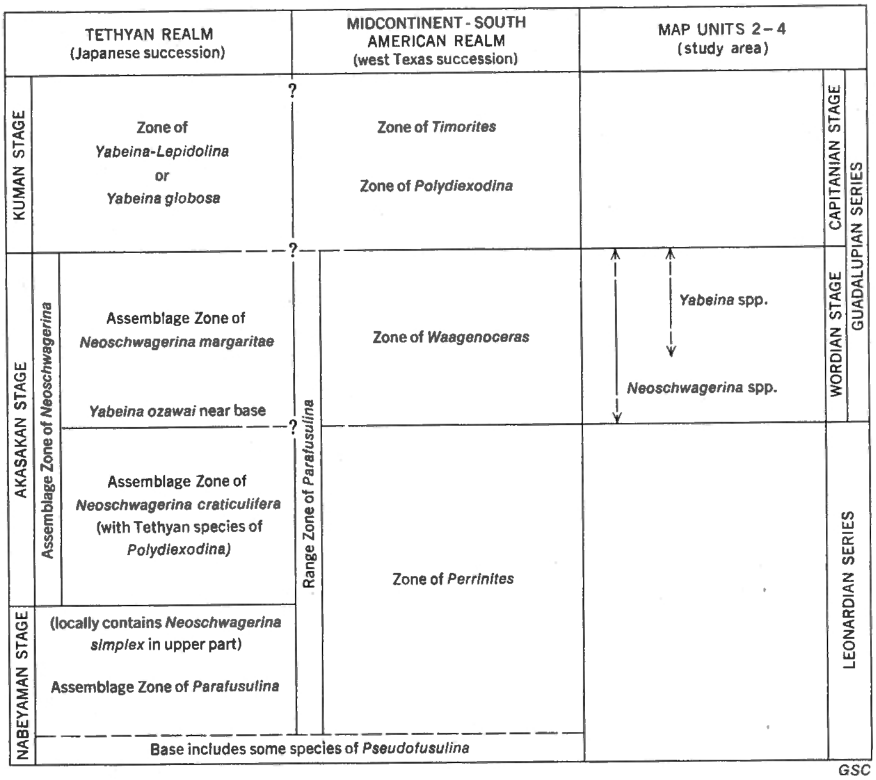


FIGURE 3. *Permian biostratigraphic zonation (from Ross and Nassichuk, 1970, Fig. 1) and approximate range of species of Yabeina and Neoschwagerina from map-units 2 and 4 of study area. C.A. Ross (pers. com., 1978) emphasizes that the age of the Kuman is in question and that its upper part includes strata younger than uppermost Guadalupian.*

The writer reconnoitered much of the central belt in 1957 and 1958 and concluded that the type area of the Marble Canyon Formation was unsuited for stratigraphic studies because of excessive deformation and insufficient exposure, but that a composite reference section could be established in the vicinity of Mount Soues (Trettin, 1961). Studies in that area, the main subject of this report, indicate that older and younger parts of the Cache Creek Group are present in the central belt in addition to the Marble Canyon Formation. The rocks underlying the Marble Canyon Formation probably are correlative with strata of the eastern belt east of Clinton, as suggested by Campbell and Tipper (1971). If strata coeval with the Marble Canyon Formation are present in the eastern and western belts, they do not consist of extensive, resistant limestones.

The western belt was mapped as lower Cache Creek Group by Dawson (1895b), who interpreted the regional structure as synclinal. Trettin (1961) concluded that the western belt is lithologically different from the eastern belt and younger, and assigned it to a new unit, the Pavilion Group, composed of two divisions. Division I was stated to consist mainly of chert and pelite with lesser amounts of limestone and volcanic rocks, and Division II mainly of volcanic rocks and lithic arenite with lesser proportions of chert, pelite, conglomerate, and limestone. Division II, which had yielded corals of post-Paleozoic, presumably Triassic age (identification by H. Duncan), was interpreted as older than the Nicola Group and tentatively assigned to the Middle Triassic in view of the fact that Lower Triassic rocks had not been reported in the region. Division I was interpreted as partly coeval with the Marble Canyon Formation -- constituting an interfingering basinal facies -- and partly as younger, i.e. as both Late Permian and Triassic in age.

Division I of the Pavilion Group, although comparable to the Cache Creek Group, was removed from it mainly because the latter was presumed to be restricted to the upper Paleozoic, but this assumption is no longer valid. The Pavilion Group therefore is abolished here as a formal rock unit and its former Division I is restored to the western belt of the Cache Creek Group. The eastern limit of that belt is placed on the southwestern slope of the Marble Range so that the belt includes not only the former Division I of the Pavilion Group but also strata east of Porcupine Creek previously included in the Marble Canyon Formation. These rocks (map-unit 6 of this report) have yielded poorly preserved fusulinaceans of probable Leonardian or earliest Guadalupian age (Appendix 2) -- that is the only direct biostratigraphic information available about the entire western belt.

The former Division II of the Pavilion Group, on the other hand, differs markedly in lithology from the Cache Creek Group in containing siliceous volcanic rocks and volcanic-derived sandstone. A limestone sample collected from an outcrop area at Big Bar (Fig. 1) yielded conodonts of Middle or Late Triassic age (see identification by M.B. Rafek in Appendix 2). The previously known fossil locality near Pavilion was revisited by Tipper (Campbell and Tipper, 1971, p. 30), and by Monger and the writer in 1978. The indeterminate scleractinian corals collected indicate a Middle Triassic to Recent age but E.W. Bamber, who identified them, points out that in southern British Columbia such fossils are most common in Norian strata. These strata therefore are possibly coeval with the nearby Nicola Group. They also are comparable to the Nicola Group in that both units consist mainly of volcanic rocks and volcanogenic sediments. However, the absence of augite porphyry, which characterizes both flows and volcanogenic clastic sediments of the Nicola Group (Preto, 1977), cautions against inclusion in that unit. The strata are here informally referred to as the Pavilion beds.

The contact between the Cache Creek Group and Pavilion beds clearly is faulted in the Pavilion area where it cuts across the structural trend. In the Big Bar Creek area, where it is parallel with the structural trend, it is concealed.

STRATIGRAPHY

Central Belt

Map-unit 1

Volcanic rocks, chert and limestone underlie the Marble Canyon Formation on the south slope of Mount Soues (Fig. 4), evidently with stratigraphic contact although it is possible that the contact is a low-angle fault.

The lowest 6 m of the exposed section (unit 1ch of Fig. 4, cf. Fig. 5) consist of medium grey chert, partly massive and partly occurring as pinching and swelling, 4 to

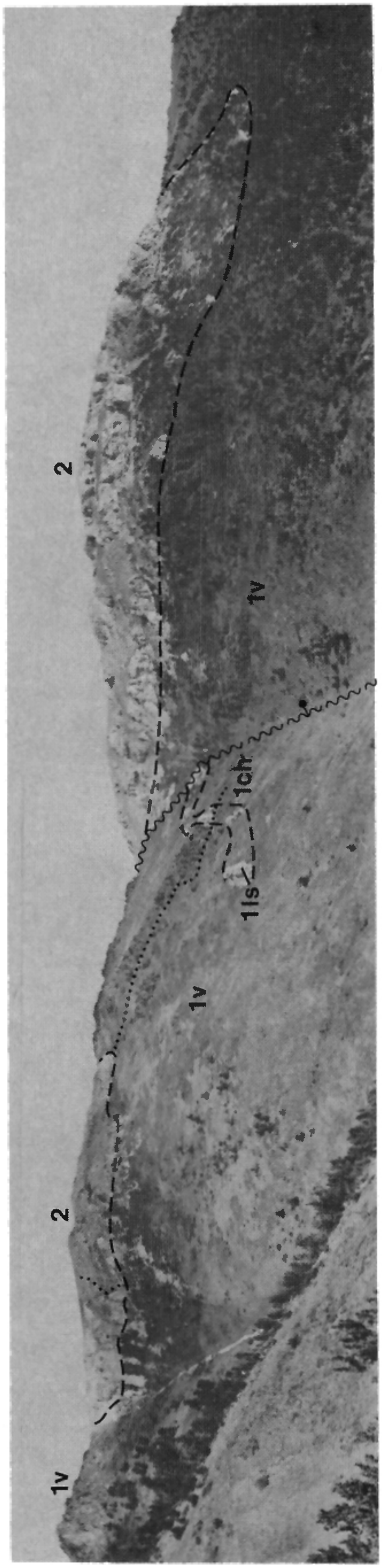


FIGURE 4. Mount Soues, view to the north (dotted line indicates section; 1 ch: chert, unit 1 of section 1-1; 1ls: limestone, units 2, 3 of section 1-1; 2: map unit 2, units 1-5 of section 1-2) (composite photograph GSC 199487).

10 cm thick beds. A representative specimen, examined in thin section, shows two sets of veinlets, filled with calcite and quartz, that intersect at low angles.

The chert is overlain by about 7 m of limestone (unit 1ls of Fig. 4) with 0.5 to 2.5 cm thick chert stringers. One specimen examined in thin section is a lime wackestone composed of peloids, about 1.5 mm in diameter, in a cryptocrystalline[1] calcite matrix. Another is a lime mudstone, composed of about 3 to 8 μm long microsparite crystals.

The contact with the overlying volcanic rocks (unit 1v of Fig. 4) is sharp but wavy, the undulations -- probably small-scale folds -- having half-wave lengths of about 30 to 45 cm and amplitudes of about 15 cm. The volcanic unit is about 139 m thick and consists mainly of basalt with minor amounts of intercalated chert and a small limestone lens. The rocks are dark greenish grey and weather brownish grey. They are massive with closely spaced fractures. A single pillow structure, about 30 cm long, was observed 53 m above the base of the section. The microscopic texture of the basalt is intersertal, intergranular, or microporphyritic. The rocks consist mostly of intensely sericitized feldspar -- largely or entirely albite -- and fresh clinopyroxene with lesser amounts of chlorite and opaque minerals, probably mainly ilmenite and magnetite. Pumpellyite may be present in small amounts but has not been identified with certainty. Shear zones and numerous veinlets in the volcanic rocks contain chlorite and lesser amounts of carbonate, quartz, and epidote. The vein material is so abundant that most rocks are unsuitable for chemical analysis. However, one specimen, the least altered, was submitted for chemical analysis and the results are listed in Appendix 3. The rock was classified as "tholeiitic basalt, K-rich series" by means of a computer analysis of the chemical data based on the classification of Irvine and Baragar (1971). It is uncertain whether the relatively large potassium content of the rock is an original feature or the result of submarine weathering or other types of alteration.

Light greenish grey, thinly laminated chert was observed 121.9 m above the base of the section. X-ray diffraction and thin section analysis indicate that it contains small amounts of white mica, and plagioclase in addition to the predominant quartz. A limestone lens, about 1 m long and 30 cm thick, and apparently oriented obliquely to bedding, occurs at a stratigraphic height of 118 m.

The nature of the upper contact of map-unit 1 with the overlying map-unit 2 is uncertain because the lower part of that unit is strongly contorted. This may indicate differential movements on a normal contact, or a low-angle fault.

Map-unit 1 has not yielded any fossils. The lower part of map-unit 2 probably is early Wordian in age. Thus, if the contact is normal, map-unit 1 probably is early Wordian and/or late Leonardian in age.

Map-units 2-5

Four different map-units are distinguished in the remaining part of the central belt -- two well exposed carbonate units (map-units 2 and 4), and two poorly exposed noncarbonate units (map-units 3 and 5). These units succeed each other in several folds (in the order indicated by their numbers), but it is uncertain whether the present order is original or the result of an episode of low-angle faulting prior

[1] For crystal size terminology *see* Appendix 4.

to the folding. Map-units 2 and 4 clearly are part of the Marble Canyon Formation, but the original position of map-unit 3 is problematic. A discussion of the lithology, thickness, and depositional environment of these units will be followed by a discussion of their age and possible stratigraphic relationships.

Lithology, thickness and depositional environment

Map-unit 2 (cherty limestone unit). Map-unit 2 consists of generally well bedded carbonate strata, mainly limestone but locally dolostone or marble, with abundant lenses and stringers of chert. A brief description of the measured sections is followed by a summary of the lithology and thickness of the unit and of its mode of origin.

At section 1-2, on the south slope of Mount Soues (Figs. 2, 4), map-unit 2 is about 75 m thick. The overlying map-unit 3 is not preserved but the present land surface probably is close to the top of the unit. It consists mainly of well-bedded limestone with stringers and thin beds of chert, about 1 to 8 cm thick, but the middle part is poorly bedded and lacks chert (Fig. 5). In the well-bedded parts of the section, bed thickness ranges from about 5 to 30 cm, and in the poorly bedded part from about 30 to 60 cm.

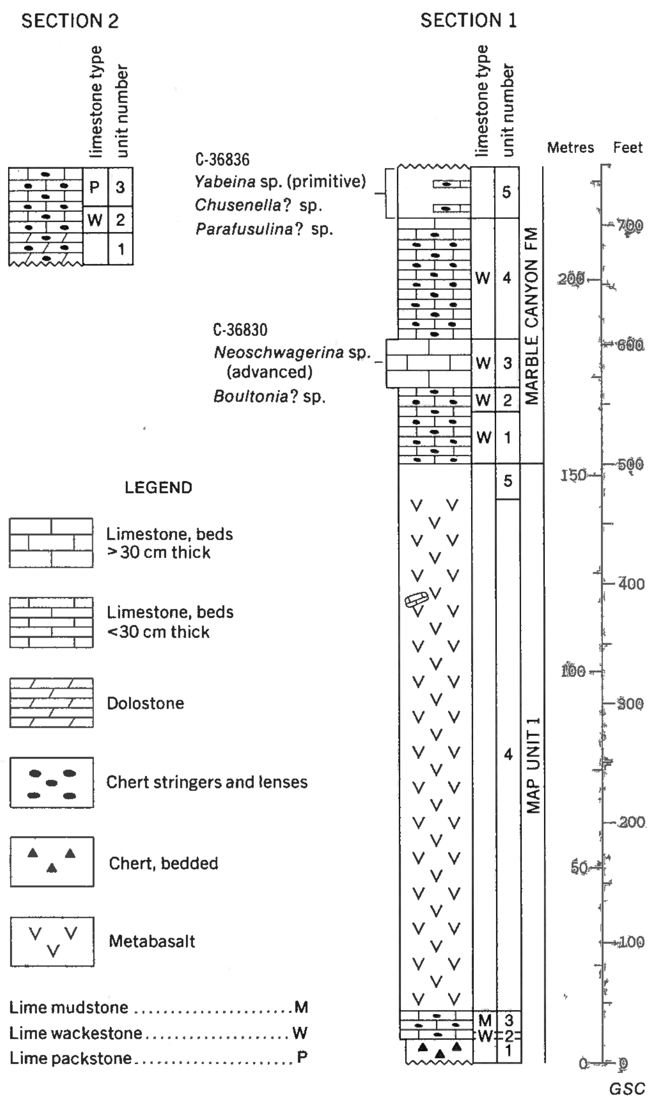


FIGURE 5. Stratigraphic sections 1 and 2 (columnar presentation).

The limestones are relatively pure. Small amounts of detrital quartz of silt to very fine sand grade were noted only in specimens from the lowermost part, about 6 to 7 m above the base of the section. Dolomite, generally euhedral and finely to medium crystalline, usually does not make up more than about 5 per cent of the carbonate fraction. The rocks contain numerous veinlets and stylolites and are partly brecciated and recrystallized in the contorted lower 10 m or so of the section, but original limestone textures are nevertheless preserved. Nineteen out of twenty thin sections are classified as lime wackestone and only one is regarded as a probable grainstone. The framework of the wackestones, in so far as it is identifiable, consists mainly of fragments of echinoderms, foraminifers -- both fusulinaceans and smaller forms (Fig. 7) -- and dasycladacean algae with abundant peloids and some oncoids. Radiating tufts of micritized bryozoans, probably in growth position, were observed about 19.5 m above the base of the member (Fig. 6). The grainstone, occurring as talus at a stratigraphic height of 62 m, consists of spar-cemented fusulinaceans and echinoderm fragments.

At section 2, west of Mount Soues (Fig. 2), map-unit 2 is represented by about 24.4 m of distorted cherty carbonate beds. The top of the unit probably coincides with the top of the uppermost resistant limestone bed, but the upper contact, with the recessive map-unit 3, is concealed. Downward, the section terminates in overburden and it is not known whether its base coincides with the base of map-unit 2 as map-unit 1 is not exposed nearby. The style of folding, however, suggests that map-unit 2 is much thinner here than on Mount Soues.

The lower 8 m consist mainly of dolostone and the rest of limestone, both rocks containing stringers and lenses of chert. The dolostone is microcrystalline, contains some echinoderms, and occurs in thick beds that show some vague laminations. The limestone beds range in thickness from about 5 to 25 cm. Petrographic classification is difficult because of recrystallization and veining. Specimens from the lower part of the section seem to be wackestones but specimens from the upper part are packstones. The latter contain echinoderms, fusulinaceans, intraclasts (some are pelletal), and small amounts of quartz of silt and very fine sand grade.

Sections 3 and 4. Map-unit 2 has a minimum thickness of 25 m at section 3 and of 18 m at section 4, both located in the vicinity of the Forestry Lookout near Clinton (Fig. 2). These figures give the approximate thickness of strata in anticlines; the contacts with underlying and overlying strata are not exposed. At both sections the unit consists of thin-bedded, variably schistose and recrystallized limestone with stringers and irregular patches of chert.

Four thin sections from section 4 consist of marble, replaced to varying extent by cryptocrystalline to very finely microcrystalline micrite or microsparite (Fig. 8) that is elongate and shows twinning and parallel orientation. The micrite-microsparite borders fractures and stylolites and seems to have formed from solutions that penetrated the rock.

At section 5, located at the Fiftytwo Creek Anticline (Fig. 2), map-unit 2 consists of well-bedded limestone with chert lenses, as in most other areas. Photogrammetric measurement indicated a thickness of about 197 m. About 4 km to the east, the limestone is locally completely replaced by chert.

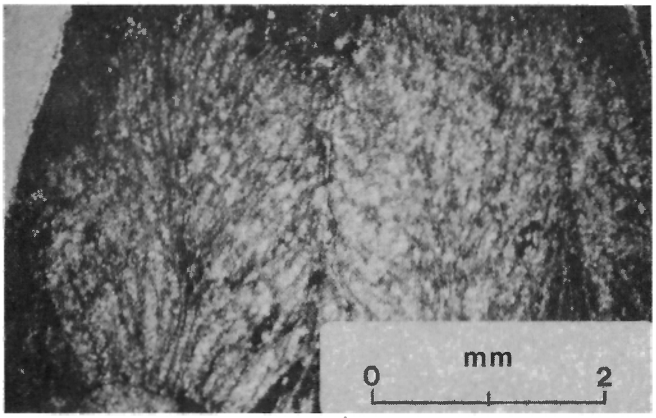


FIGURE 6. *Bryozoans (micritized), probably in growth position, in lime wackestone of map-unit 2, section 1-2, 19.5 m; ordinary light.*

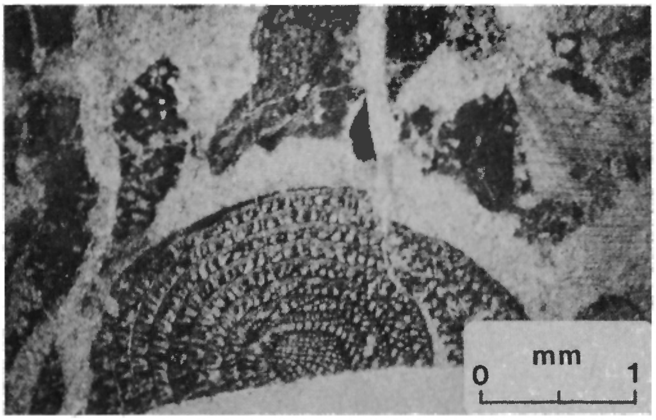


FIGURE 7. *Fusulinaceans (Yabeina sp., advanced in lower half -- identification by C.A. Ross) and echinoderm fragment (centre right) in grainstone of map-unit 2, section 1-2, 62.2 m (talus); ordinary light.*

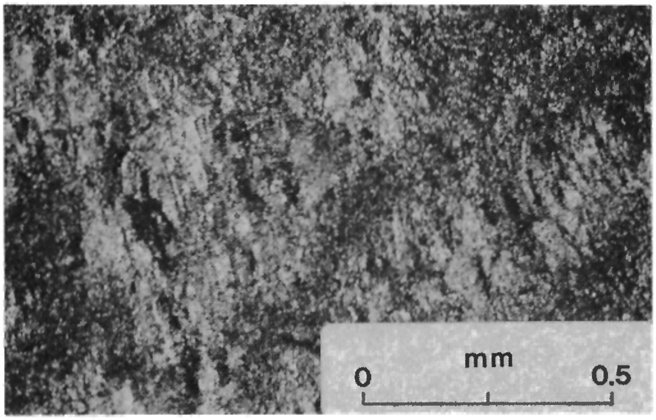


FIGURE 8. *Marble of map-unit 2 partly replaced by micrite, section 4; cross-polarized light.*

Summary of lithology, mode of origin and thickness

Limestone is the most common carbonate rock, but it is metamorphosed to marble in the eastern part of the study area, and dolostone is relatively rare. The limestone is generally well bedded with bed thickness ranging from about 5 to 30 cm, but beds up to 60 cm thick also occur. Most limestone specimens analyzed in thin section were wackestones; packstones and grainstones were less common. Bioclastic fragments in these rocks were derived mainly from echinoderms and foraminifers and to a lesser extent from dasycladacean algae and bryozoans; oncoids and peloids also are present.

Texture and biota of the lime wackestones suggest deposition in a protected but well-aerated subtidal shelf environment favourable to a variety of organisms. The packstone at section 2 could have formed in a slope environment, but this is not certain.

The chert stringers and lenses, which are the most characteristic features of this unit, probably are of replacement origin because they are irregular in shape and seem to lack radiolarians. Locally the carbonate rocks are entirely replaced by chert.

Measured thicknesses (Fig. 9) range from 18+ to 197 m. Although none of the sections are complete, they probably indicate at least the order of thickness in given areas, and the overall pattern of variation in thickness. The unit is thickest in the north-central part of the study area and thins along strike toward the southeast. It also thins markedly toward the southeastern and southwestern flanks of the range. The thickness could have been affected by low-angle faulting. However, the occurrence of lime packstone and dolostone, rocks suggestive of a shelf margin setting, in an area where the unit is relatively thin (section 2), supports the view that the thicknesses are original.

Map-unit 3. This is a poorly exposed, recessive unit, which in the vicinity of section 2 is composed of lithic arenite, siltstone, chert, volcanic flow rocks, and limestone. Its apparent thickness in that area is about 90 m, but the true thickness could be much larger or smaller because the concealed internal structure almost certainly is complex.

Lithic arenite and siltstone are intermittently exposed through a 38 m thick interval in the middle of the unit and are composed of angular to subrounded fragments of chert, cherty limestone, and limestone. A specimen of medium grained arenite is poorly sorted whereas a specimen of fine grained, silty arenite is well sorted. The fragments are tightly packed, commonly with pressure-solution contacts. They obviously were derived from Cache Creek strata but exposure of primary structures was too poor to determine mode of derivation -- whether by subaerial or submarine erosion -- and depositional environment.

A characteristic specimen of volcanic rock is medium grey, brownish grey weathering, porphyritic and has amygdules of calcite and chlorite. The phenocrysts, up to about 5 mm long and comprising a few per cent of the rock, consist of albite that is mostly replaced by sericite and chloritized glass. The groundmass is composed of unidentifiable plagioclase microlites, clinopyroxene and iron ore.

The chert, which is very poorly exposed, is dark grey and argillaceous.

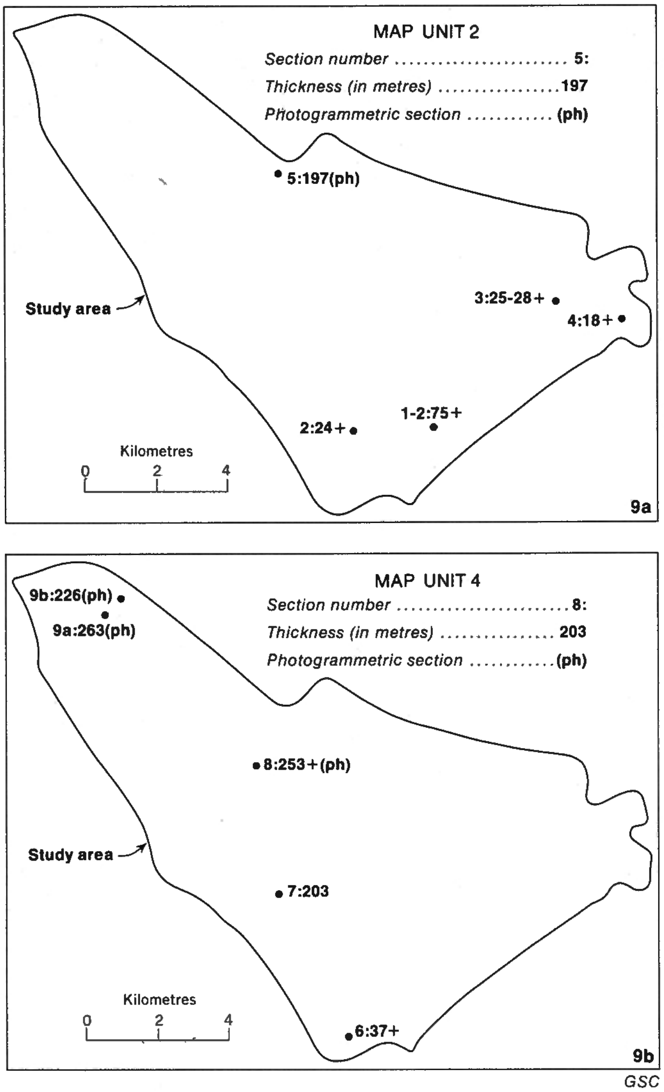


FIGURE 9. *Variations in apparent thickness of map-units 2 and 4. For location of sections, see Figure 2.*

Map-unit 4 (massive limestone unit). This unit, composed of limestone, is distinguished from map-unit 2 by its massive character, lesser chert content and greater maximum thickness.

The thickness of the unit generally is difficult to determine because of the obscurity of bedding and the locally complex structure. Measured thicknesses (Fig. 9b) range from 37+ to 253+ m and demonstrate marked thinning on the southwestern flank of the range, as also is shown by map-unit 2 (Fig. 9a). If the unit is bounded at the base by a low-angle fault, as suggested below, then the thinning could be the result of truncation by this fault (cf. Fig. 13).

Eight specimens from sections 6 and 7, examined in thin section, all are classified as lime wackestone. The identifiable skeletal grains were derived from echinoderms, fusulinaceans and other foraminifers (Fig. 10), and dasycladacean algae (Fig. 11). Oncoids (Fig. 12) are common at both sections, and peloids also are present. The oncoids range in diameter from about 0.3 to 3.74 mm and are spheroidal, ellipsoidal, or irregular in shape. Most are simple but some are compound. They are characterized by

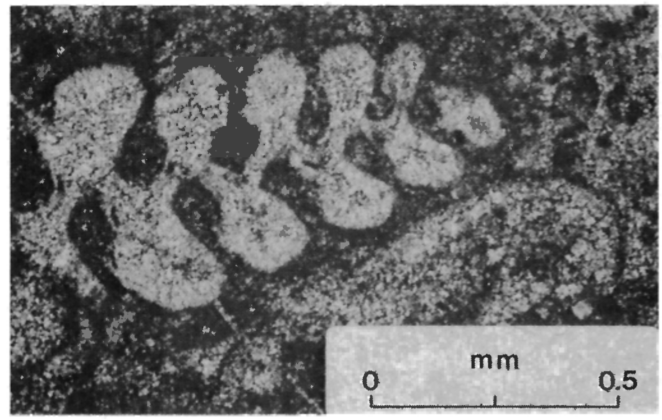


FIGURE 10. *Photomicrograph of foraminifer (either Palaeotextularia or Dexterella -- identification by B.L. Mamet) in lime wackestone of map-unit 4, section 7, uppermost beds; ordinary light.*

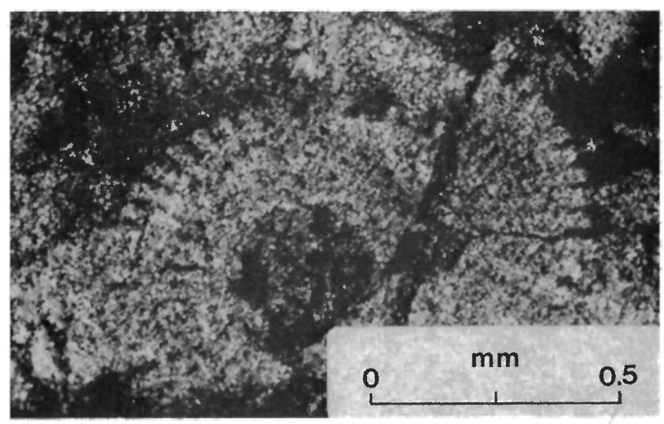


FIGURE 11. *Photomicrograph of dasycladacean algae in lime wackestone of map-unit 4, section 7, uppermost beds; ordinary light.*

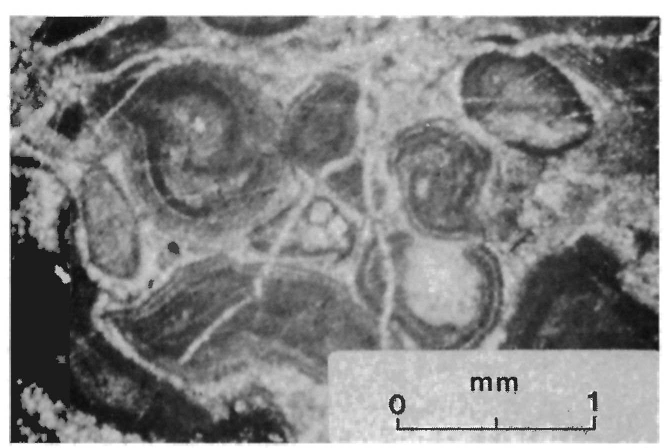


FIGURE 12. *Photomicrograph of oncoids in lime wackestone of map-unit 4, section 7, basal strata; ordinary light.*

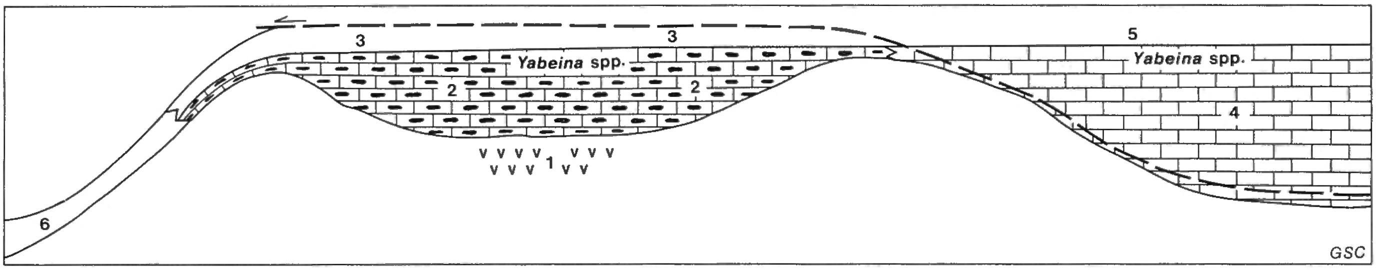


FIGURE 13. *Possible stratigraphic and structural relationships of map-units. Heavy dashed line indicates thrust fault. Map-unit 6 probably includes strata older than map-unit 2 and also may include strata younger than map-unit 3.*

concentric dark layers, about 8 to 180 μm thick, composed of cryptocrystalline calcite with a relatively large concentration of submicroscopic carbonaceous matter, separated by slightly coarser (finely microcrystalline) and purer layers. Most oncoids have several dark layers but some have only one. The cores usually consist of clear to moderately cloudy, finely microcrystalline calcite, in some cases with coarser grained, euhedral dolomite. Oncoids are generally interpreted as the product of blue-green algae.

The unit appears to have been deposited in a subtidal shelf environment, comparable to the depositional environment of map-unit 2. The texture of the rocks (wackestones) as well as the delicate dasycladacean algae indicate a tranquil setting.

Map-unit 5. North of Twomile Creek, the only area where it was observed during the present investigation, map-unit 5 consists of lithic arenite, phyllite, and one bed of fractured dolostone. It seems to overlie map-unit 4, but the contact is concealed and could be a fault. The arenite is represented mostly by rubble and its primary structures are not apparent. It ranges in grain size from medium to very coarse and pebbly. The arenites consist mostly of chert with some limestone fragments in pebbly rocks. The chert is variably argillaceous, commonly contains radiolarians, and appears to be mostly of primary origin. The clasts generally are poorly sorted and evidently have been abraded in situ by tectonic processes. They are fairly closely packed but surrounded by a matrix of white mica that has recrystallized in a plane of schistosity coinciding with the plane of flattening of the fragments. These arenites, like those of map-unit 3, were derived from the Cache Creek Group, but their mode of origin and depositional environment are uncertain.

An outcrop of chert and pelite, and another outcrop of carbonate rocks, mapped on the northeastern flank of the First Ridge Anticline in 1958 (Trettin, 1961, Fig. 1B) are also included in map-unit 5.

Fusulinacean fauna and age

Fossil collections are limited to map-units 2 and 4 and the present age assignments are based on fusulinaceans although other diagnostic foraminifers are also present.

Map-unit 2. The collections from map-unit 2 all apear to be early Guadalupian (Wordian) in age. An early Wordian age probably is indicated by GSC locality C-82 from north of the Forestry Lookout near Clinton which contains undetermined species of Neoschwagerina typical of the middle part of the Assemblage Zone of Neoschwagerina (cf. Fig. 3). GSC locality C-36836, from the uppermost part of the Mount Soues section (Fig. 5), contains an undetermined primitive species of Yabeina, comparable to forms from the Marble Canyon, of probable late Wordian age.

Map-unit 4. Four collections from the uppermost part of the unit (*see* Appendix 2) are comparable to those from the Marble Canyon (Skinner and Wilde, 1966) in lacking Neoschwagerina and in containing certain species of Yabeina (Y. minuta, Y. parvula) that are more advanced than the early Wordian Yabeina cf. Y. ozawai from the Horsefeed Formation of the Atlin Terrane (Ross and Nassichuk, 1970; Monger, 1975, p. 51), but less so than Yabeina globosa of probable late Guadalupian or Kuman age. Schwagerina acris also occurs both in map-unit 4 and in the Marble Canyon. These four collections probably are late Wordian in age and approximately coeval with GSC locality C-82 from the uppermost part of Map-unit 2.

Neoschwagerina sp. occurred in a boulder of massive limestone (at locality F6, Fig. 12), derived almost certainly from map-unit 4, but from an unknown stratigraphic level).

Possible stratigraphic relationships of map-units 2-5, and implications for nomenclature

As mentioned, the true stratigraphic order of map-units 2-5 is uncertain because we do not know whether or not the original order has been upset by an early phase of low-angle faulting. If not, then map-units 2-4 should be regarded as members of the Marble Canyon Formation, and map-unit 5 as the basal part of an overlying unnamed formation. In this case, the present Yabeina fauna would range from the upper part of map-unit 2 through map-unit 3 to the top of map-unit 4, an interval that probably is more than about 350 m thick in the north-central part of the study area.

If faulting has occurred, the simplest solution would be that map-units 4 and 5 constitute a thrust sheet that overlies and repeats map-units 2 and 3 (Fig. 13). Map-unit 4 differs in some respects from map-unit 2 but could be a facies equivalent. Map-unit 5 is comparable to map-unit 3 except for the apparent lack of volcanic rocks. Such rocks, however, may well be present as the unit is very poorly exposed. In this case, the Marble Canyon Formation would consist of a single limestone body, as proposed by Campbell and Tipper (1971) and the vertical range of the present Yabeina fauna would probably be less than 200 m. Structural evidence (*see* below) seems to support the second alternative but is not conclusive because of the insufficient exposure.

Western Belt

Map-unit 6

This unit comprises poorly exposed, recessive strata of chert, pelite, limestone and volcanic rocks on the southwestern flank of the Marble Range.

At a locality north of lower Twomile Creek, chert occurs in 1 to 3 cm thick beds that are separated by argillaceous partings. The rock is medium grey on fresh surfaces and weathers brownish owing to limonite stain derived from weathered pyrite. A thin section of this rock is traversed by numerous shear zones and veinlets. The argillaceous matter has recrystallized to white mica that is oriented in three different planes. Radiolarian skeletons are preserved as inclusion-free ellipsoidal nodules, about 0.06 to 0.3, commonly 0.2 mm long, that are elongate in the plane of the principal schistosity (Fig. 14).

The limestones observed are perhaps 5 to 7 m thick. A specimen from lower Twomile Creek is a lime wackestone composed of oncoids and coated grains, similar to those in map-unit 4, in a cryptocrystalline to finely microcrystalline calcite matrix. Dolomite makes up a few per cent of the rock and occurs as rhombohedra, very fine to finely crystalline in size. The rock is brecciated and traversed by stylolites.

A specimen of flow breccia from this general area consists of intensely sericitized, unidentifiable plagioclase microlites in a matrix of altered glass. Calcite veinlets and replacements are common.

The preponderance of interstratified radiolarian chert and pelite in this unit suggests a deeper water environment. If so, the limestones must be submarine slide deposits, but this has not been established.

The only fossil collected from map-unit 6 is a Neoschwagerina sp. from locality F7 (Fig. 2) that probably is late Leonardian or earlier Guadalupian (early Wordian) in age. The unit may include deep water facies equivalents of the Marble Canyon Formation, but the precise relationship between the shelf limestones and deep water sediments could not be established because of the poor exposure of the noncarbonate rocks, tight folding, and scarcity of fossils.

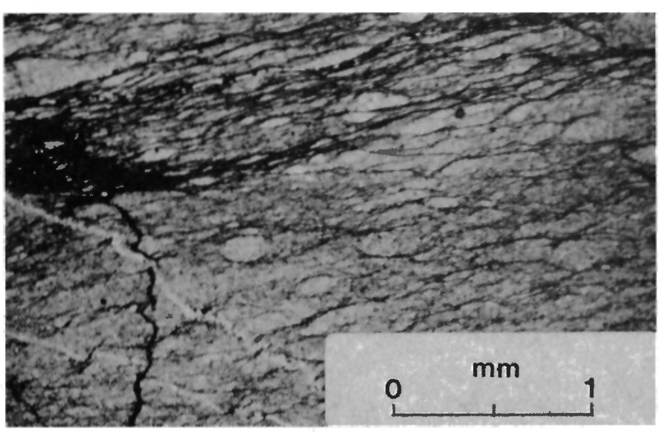


FIGURE 14. *Photomicrograph of phyllitic chert in map-unit 6 (north of Twomile Creek, close to power line); light grey ellipsoidal nodules are radiolarians; dark grey carbonaceous matter concentrated in S-planes; ordinary light.*

STRUCTURAL GEOLOGY

The major structural features of the area, suspected or established, are discussed in their probable chronological order.

Early thrust faults(?). Campbell and Tipper (1971) recognized southwestward directed thrust faults on Mount Kerr. A major thrust fault that involves strata probably correlative with map-unit 1 of this report is shown on their map, and others, as they point out, are present within the thick limestone succession assigned to the Marble Canyon Formation. It is reasonable to assume that this faulting extended into the present study area where it is less evident -- partly because of the involvement of poorly exposed noncarbonate strata (map-unit 3), and partly because of the more intense overprinting by a later phase of folding.

Stratigraphic observations, as pointed out above, are compatible with the hypothesis that map-units 4 and 5 combined constitute a major thrust sheet that overrides and repeats map-units 2 and 3. This concept is supported by the structure north of upper Porcupine Creek (Fig. 2, cross-section A-A'; and Fig. 15) where map-unit 4 shows anomalously low dips. In its overall configuration, the suspected thrust fault dips southwestward; this attitude is not necessarily original but could have resulted from the rise of the Fortyseven Creek Anticlinorium to the east. The suspected thrust sheet has a minimum strike length of 16.5 km and a minimum width of about 4.3 km.

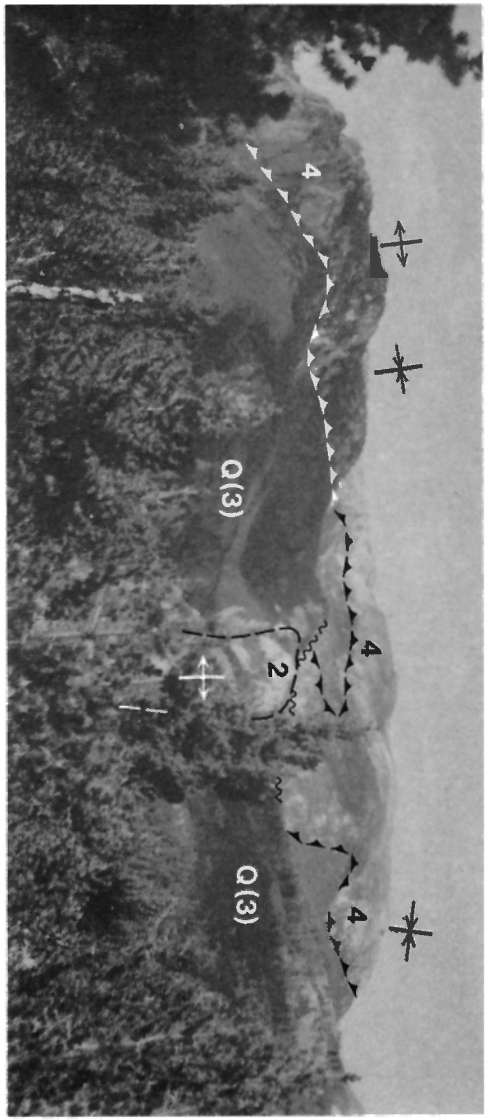
The problem of whether the presumed low-angle fault at the base of map-unit 4 was caused by gravitational gliding or compression can only be resolved when the age relationships between map-units 3 and 4 have been established. (Superposition of older on younger rocks would suggest compression.) If gliding has occurred, it probably did not follow immediately upon deposition in the marine environment because boulder-grade subaqueous debris flows, usually associated with such slides, have not been recognized in the Marble Range.

Folds. The western part of the map-area is characterized by northeast-trending concentric folds formed in massive limestone of map-unit 4. The most extensive fold recognized is the First Ridge Anticline, traced for 12.8 km. The folds are tight and overturned steeply to the northeast in the southwestern part of the belt and upright and open in the northern part. Because of the massive nature of map-unit 4, these folds are not obvious and were not recognized in 1958 (Trettin, 1961, Fig. 1B). During later work, some were recognized on air photographs (Fig. 16), others from a distance (Fig. 15), and only a few from nearby. The structural interpretation of map-unit 4 is still incomplete, especially in the northwestern and southwestern parts of the study area.

Several extensive, upright, northwesterly plunging anticlines within map-unit 2 are present in the north-central part of the map-area, where the unit is relatively thick. Most prominent is the Fiftytwo Creek Anticline, exposed for about 6.4 km. Some short, relatively shallow folds are apparent on Mount Soues (Fig. 4).

In the eastern part of the map-area, map-unit 2 is thin and forms complex minor folds. A few northwesterly to northerly trending anticlines are recognized in the western part of this area; farther east the structures become too small and complex for mapping at the present scale.

Why are extensive, fairly simple folds present in the central and western parts of the study area but absent from Mount Kerr and the northern part of the Marble Range? The



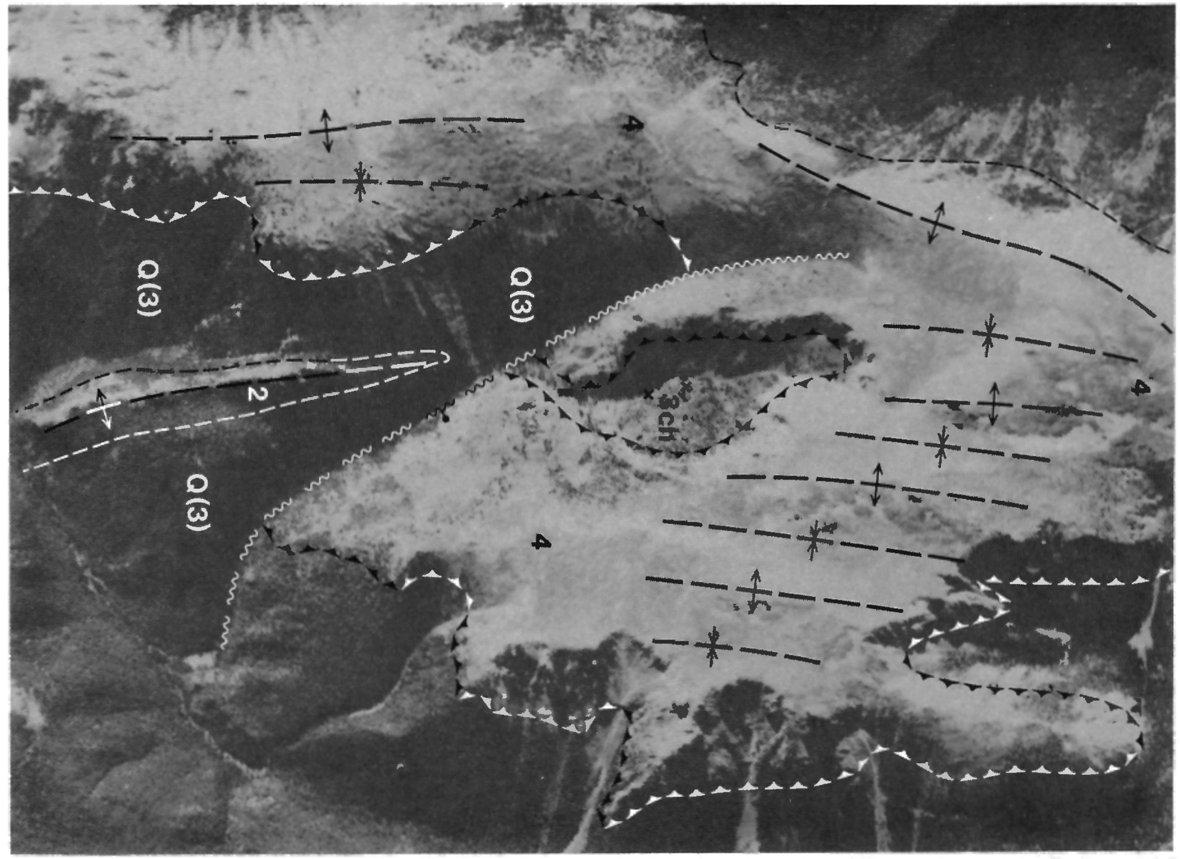


FIGURE 15. Photographs of area north of upper Porcupine Creek, demonstrating superposition of map units 2, 3, and 4. The contact of map unit 4 with the largely covered map unit 3 is interpreted as a major thrust fault (cf. geological map and cross-section A-A', Figure 2). Above: enlarged part of air photo A16320-117; left: view to the north GSC 199485.

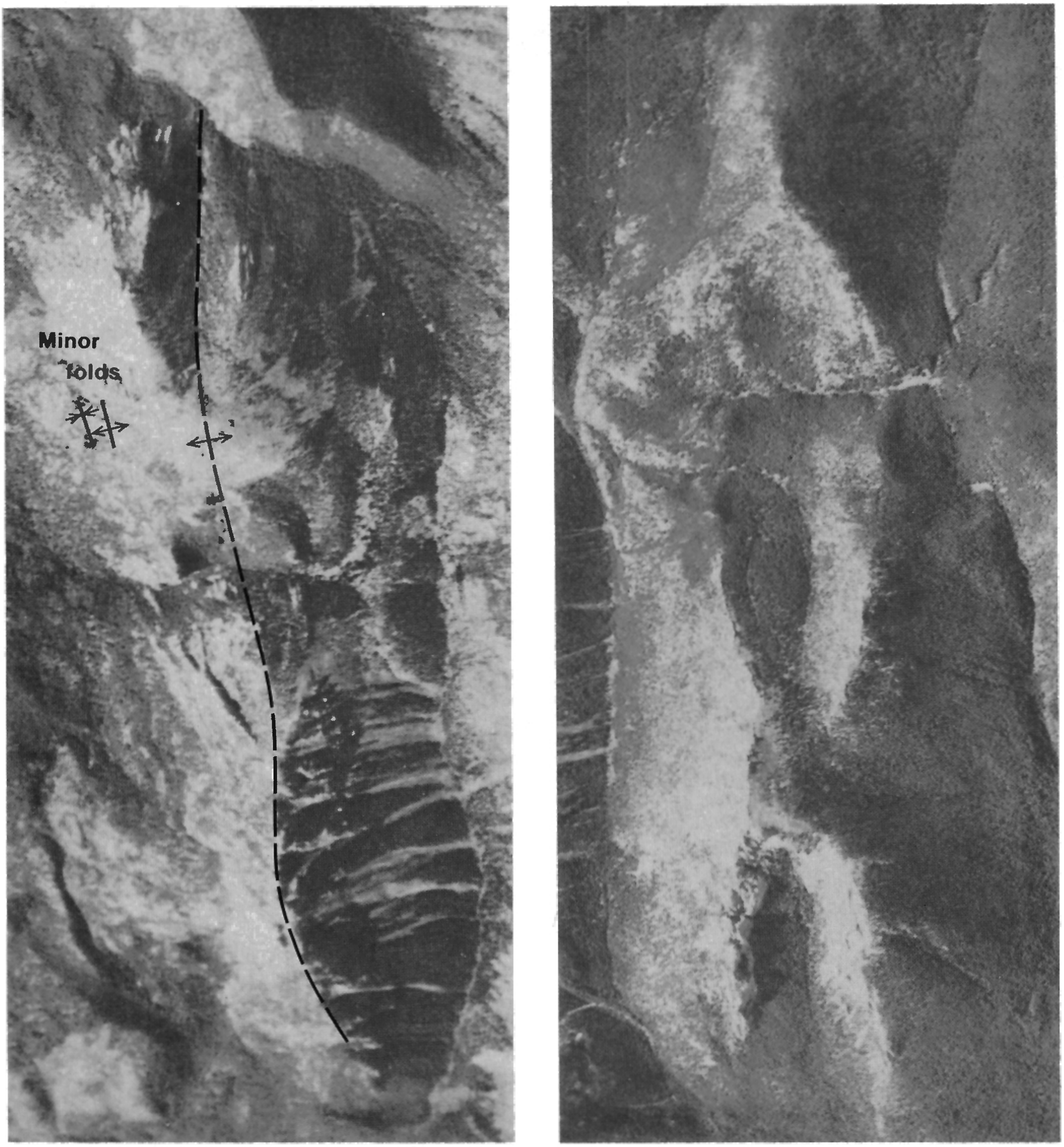


FIGURE 16. Anticlines formed in map unit 4. Left: First Ridge Anticline (from air photo A13320-116). Right: Third Ridge Anticline (from air photo A13320-117).

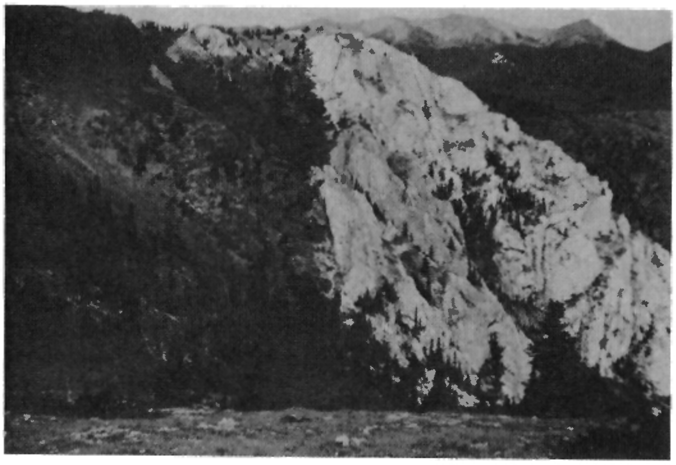


FIGURE 17. *Nearly vertical fault on east side of Mount Soues, looking northwestward. On the left, basalt of map-unit 1 overlain by limestone of map-unit 2; on the right, down-dropped block of map-unit 2 (GSC 199486).*

simplest explanation is that in the study area the postulated early thrust faulting produced a succession of alternating competent carbonate and incompetent noncarbonate units that was far better suited to folding than the thick and probably irregular stack of carbonate thrust slices at Mount Kerr and farther north.

The noncarbonate units of the study are are too poorly exposed for structural interpretaion. Folds in map-unit 6 at Twomile Creek are tight and have halfwave lengths in the order of metres.

Late faults. The folds are offset or terminated by numerous faults that include a nearly vertical fault on Mount Soues with relative downdrop on the east (Fig. 17) and a sinistral transcurrent fault cutting the Fiftyseven Creek Anticline.

Fortytwo Creek Anticlinorium. The base of map-unit 2 outlines a broad, complex, northwesterly plunging anticlinorium that probably is underlain by map-unit 1. It is not clear whether it formed contemporaneously with the folds discussed or during a later phase of less intense deformation.

Age of deformations. At Big Bar Creek, steeply dipping strata of Cache Creek Group and Pavilion beds are unconformably overlain by nearly horizontal strata of late Miocene to Pliocene age (cf. Trettin, 1961, Fig. 1C). This demonstrates that the deformations occurred prior to late Miocene time, and is the only evidence in the immediate vicinity of the study area. Correlation of the different phases of deformation inferred for the study area with documented or inferred events in adjacent areas is difficult and beyond the scope of the present study.

In summary, in the central and southwestern parts of the Marble Range the Cache Creek Group is intensely deformed, and only the structure of the well-exposed limestone bodies, map-units 2 and 4 is intelligible to some extent. The mapping of these units, combined with stratigraphic studies suggests an early phase of extensive thrust faulting, followed by folding along northwesterly trending axes, in turn followed by faulting with vertical and horizontal displacements and the development of a broad, northwesterly plunging anticlinorium. The deformations occurred prior to the late Miocene but their precise ages and significance are unknown.

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APPENDIX 1: STRATIGRAPHIC SECTIONS

SECTION 1

Located on southeastern slope of Mount Soues; measured from base up by four-foot staff (1.22 m).

Section 1-1

Map-unit 1

unit 1 0-6.1 =6.1 m	Chert, medium grey, mostly massive with 4-10 cm thick, pinching and swelling beds in upper part; numerous quartz and calcite veinlets
unit 2 6.1-7.6 =1.5 m	Lime wackestone, peloidal, massive with numerous veinlets and stylolites and stringers of chert, 0.5-2.5 cm thick
unit 3 7.6-13.1 =5.5 m	Lime mudstone, massive with stringers of chert as in unit 2 and more diffuse, incomplete chert replacement; veinlets and stylolites common; one specimen shows thin layer of caliche
unit 4 13.1-143.2 =130.1 m	Basalt, altered and containing closely spaced fractures; pillow, about 30 cm long at 53.0 m; lens of limestone, about 1 m long, 30 cm thick, oblique to bedding at 118.3 m; upper 15 m partly covered; contact with underlying limestone is undulating (half-wave length of folds 30-45 cm; amplitude 15 cm)
unit 5 143.2-152.4 =9.1 m	Covered, probably underlain by basalt

Section 1-2

Map-unit 2

unit 1 0-13.4 =13.4 m	Limestone, wackestone, crinoidal, in 5-15 cm beds with 1-8 cm thick chert lenses; veins and stylolites common; replacement by chert and quartz; small amounts of microcrystalline to medium crystalline dolomite; contorted, thickness uncertain
unit 2 13.4-19.5 =6.1 m	Limestone wackestone in 20-30 cm beds with interbedded chert as in unit 1
unit 3 19.5-31.7 =12.2 m	Lime wackestone, mostly massive with some vague bedding (about 30-60 cm); relatively resistant with recessive interval near top; includes echinoderms, sponges, bryozoans (at 19.5 m), fusulinaceans and other foraminifers, dasycladaceans(?), oncoids and peloids; small amounts of dolomite; veinlets common Microfossils: GSC loc. C-36830 at 24 m
unit 4 31.7-62.5 =30.8 m	Lime wackestone in beds about 8-30, mostly 10-20 cm thick with chert lenses 2-8 cm thick; foraminifers, echinoderms, oncoids, peloids; very small amounts of dolomite; veinlets common
unit 5 62.5-75.0 =12.5 m	Mostly covered, with about 10% of outcrop of limestone and chert Microfossils: GSC loc. C-36836 from large, angular talus block of limestone almost certainly was derived from this unit

SECTION 2

Located about 1.1 km north of forks of Two-Mile Creek; measured from base up by four-foot staff. Base of map-unit 2 not exposed.

Map-unit 2

unit 1 0-7.9 =7.9 m	Dolostone, microcrystalline, calcareous with some echinoderm fragments; beds up to 90 cm thick with some vague lamination; chert lenses 8-30 cm long and up to about 4 cm thick
unit 2 7.9-14.6 =6.7 m	Limestone in beds about 5 to 25 cm thick with chert as in unit 1; stylolites and veinlets common; two specimens examined in thin section appear to be crinoidal wackestone
unit 3 14.6-24.4 =9.8 m	Limestone in beds commonly 8-13 cm thick; two thin sections, from 16.5 and 22.3 m, are packstones composed of echinoderm and foraminiferal fragments with limestone fragments and detrital quartz of silt to very fine sand grade; a poorly preserved specimen from 23.5 m could be a wackestone; chert lenses, both parallel with bedding and cutting across it, form 30 to 50 per cent of the rock

APPENDIX 2: FOSSIL IDENTIFICATIONS

In this appendix, fossil collections made during the present study are combined with earlier collections (from the study area only). The age assignment of some earlier collections has been revised on the basis of the zonation of Ross and Nassichuk (1970) and other more recent information. One collection made during the present study (GSC loc. 65048) is from a structurally very complex area on Mount Kerr that has not been remapped.

Map-Unit 2 (Cherty Limestone Unit)

GSC Locality C-36830: Section 1-2 (at Mount Soues); 24.4 m above base of map-unit; identification by C.A. Ross

Neoschwagerina sp. (advanced)
Boultonia? sp.
age: Late Permian, Guadalupian, probably Wordian.

GSC locality C-36836: Section 1-2; talus from 62.2 m, probably derived from immediately overlying strata; identification by C.A. Ross

Yabeina sp. (primitive)
Chusenella? sp.
Parafusulina? sp.
age and comments: Late Permian, Guadalupian, probably late Wordian. The species of Yabeina is more advanced than Yabeina cf. Y. ozawai Honjo from the Atlin terrane (Monger, 1975, p. 51, GSC loc. 79412), probably close in age to Yabeina parvula Skinner and Wilde, Yabeina minuta Thompson and Wheeler, and Yabeina columbiana (Dawson) but probably older than Lepidolina Lee and associated advanced species of Yabeina, such as Y. globosa Yabe, of Kuman age.

GSC loc. 68097: 270 m east of Mount Soues; identification by C.A. Ross (from Campbell and Tipper, 1971, p. 28)

Neoschwagerina sp.
Cancellina sp.
Boultonia sp.
Kahlerina sp.
Schwagerina sp.
Reichelina sp.
Chusenella sp.
age: Late Permian, Guadalupian, probably Wordian.

GSC loc. 68094: 180 m east of Mount Soues; identification by C.A. Ross (from Campbell and Tipper, 1971, p. 28)

Yabeina sp.
Neoschwagerina sp.
Schwagerina sp.
Chusenella sp.
Nankinella? sp.
Kahlerina? sp.
age and comments: age originally was stated as Late Permian, Guadalupian; present information suggests no younger than early Guadalupian, Wordian (cf. GSC. loc. C-36836).

GSC locality C-82: locality F1 of Fig. 2, about 1.1 km north of Forestry Lookout on mountain west of Clinton; identification by C.A. Ross

Schwagerina sp.
Neoschwagerina spp.
age and comments: Late Permian, Guadalupian, Wordian; both of these forms are typical of the middle part of the Zone of Neoschwagerina.

GSC locality 68096: 90 m south of Forestry Lookout on mountain west of Clinton; identification by C.A. Ross (from Campbell and Tipper, 1971)

Condonofusiella sp.
Neoschwagerina sp.
Schwagerina? sp. or Parafusulina ? sp.
Kahlerina? sp.
age and comments: Late Permian; original age assignment was late Guadalupian on the basis of Condonofusiella, but that genus now is known to range down into the Wordian; the age of the collection therefore can be stated no more precisely than as Guadalupian.

Map-unit 4 (Massive Limestone Unit)

GSC locality C-36707: Section 7 (at Porcupine Creek), 154.2 m above base of section; identification by B.L. Mamet

Palaeotextularia sensu stricto or early part of Deckerella sp.
Hamigordius sp.
ghosts of nodosariids

age and comments: Late Permian. Precise generic identification of the first-mentioned form is impossible because the thin section is oblique and does not show the proloculum (inner part) or the aperture. The heavy, stout, inflated septa resemble those in a form described as Deckerella from the Murghabian of Iran by Bozorgnia (1973). (The Murghabian is the lower of two stages recognized in the Upper Permian of Iran; it overlies the Artinskian).

Locality F2 of Figure 2: (locality F1 of Trettin, 1961, Fig. 1), first major ridge northeast of Kelly Lake – Jesmond Road, probably from uppermost part of unit; identification of dasycladacean algae by J.H. Johnson and of other forms by W.R. Danner (from Johnson and Danner, 1966 and Trettin, 1961, p. 17 respectively).

Yabeina sp.
Schwagerina sp.
Verbeekina sp.
Glomospira sp.
Mizzia velebitana Schubert
Gyroporella nipponica Endo and Hashimoto
Macroporella apachena Johnson
Macroporella sp.
Oligoporella expansa Endo
Physoporalla sp.
coral, small fusulinaceans

age: Late Permian

Locality F3 of Figure 2: (locality F3 of Trettin, 1961, Fig. 1), second major ridge northeast of Kelly Lake – Jesmond Road, probably from uppermost part of unit; identification by W.R. Danner (from Trettin, 1961, p. 17).

Yabeina minuta Thompson and Wheeler
Schwagerina acris Thompson and Wheeler
Condonofusiella sp.
Textularia sp.

age and comments: W.R. Danner originally assigned an unspecified Late Permian age to this collection and now considers it as probably late Guadalupian (Capitanian). C.A. Ross (who has not seen this collection) places the fusulinaceans listed into the late Akasakan or late early Guadalupian (late Wordian).

Locality F4 of Figure 2: (locality F2 of Trettin, 1971, Fig. 1), second major ridge northeast of Kelly Lake – Jesmond road, about 4 km southeast of Mount Bowman; probably from uppermost part of unit; identification of dasycladacean algae by J.H. Johnson and of other forms by W.R. Danner (from Johnson and Danner, 1966 and Trettin, 1961, p. 17, respectively).

Yabeina sp.
small Verbeekina-type fusulinacean
foraminifera, one similar to Pachyploia
Tetrataxis sp.
Mizzia velebitana Schubert
Macroporella apachena Johnson
echinoid debris, mollusc shells, coral

age and comments: Late Permian, probably slightly older than F2 and F3.

GSC locality 65048: locality F5 of Fig. 2, from thrust slice of map-unit 4 on west side of Mount Kerr; identification by C.A. Ross

Yabeina parvula Skinner and Wilde
Schwagerina sp.

age: Late Permian, Guadalupian, probably late Wordian.

GSC locality C-80: locality F6 of Fig. 2, about 1.7 km south of peak of Mount Bowman; large boulder of massive limestone, presumably derived from map-unit 4.

Neoschwagerina sp.

age and comments: Late Permian, Guadalupian, Wordian; middle or upper part of Zone of Neoschwagerina.

Map-unit 6

GSC locality C-81: locality F7 of Fig. 2; 1.45 km east of junction Barney Creek – Porcupine Creek; identification by C.A. Ross

Neoschwagerina sp.

age and comments: Early or Late Permian, late Leonardian or early Guadalupian (early Wordian), lower or middle part of Zone of Neoschwagerina. Specimens are deformed by metamorphism but appear to be elongate, simple species of Neoschwagerina.

Pavilion Beds

The term Pavilion beds is here used informally for strata previously (Trettin, 1961) assigned to Division II of the Pavilion Group (*see* above, Regional geological setting and stratigraphic framework).

GSC locality C-54823: Yalakom River area, southwestern slope of Mount Kostering, about 3.8 km east of Big Bar ferry; NTS 92 0/1 E; UTM Zone 10 U, 5664390 E, 5671130 N; collected by J.H.W. Monger; identification by M.B. Rafek.

Epigondolella primitia Mosher (3)
Neogondolella bifurcata (Budurov and Stefanov) (2)
Neogondolella excentrica Budurov and Stefanov (1)
Neogondolella polygnathiformis (Budurov and Stefanov) (3)
Neogondolella sp.

age and comments: Middle or early Late Triassic. Epigondolella primitia Mosher, 1970 indicates a Late Karnian to Early Norian age. Neogondolella bifurcata (Budurov and Stefanov, 1972) was first reported from the lowermost Illyr of Bulgaria, from the conodont Zone AIII-alpha, where it defines the bifurcata-Zone (Budurov and Stefanov, 1972). It occurs in the Middle Triassic Upper Muschelkalk facies of southern Germany and northeastern France (Rafek, 1977) and in the Pelsonian of the Holy Cross Mountains, Poland (Trammer, 1975). It therefore ranges from the Pelsonian (Middle Anisian) into the Ladinian. Neogondolella excentrica Budurov and Stefanov, 1972 was first encountered in the Lower Fassanian (lowermost Ladinian) of Bulgaria. Trammer (1975) reported it from lower Fassanian strata in the Holy Cross Mountains of Poland, while Gedik (1975) described a similar species from the lowermost Ladinian of Turkey. In southern Germany and northeastern France it occurs in the Upper Muschelkalk facies (Rafek, 1977). Neogondolella polygnathiformis (Budurov and Stefanov, 1965), which defines the Assemblage Zone named for it, has its type locality in Bulgaria where it occurs in the Zone of Trachyceras aon of Early Karnian age. In Canada, Mosher (1973) reported it from the middle Late Ladinian Maclearni Zone, the late Early Karnian Nanseni Zone and the middle Late Karnian Welleri Zone.

All conodonts are black and have an alteration index of 5, which, according to Epstein et al. (1977), begins at a depth of about 7.6-9.1 km.

GSC locality C-54824: Pavilion area, south-facing slope north of Keatly Creek, 2.35 km due east of railroad; NTS 92 I/13 W; UTM Zone 10 U; 583370 E, 5629350 N; collected by J.H.W. Monger and H.P. Trettin; identification by E.W. Bamber

scleractinian corals -- colonial and solitary

age and comments: Middle Triassic or younger. These corals are very poorly preserved and more precise identification and age determination are not feasible. Scleractinian corals range in age from Middle Triassic to Recent; in southern British Columbia they are most common in the Norian.

Analysis of C-54824 and C-54825 (from same locality) by M.B. Rafek did not yield any conodonts but ostracodes, radiolarians, foraminifers and sponge spicules.

APPENDIX 3: CHEMICAL ANALYSIS OF VOLCANIC ROCK FROM MAP-UNIT 1

Specimen C-36729, approximately 1.2 m above base of volcanic unit at section 1-1 (Mount Soues)

X-Ray Fluorescence Analysis

MnO	0.24	%	
TiO_2	4.18	%	
CaO	5.03	%	
K_2O	2.59	%	
SiO_2	43.7	%	
Al_2O_3	18.1	%	
MgO	4.44	%	
FeO	8.4	%	
Fe_2O_3	4.7	%	
Na_2O	3.1	%	
P_2O_5	0.39	%	
CO_2	0.2	%	
H_2O	5.6	%	(total H_2O)
S	0.09	%	
Rb	0.003	%	
Zn	0.012	%	
Total	100.9	%	

* Optical emission spectroscopic analysis more reliable for MnO

Optical Emission Spectroscopy

Mn	0.18	Mo	< 0.0050
Ag	< 0.0005	Ni	0.0090
As	< 0.20	Pb	< 0.070
B	< 0.0050	Sb	< 0.05
Ba	0.044	Sn	< 0.020
Be	0.00044	Sr	0.027
Ce	< 0.020	U	0.056
Co	0.0068	Yb**	0.00049
Cr	0.0035	Zn	< 0.02
Cu	0.012	Zr	0.025
La	< 0.010		

** Yb unreliable because of Ti content

APPENDIX 4: TERMS USED TO INDICATE THE SIZE RANGES OF CARBONATE CRYSTALS

2-1 mm	very coarsely crystalline
1-0.5 mm	coarsely crystalline
0.5-0.25 mm	medium crystalline
0.25-0.12 mm	finely crystalline
0.12-0.06 mm	very finely crystalline
0.06-0.004 mm	microcrystalline
0.06-0.03 mm	coarsely microcrystalline
0.03-0.004 mm	finely microcrystalline
0.004 mm or less	cryptocrystalline