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BULLETIN 301

UPPER CARBONIFEROUS AND PERMIAN STRATIGRAPHY OF THE MONKMAN PASS AND SOUTHERN PINE PASS AREAS, NORTHEASTERN BRITISH COLUMBIA

E.W. Bamber and R.W. Macqueen

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Preface

The thin, discontinuous succession of Upper Carboniferous and Permian strata in the Monkman Pass and Pine Pass areas represents a lengthy but poorly known interval in the late Paleozoic history of western Canada. Geological events during this time profoundly affected the distribution, thickness and diagenetic history of underlying petroleum-bearing Lower Carboniferous formations. This report provides data on sedimentation, erosion, tectonics, and age relationships necessary for evaluation of the petroleum potential of upper Paleozoic rocks in the area.

D.J. McLaren
Director General
Geological Survey of Canada

Ottawa, November 1978

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ABSTRACT

The upper Paleozoic succession in the study-area is characterized by thin units of shallow-marine shelf carbonates, chemical sediments, and terrigenous clastic sediments, separated by regional disconformities. The oldest unit in the succession is the lower Moscovian (Atokan) Hanington Formation (new), which occurs as erosional remnants lying disconformably between units of Early Viséan (Mississippian) and Early Permian age. The Hanington Formation results from marine transgression and shelf sedimentation following a major period of uplift and erosion of older Carboniferous rocks. It consists of carbonate rocks occurring in two facies: a deep-water, open-marine carbonate facies, now mainly dolomite, in the northwestern part of the area; and a shallow-water, subtidal carbonate facies of lime-packstone and wackestone to the southeast.

Following a second episode of regression and subaerial erosion, during which most of the Upper Carboniferous strata were removed and relief was developed on the erosional surface, the basal conglomerate and carbonate sediments of the Asselian to Sakmarian Belcourt Formation were deposited during renewed, Early Permian marine transgression and shallow shelf deposition. Age and facies relationships within the Belcourt Formation indicate easterly directed depositional transgression over Carboniferous units. This second phase of marine sedimentation was terminated by renewed regression and erosion, marked by a regional intra-Permian disconformity separating the Belcourt Formation from the overlying Upper(?) Permian Fantasque, Ranger Canyon, and Mowitch Formations.

The well-bedded chert and siltstone of the Fantasque Formation, in the northwestern part of the area, appear to be western facies equivalent of the phosphatic chert, siltstone, sandstone, and silicified carbonates of the Ranger Canyon Formation, which is restricted to the central part of the area. These two formations show evidence of extensive early diagenesis of original shallow-marine carbonates. By an increase in the proportion of sandstone to chert, the Ranger Canyon Formation apparently grades laterally into the Mowitch Formation, which is composed almost entirely of sandstone, and occupies the total interval between the Belcourt Formation and the Triassic in the southeastern part of the area. Triassic rocks rest disconformably on Permian beds throughout most of the area, but at some northern localities they rest directly on the Lower Carboniferous Rundle Group, indicating considerable local uplift and erosion in latest Permian to earliest Triassic time.

RÉSUMÉ

Dans la région étudiée, la succession du Paléozoïque supérieur est caractérisée par la présence de minces unités constituées de carbonates, sédiments chimiques et sédiments clastiques terrigènes déposés sur une plate-forme marine peu profonde; ces unités sont séparées par des discordances d'érosion régionales; la plus ancienne unité de cette succession est la formation de Hanington (récemment désignée) du Moscovien inférieur (Atokien), dont il ne reste que des vestiges laissés par l'érosion, et qui repose en discordance entre des unités du Viséen inférieur (Mississipien) et du Permien inférieur. La formation de Hanington a été créée par une transgression marine et une sédimentation de plate-forme, après une période prolongée de soulèvement et d'érosion des roches carbonifères plus anciennes. Elle consiste en roches carbonatées que l'on rencontre dans deux faciès: un faciès carbonaté d'eau profonde et de pleine mer, maintenant surtout constitué de dolomite, dans la partie nord-ouest de la région; et un faciès carbonaté subtidal d'eau peu profonde, constitué de packstone et de wackestone, au sud-est.

A la suite d'un second épisode de régression et d'érosion subaérienne, pendant lequel l'érosion a enlevé la plupart des strates du Carbonifère supérieur et créé un modelé de dissection, le conglomérat de base et les sédiments carbonatés de la formation de Belcourt dont l'âge s'étant du Asselien au Sakmarien se sont déposés pendant un nouvel épisode de transgression marine et de sédimentation de plate-forme au début du Permien. Les relations d'âge et de faciès qui caractérisent la formation de Belcourt indiquent qu'a eu lieu une transgression dirigée vers l'est, au-dessus des unités carbonifères. Cette second phase de sédimentation marine s'est terminée par une reprise des processus de régression et d'érosion; elle est marquée par une discordance d'érosion régionale intra-permienne qui sépare la formation de Belcourt des formations sus-jacentes de Fantasque, Ranger Canyon, et Mowitch, qui sont peut-être du Permien supérieur.

Le chert et les siltstones bien stratifiés de la formation de Fantasque, dans la partie nord-ouest de la région, constituent peut-être un faciès occidental qui serait l'équivalent des cherts phosphatiques, des siltstones, des grès et des carbonates silicifiés de la formation de Ranger Canyon, qui se limite à la partie centrale de la région. Ces deux formations portent les marques d'une diagénèse ancienne et très étendue des carbonates originaux formés en mer peu profonde. La formation de Ranger Canyon passe latéralement, par une augmentation de la proportion du grès au chert, à la formation de Mowitch, qui est composée presque entièrement de grès, et elle occupe tout l'intervalle situé entre la formation de Belcourt et le Trias dans la partie sud-est de la région. Les roches triasiques reposent en discordance sur les lits permiens dans la plus grande partie de la région mais, dans certaines localités situées au nord, elles reposent directement sur le groupe de Rundle du Carbonifère inférieur, ce qui indique qu'il s'est produit un soulèvement local et une érosion considérables entre le sommet du Permien et la base du Trias.

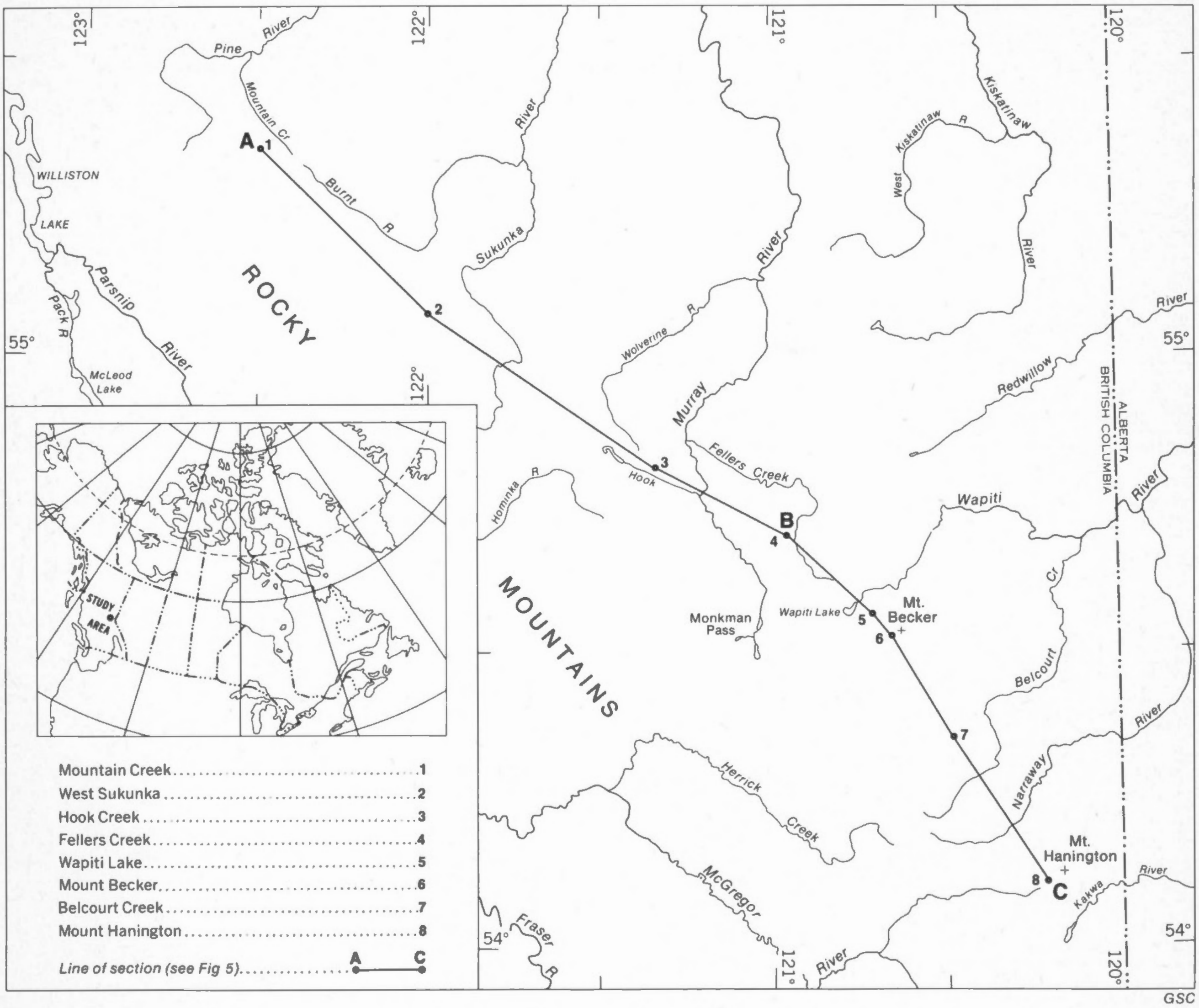

FIGURE 1. Index map

UPPER CARBONIFEROUS AND PERMIAN STRATIGRAPHY OF THE MONKMAN PASS AND SOUTHERN PINE PASS AREAS, NORTHEASTERN BRITISH COLUMBIA

INTRODUCTION

REGIONAL SETTING

Upper Carboniferous and Permian strata are preserved along almost the entire length of the eastern margin of the Canadian Cordillera. In western Alberta and northeastern British Columbia they are restricted mainly to the Foothills and Front Ranges of the Rocky Mountains. Late Paleozoic and Mesozoic erosion has removed these strata from most of the Plains area to the east, with the exception of the Peace River Basin, where a thin veneer remains. The sequence of shallow-marine carbonates and terrigenous clastic strata described in this report outcrops in a narrow belt between Kakwa River and Pine Pass, in the Monkman Pass map-area (NTS 93I), and the southern part of the Pine Pass map-area (NTS 93-O) (Fig. 1). This succession contains several disconformities of regional extent (McGugan *et al.*, 1964; McGugan, 1965) and forms part of the Proterozoic to Mesozoic miogeocline-platform wedge (Wheeler *et al.*, 1972).

PREVIOUS WORK

Permian rocks were reported first from the Monkman Pass-Pine Pass area by Forbes and McGugan (1959), who described upper Paleozoic units in five stratigraphic sections between the Wapiti Lake area and Narraway River (Fig. 1). They divided the succession into three informal units as follows (Fig. 2): a basal breccio-conglomerate, from 2 to 4 feet (0.6-1.2 m[1]) thick, consisting of chert pebbles in a matrix of light grey to white dolomite or limestone; a "Lower Unit" of Early Permian and ?Pennsylvanian age, comprising 37 to 56 feet (11.3-17.1 m) of dolomite, dolomitic limestone, and chert, containing fusulinacean foraminifers; and a ?Permian "Upper Unit" ranging from 4 to 50 feet (1.2-15.2 m) in thickness and consisting of dolomitic sandstone, conglomerate, and chert. Lower Permian fusulinaceans were described by these authors (*ibid.*, p. 40, 41) from sandy, silicified carbonates outcropping in the vicinity of Wapiti Lake. A Mississippian age formerly had been assigned to these beds by Laudon *et al.* (1949), who included them in the upper part of the Rundle Formation (restricted). The fusulinacean-bearing beds and the underlying breccio-conglomerate were traced as far south as Narraway River by Forbes and McGugan (1959, p. 38). According to these authors, the breccio-conglomerate is unconformably underlain by carbonates of Mississippian age. Sutherland (1958, p. 11) gave a brief description of the Mount Hanington section (Fig. 1, Loc. 1) near the southern boundary of the study-area. He used the name Rocky Mountain Formation for the Paleozoic rocks overlying the Rundle Group.

The name Ishbel Group was applied subsequently to the Permian succession between Wapiti Lake and Jasper, Alberta by McGugan and Rapson (1963). Three formations were recognized within this group (Fig. 2): the Belcourt Formation (basal breccio-conglomerate and "Lower Unit" of Forbes and McGugan, 1959), which was assigned a Wolfcampian to ?Leonardian age based on fusulinacean foraminifers, and consists of limestone, dolomite, and conglomerate; the overlying Ranger Canyon Formation, which was assigned a ?Late Permian (post-Guadalupian) age, and consists of phosphatic chert and siltstone with minor sandstone and silicified carbonates; and the Mowitch Formation, which caps the succession and consists of calcareous, glauconitic, phosphatic sandstone with bedded, lenticular chart and minor amounts of silicified carbonates. McGugan and Rapson (1963, p. 57-59) also reported the presence of an unconformity at the base of the Ranger Canyon Formation, marked by erosional relief on the underlying beds and by the presence of a thin, phosphatic chert conglomerate throughout the area. They noted the general absence of Pennsylvanian beds and the presence of an unconformity between Lower Permian and underlying Mississippian carbonates. In a summary paper on the Permian of western Canada, in which detailed north-south cross-sections and correlations were presented, the Wapiti Lake-Jasper succession was included under the term "northern shelf carbonate facies" by McGugan *et al.* (1964, p. 105, Fig. 8-4).

Bamber and Macqueen (1971, p. 195) reported a predominance of micritic and skeletal limestone in the Belcourt Formation of the northern Monkman Pass area, and a truncation of the Permian units north of Wapiti Lake beneath the sub-Triassic unconformity, such that only the basal conglomerate of the Belcourt Formation remains at Hook Lake (Figs. 1, 4; Hook Creek section). Recently described fusulinaceans from the study-area (Ross and Bamber, 1978) include Lower Permian (Asselian and Sakmarian) species from the Belcourt Formation, and lower Moscovian species (Pennsylvanian, Atokan) from the newly discovered Hanington Formation, discussed below. The age and stratigraphic relationships of the Permian fusulinaceans of the Belcourt Formation indicate that this represents easterly directed depositional transgression over Carboniferous rocks during Early Permian time (Ross and Bamber, 1978, Fig. 2).

In a recent paper on the Wapiti Lake-Belcourt Creek area (Fig. 1), McGugan and Rapson-McGugan (1976) provided additional information on the lithology, facies variation, age, and distribution of the Belcourt, Ranger Canyon, and Mowitch Formations. According to these authors, the Belcourt Formation has a thickness of only 3 m or less, and is conglomeratic in westerly sections south of Wapiti Lake.

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[1]Conversions to metric units are accurate to 1 decimal place.

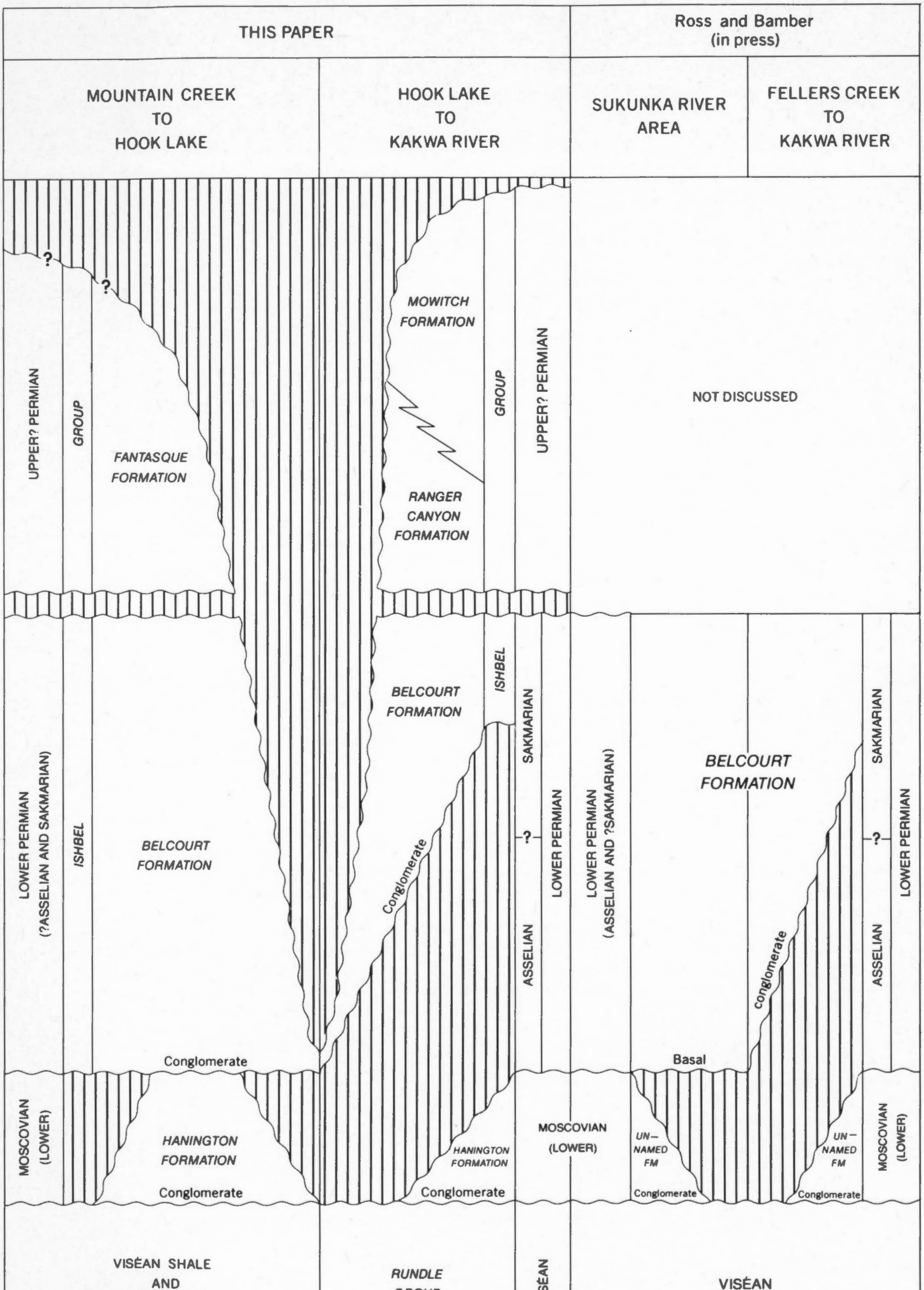

FIGURE 2. Summary of upper Paleozoic correlations, Monkman Pass and southern Pine Pass area.

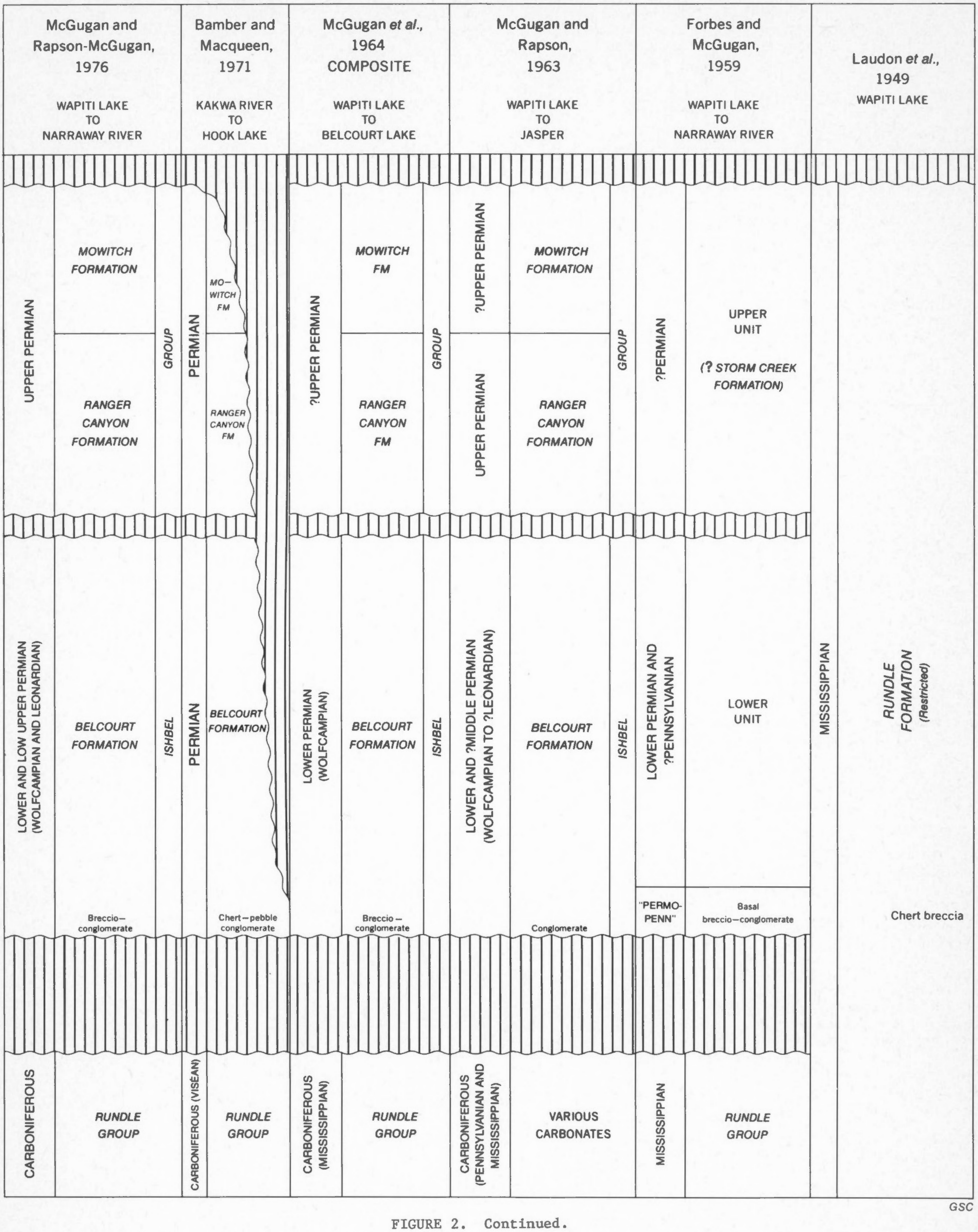

FIGURE 2. Continued.

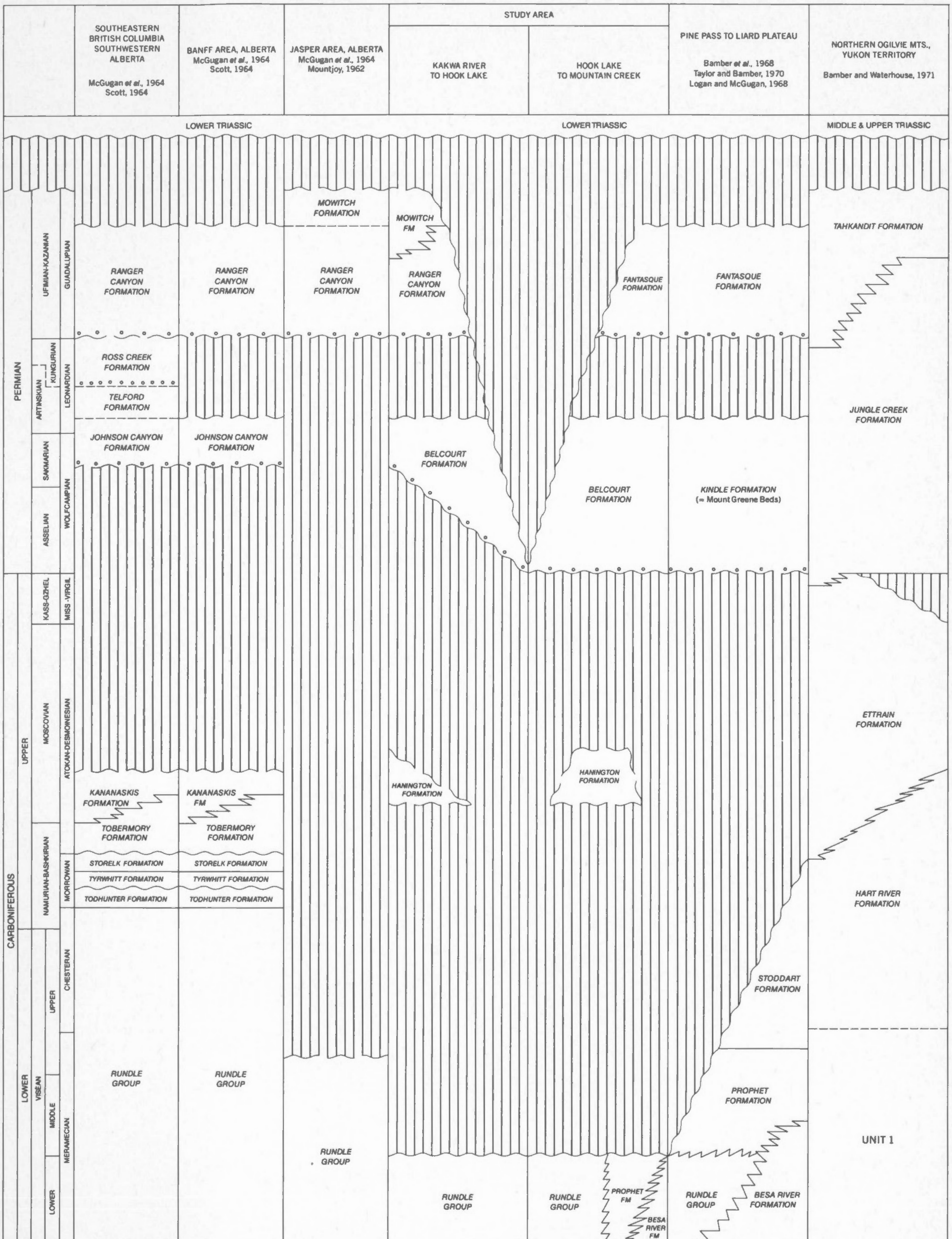

FIGURE 3. Correlation of upper Paleozoic formations, Rocky Mountains, Liard Plateau and northern Ogilvie Mountains

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The writers wish to thank D.W. Gibson and A.D. Miall, who critically read the manuscript, for their helpful comments and suggestions. C.A. Ross studied the microfauna and provided biostratigraphic interpretations essential to the paper. Thin-section photographs were taken by B.C. Rutley and D.G. Lawrence.

STRATIGRAPHY

The Upper Carboniferous and Permian succession of the Monkman Pass-Pine Pass area is dominated by shallow-marine carbonates, chert, and terrigenous clastic strata, and is characterized by the presence of thin stratigraphic units bounded by four disconformities of regional extent: a sub-Moscovian (Middle Pennsylvanian) disconformity beneath the newly named Hanington Formation; a sub-Permian disconformity beneath the Belcourt Formation; an intra-Permian disconformity beneath the Ranger Canyon and Fantasque Formations; and a sub-Triassic disconformity at the top of the succession.

Discontinuous erosional remnants of lower Moscovian (Middle Pennsylvanian) skeletal wackestones and packstones of the Hanington Formation, locally present at the base of the succession, rest disconformably on a variable succession of Viséan (Mississippian) carbonates and shale (Fig. 3, Rundle Group, Besa River Formation). Throughout much of the area, however, Moscovian rocks are absent, and Viséan rocks are overlain disconformably by the Permian Ishbel Group (Fig. 4). Within the Ishbel Group, the basal conglomerate and carbonates of the Lower Permian Belcourt Formation extend throughout the area. This formation displays considerable variation in thickness, and contains several lithofacies ranging from dolomitic packstone and wackestone and dolomite in the southeast to grainstone/packstone and dolomite in the northwest (Fig. 4). Age relationships and facies distribution indicate that older sediments were onlapped progressively from west to east by sediments of the Belcourt Formation (Fig. 5; Ross and Bamber, 1978). In the southeastern part of the area (Fig. 1), the Belcourt Formation is overlain disconformably by the interfingering terrigenous clastics and chert of the Upper? Permian Ranger Canyon and Mowitch Formations (Figs. 1, 4, Wapiti Lake to Mt. Hanington). As indicated by McGugan and Rapson (1963, p. 60; McGugan and Rapson-McGugan, 1976, p. 201), these two units are difficult to distinguish at some localities because of variations in the relative abundance of chert and clastics. The Permian succession has been partly removed by erosion associated with the sub-Triassic disconformity, such that only the basal conglomerate of the Belcourt Formation remains in the northwestern part of the area near Hook Creek (Fig. 1). Farther to the northwest, in the Sukunka River-Mountain Creek area, a thicker succession of Permian rocks is preserved beneath the sub-Triassic disconformity.

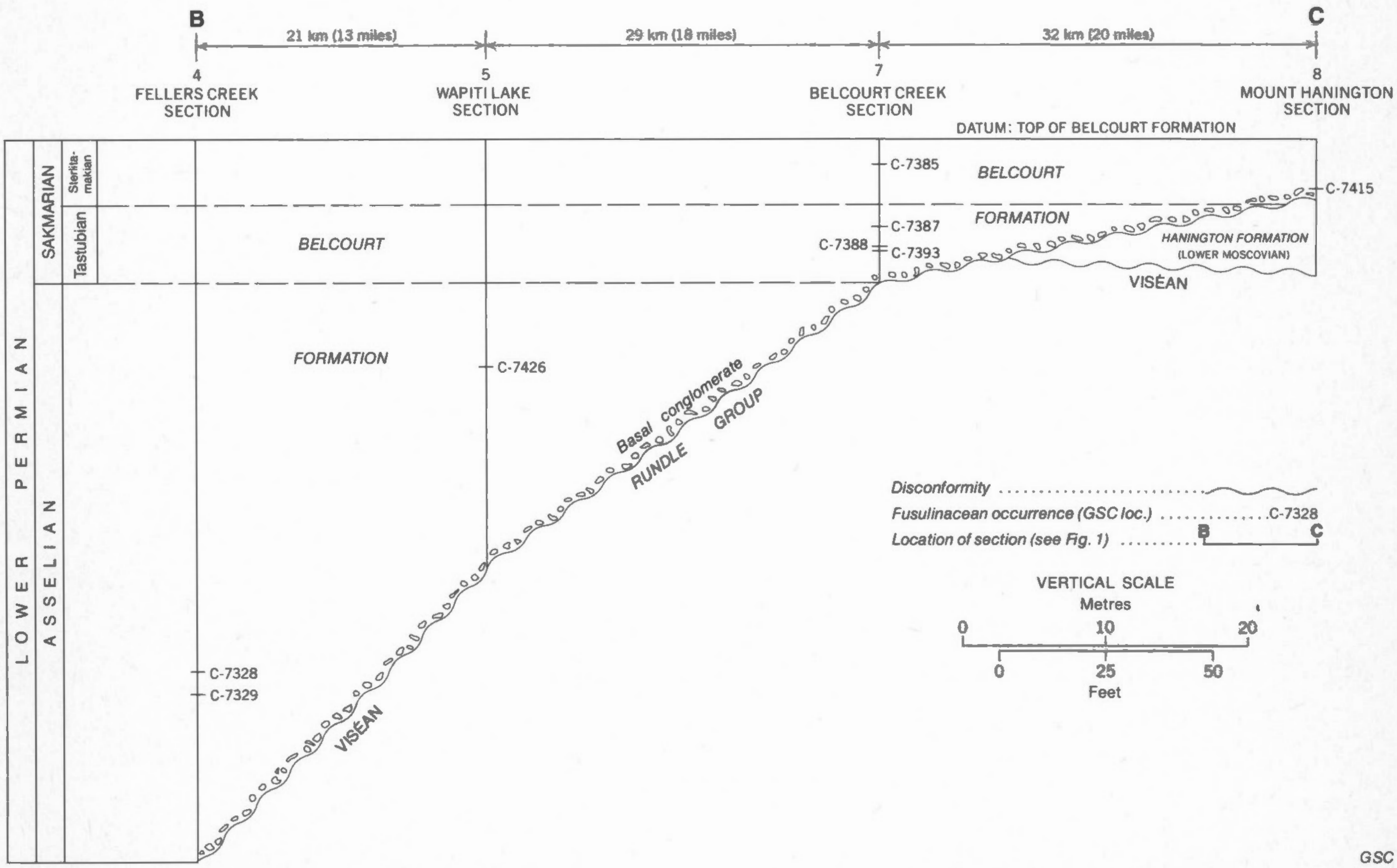


FIGURE 5. Schematic illustration of diachronism at base of Belcourt Formation (after Ross and Bamber, in press). Age relationships based on fusulinacean occurrences (GSC locs. C-7328 to C-7426).

There, the Belcourt Formation is well developed and is overlain by dark grey chert and shale of the Fantasque Formation, which caps the Paleozoic and is the northwestern equivalent of the Ranger Canyon Formation, and possibly the Mowitch Formation.

UPPER CARBONIFEROUS

Hanington Formation (new name)

The new name Hanington Formation is applied to a discontinuous lithologic unit comprising carbonates of Moscovian (Atokan) age lying between beds of the Rundle Group or Besa River Formation (Viséan) and strata of the Belcourt Formation (Early Permian). Although only two outcrops of the unit are known at present (*see* below), it is assigned formational status because it contains distinctive lithologies and, thus, is easily separated from underlying and overlying units, and because it is bounded by major disconformities of regional extent. The Hanington is a lithologic unit that can be mapped at a scale on the order of 1:25 000 (1" = ≈2/5 mile) and, thus, accords with procedures outlined in the Code of Stratigraphic Nomenclature for the recognition of lithostratigraphic units at the level of the formation (American Commission on Stratigraphic Nomenclature, 1970). Additionally, the Hanington is the only stratigraphic unit in the area known to be of Late Carboniferous age, although the age properly plays no part in recognition of the Hanington as a new formation.

Type section

Located on ridge west of Mount Hanington (Fig. 1), approximately 1.5 miles (2.5 km) north of Jarvis Lakes; Latitude 54°07'N, Longitude 120°12°30"W; southeastern corner of NTS 1:250 000 sheet 93I, Monkman Pass; aerial photograph BC 2124:12, west and north of centre, base of section at photo co-ordinates X = -7.95, Y = +4.1 (Fig. 15).

Unit	Lithology	Thickness feet (metres)	Height Above Base feet (metres)
	Overlying beds - basal conglomeratic limestone of Belcourt Formation (*see* description of Loc. 8). Contact with Belcourt sharp, lower surface of Belcourt "wavy", with up to 1.5 feet (0.37 m) of relief (Figs. 18, 19). Age of Belcourt at this locality is Early Permian (latest Wolfcampian or early Leonardian), based on fusulinaceans.		
	HANINGTON FORMATION (type section) [lower Moscovian (Middle Pennsylvanian)]		
2	Limestone, dolomitic, locally grading to calcareous dolomite, brownish grey, weathering same, medium to thick bedded, resistant. Generally skeletal wackestone and packstone with very abundant lime mud, foraminifers, indeterminate skeletal material, and pelletoid grains. Many polycrystalline calcite mosaics or single crystals of calcite apparently filling leached porosity. Lower half of unit is more dolomitic (30%) than upper half. Scattered chert nodules, dark grey to black, with poorly preserved skeletal wackestone texture. At 3 feet (0.9 m) below top of unit, a 0.5 foot (15 cm) zone of chert occurs, dark grey, wavy, irregular, replacing limestone. Scattered chert nodules occur below. Basal 6 to 12 inches (15-30 cm) of unit contain chert nodules, rusty weathering, 1 to 2 feet (0.3-0.6 m) in plane of bedding, 2 to 5 cm thick. Fauna: At 1 to 2 feet (0.3-0.6 m) and 3 to 4 feet (0.9-1.2 m) below top: *Profusulinella* sp., small, immature, rare; age early Moscovian, probably Vereyan (GSC locs. C-44553, C-44555). At 4 to 5 feet (1.2-1.5 m) below top: *Profusulinella*? sp.; age as in GSC locality C-44553 (GSC loc. C-44556). At 8 to 9 feet (2.4-2.7 m) below top: *Profusulinella* sp. cf. *P. copiosa* Thompson; age as in GSC locality C-44553 (GSC loc. C-44560). At 10 feet (3 m) below top: *Profusulinella*? sp., silicified specimens; age as in C-44553 (GSC loc. C-44562)	10.5 (3.2)	17 (5.2)

Unit	Lithology	Thickness feet (metres)	Height Above Base feet (metres)
1	Limestone, brownish grey, weathering same, medium to thick bedded, resistant, similar to upper unit. Predominantly skeletal packstone or wackestone, with foraminfers, molluscan detritus, ostracodes, rare echinoderm detritus, scattered calcispheres. A small sediment-filled fissure or "veinlet" occurs at 3 inches (5 cm) below top of unit (Figs. 7, 8): The "veinlet" is made up of small chert granules and pebbles in a skeletal packstone matrix, within which Permian fusulinacean foraminfers occur (*see* GSC loc. C-44563, below). The chert granules and pebbles contain ostracodes, pelletoid grains, and small foraminifers, and are subrounded. At 2.5 to 5 feet (0.8-1.7 m) below the top of the unit, the ?hydrozoan *Palaeoaplysina* sp. occurs, also *Tubiphytes* sp., in skeletal wackestone with very abundant foraminifers of Moscovian age. At 3 feet (0.9 m) below top of unit, there is a light grey lens of chert approximately 12 cm thick, replacing skeletal wackestone, including echinoderm detritus and indeterminate skeletal debris. In thin-section, these grains are seen to be cryptocrystalline quartz (chert), whereas matrix is microcrystalline quartz, in part pseudomorphous after original carbonate cement fabric. Basal bed of unit consists of partly dolomitized skeletal packstone/wackestone with echinoderm detritus, pelletoid grains, and indeterminate skeletal material, all in sharp contact with underlying beds of Rundle Group. Scattered chert granules and pebbles in basal beds of Hanington, but basal conglomerate is lacking. Lower contact sharp. Fauna: At 10.75 feet (3.3 m) below top of formation: *Profusulinella* sp. cf. *P. copiosa* Thompson; also sediment-filled fissure or "veinlet" with *Schwagerina* sp. cf. *S. emaciata* Beede; age early Moscovian, probably Vereyan, except "veinlet" fauna which is Early Permian (Asselian?) (GSC loc. C-44563). At 11 feet (3.6 m) below top of formation: *Bothrophyllum* sp., *Kleopatrina* (*Porfirievella*) sp., *Profusulinella* sp. cf. *P. walnutensis* Ross and Sabins, *Eoschubertella* sp.; age Moscovian (GSC loc. C-7416). At 11.5 feet (3.5 m) below top of formation: *Kleopatrina* (*Porfirievella*) sp. (GSC loc. C-44564). At 12 to 13 feet (3.7-4 m) below top of formation: *Profusulinella* sp.; age early Moscovian, probably Vereyan (GSC loc. C-44565). At 13.5 feet (4.2 m) below top of formation: *Profusulinella* sp. cf. *P. walnutensis* Ross and Sabins, *Pseudendothyra* sp. cf. *P. bradyi* (Möller); age early Moscovian (GSC loc. C-7417). At 13 to 14 feet (4-4.3 m) below top of formation (GSC loc. C-44567), 13.5 feet (4.2 m) below top of formation (GSC loc. C-44568), and 15 to 16 feet (4.6-4.9 m) below top of formation (GSC loc. C-44570), microfauna and age as in GSC locality C-44565 (*Profusulinella* sp. early Moscovian, probably Vereyan). *Kleopatrina* (*Porfirievella*) sp. also present at GSC locality C-44568	6.5 (2)	6.5 (2)

Underlying beds - Rundle Group (Turner Valley Formation, Viséan), finely to medium crystalline dolomite (*see* description of Loc. 8, Appendix).

Distribution and thickness

The Hanington Formation occurs as erosional remnants preserved locally and disconformably beneath the Permian Belcourt Formation. Rock types found within the Hanington suggest that formerly it was a widespread shallow-water carbonate unit of regional extent, possibly similar in lithology and distribution to the overlying Belcourt Formation of the Permian succession. At present, however, the Hanington is known only from its type section near Mount Hanington (Fig. 1, Loc. 8), where it is 17 feet (5 m) thick, and from the West Sukunka section (Fig. 1, Loc. 2) located about 100 miles (160 km) to the northwest, where it is 220 feet (67 m) thick. Regional observations in the vicinity of the two known Hanington sections suggest that the Hanington persists at least several miles along strike from each section. In all other sections studied within the area (Figs. 1, 4), rocks assigned to the Hanington Formation are absent, and rocks of the Belcourt Formation (Permian) rest directly on rocks of the Rundle Group or Besa River Formation, of Viséan age. Probably there are other, undiscovered erosional remnants of the Hanington Formation present in the area, in outcrops not examined.

Lithology and facies variation

At its type section, the Hanington Formation consists of medium- to thick bedded, dolomitic, skeletal wakestone and packstone with very abundant lime-mud, foraminifers, and pelletoid grains (Figs. 7-9, 16). Skeletal material present in lesser amounts includes echinoderm and molluscan detritus, ostracodes, and scattered calcispheres. A notable faunal occurrence is that of the ?hydrozoan *Palaeoaplysina* Krotov at several levels in the basal 6.5 feet (3 m) of the Hanington (Macqueen and Bamber, 1977). *Palaeoaplysina* is known elsewhere from Middle Pennsylvanian to Lower Permian sediments in east-central Idaho, northern Yukon Territory, Ellesmere Island, and the Soviet Union (Davies and Nassichuk, 1973). It is not a major biogenic component of the Hanington Formation, nor does it appear to have built mounds, as described from Ellesmere Island (Davies and Nassichuk, *ibid.*). Limestone of the Hanington is replaced locally by thin, irregular zones of chert or chert nodules. Conglomeratic limestone occurs at two levels in the type section. The basal bed of the formation consists of partly dolomitized skeletal wackestone/packstone, with scattered chert granules and pebbles close to the base; a well-developed basal conglomerate is lacking. The other conglomeratic limestone occurrence known at the type section is just below the top of unit 1 at about 10.5 to 11 feet (3.2-3.3 m) below the top of the formation. There, what is apparently a sediment-filled fissure or "veinlet" contains chert granules and pebbles in a skeletal packstone matrix; it also contains Permian fusulinaceans (GSC loc. C-44563) (Figs. 7, 8). Thin-sections of limestone from the type section show many polycrystalline calcite mosaics or single crystals of calcite, apparently filling pores caused by leaching.

At the West Sukunka section (Fig. 1, Loc. 2), the only other presently known occurrence of the Hanington, the unit is much thicker (220 feet; 67 m) and consists predominantly of thin- to medium-bedded wackestone and very finely to finely crystalline dolomite. In comparison with the type section, the Hanington at the West Sukunka locality is much more dolomitic, more argillaceous (i.e. contains minor amounts of silt and clay-size quartz, and probably clay minerals), thinner bedded,

FIGURE 6. Skeletal packstone, poorly sorted, with mollusc, echinoderm, some brachiopod fragments, bryozoans, foraminifers and indeterminate skeletal detritus. Thin section, plane light. Hanington Formation, unit 2; 10-15 feet (3-4.5 m) above base of formation, West Sukunka section (Loc. 2) (GSC loc. C-44591). Bar scale 1 mm.

FIGURE 7. *Palaeoaplysina*-bearing packstone at base overlain by fine-grained skeletal wackestone/packstone with a few fragments of *Palaeoaplysina*. In upper left corner, a sediment-filled fissure or "veinlet" with chert pebbles and granules and Permian schwagerinid fusulinaceans occurs. Thin section, plane light. Hanington Formation, type section, unit 1; 10.25 feet (3.0 m) below top of formation, Mount Hanington section (Loc. 8) (GSC loc. C-44563). Bar scale 5 mm.

FIGURE 8. *Palaeoaplysina*-bearing skeletal wackestone, with molluscan, brachiopod and ostracode fragments, and indeterminate skeletal fragments; overlain by a sediment-filled "veinlet" with Permian schwagerinid fusulinaceans and chert granules in a packstone/wackestone matrix. Thin section, plane light. Hanington Formation, type section, Mount Hanington section (Loc. 8) (GSC loc. C-44563). Bar scale 5 mm.

FIGURE 9. *Palaeoaplysina*-bearing packstone containing abundant delicate skeletal material (ostracodes, ?molluscs, indeterminate) as well as Pennsylvanian fusulinaceans. Thin section, plane light. Hanington Formation, type section, Mount Hanington; 2.5 feet (0.75 m) below top of unit 1 (Loc. 8) (GSC loc. C-44566). Bar scale 5 mm.

FIGURE 10. Pelletoid grain and ?echinoderm packstone, fine to medium grained; consists of pelletoid grains (black) and microcrystalline calcite grains probably of echinoderm origin, with syntaxial calcite overgrowths. Scattered foraminifers; about 5 per cent of matrix and some grains replaced by chert. Thin section, plane light. Hanington Formation, unit 5; 48-100 feet (14.6-30.5 m) above base of formation, West Sukunka section (Loc. 2) (GSC loc. C-39076). Bar scale 1 mm.

FIGURE 11. Intraclast and lump grainstone, very coarse grained with mollusc, bryozoan and echinoderm detritus, calcareous algae, foraminifers, rare ooids, chert pebbles, granules and sand; sparry calcite cement. Darker grains commonly bitumen-impregnated. Thin section, plane light. Hanington Formation, lower part, unit 3; 37-41 feet (11.3-12.5 m) above base of formation, West Sukunka section (Loc. 2) (GSC loc. C-39074). Bar scale 2 mm.

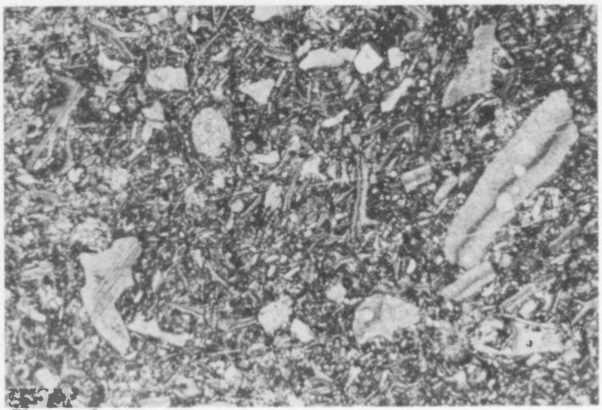


Figure 6

Figure 9

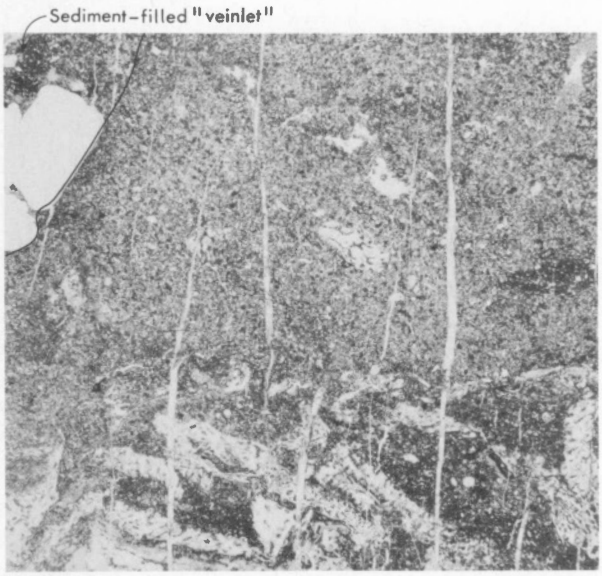


Figure 7

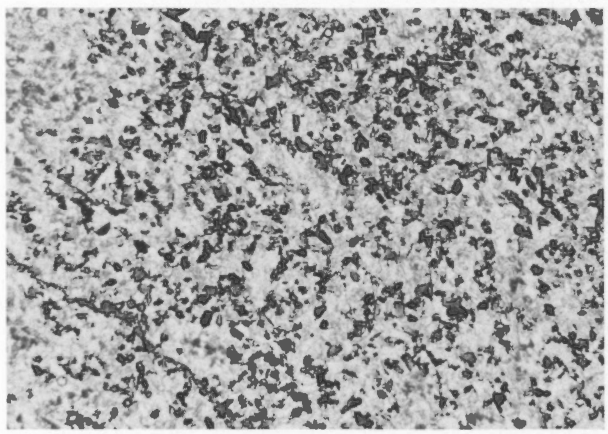
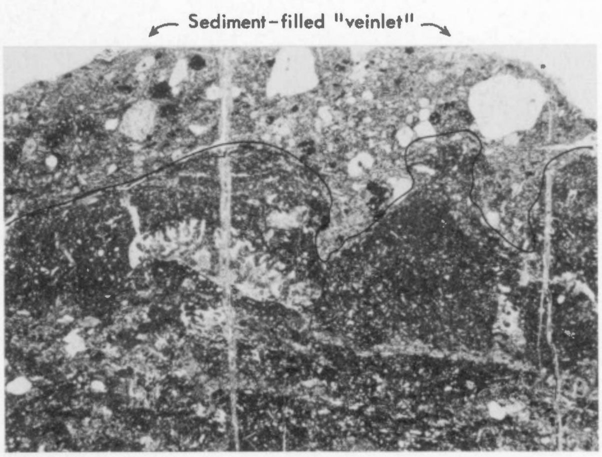


Figure 10



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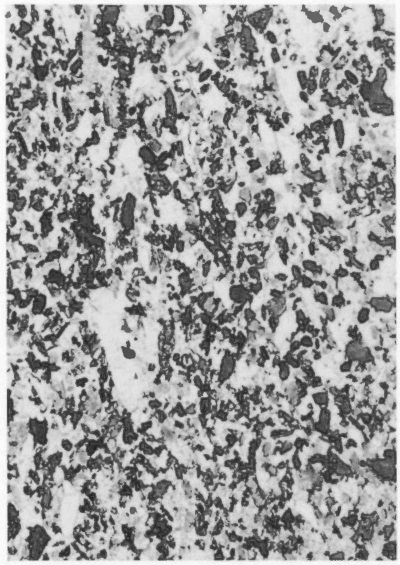
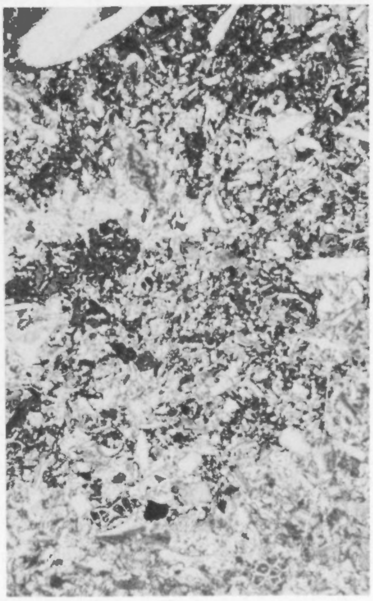


Figure 11



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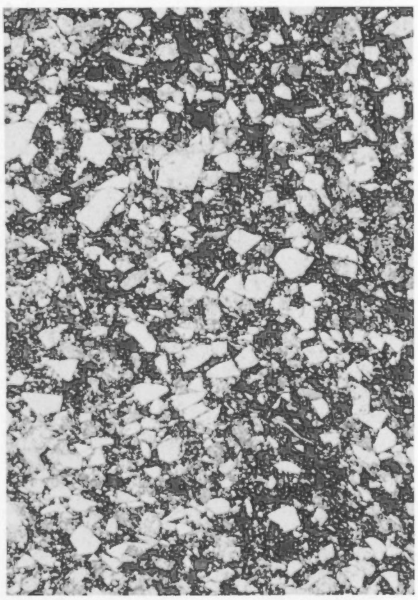


Figure 13

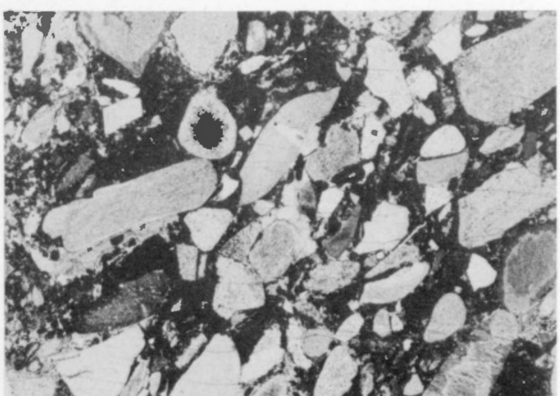


Figure 14

FIGURE 12. Skeletal packstone, coarse grained, containing brachiopod, mollusc, bryozoan and echinoderm detritus, echinoid spines and abundant foraminifers. Thin section, plane light. Hanington Formation, lower part, unit 2; 25-37 feet (≈7.6-11.3 m) above base of formation, West Sukunka section (Loc. 2) (GSC loc. C-44592). Bar scale 1 mm.

FIGURE 13. Conglomeratic packstone consisting of angular chert granules (≈2-4 mm, white in photograph) and sand-size grains in a skeletal carbonate matrix; some mollusc and indeterminate skeletal material; carbonate matrix partly replaced by euhedral dolomite crystals. Thin section, plane light. Hanington Formation, lower part, basal 1 foot (0.3 m) of unit 2; West Sukunka section (Loc. 2) (GSC loc. C-44590). Bar scale 1 mm.

FIGURE 14. Conglomerate consisting of angular to well-rounded chert pebbles, some spicular and some skeletal material and ?Lower Carboniferous foraminifers, in a matrix of intraclast, lump, and skeletal grainstone (dark grey). Most granule- to pebble-size material is chert; rarely carbonate. Partly cemented by drusy quartz crystals, followed by fibrous, brown chalcedony; remaining pore space filled with sparry calcite. Thin section, plane light. Hanington Formation, intraformational conglomerate in unit 3; 37 feet (11.1 m) above base of formation, West Sukunka section (Loc. 2) (GSC loc. C-39073). Bar scale 1 mm.

FIGURE 15. Type section of Hanington Formation; northwest corner of air photo BC 2124:12 with enlarged (x4) insert showing stratigraphic succession; photo co-ordinates of type section: X = -7.95, Y = +4.1. GSC 199402.

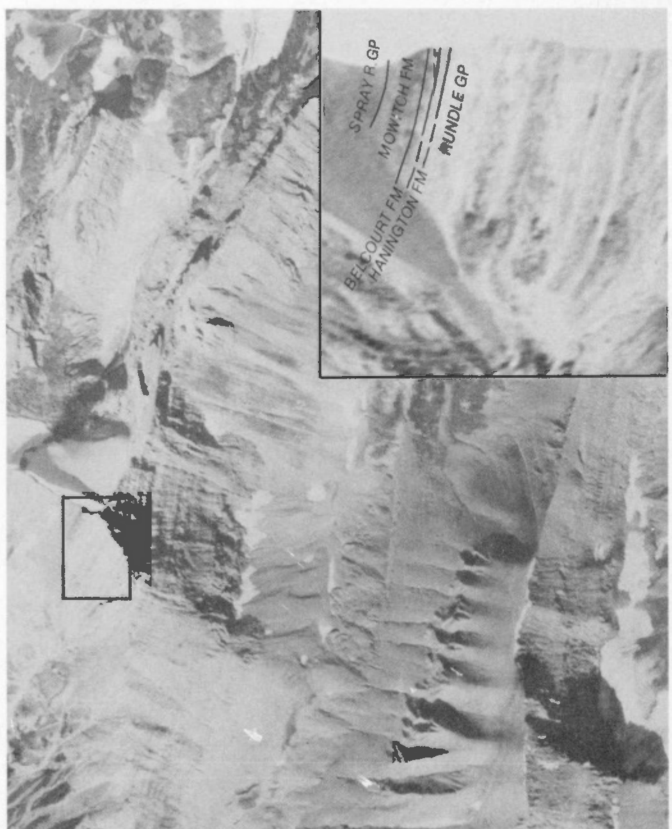


Figure 15

and is dominantly wackestone with only rare packstone and grainstone. A conglomeratic limestone, approximately 4 feet (1.2 m) thick, is present in the lower part of the formation (Fig. 14). This conglomeratic unit contains numerous rounded chert and limestone pebbles up to 5 cm across set in a grainstone matrix with echinoderm and bryozoan detritus. Its lower contact shows relief of 1 to 2 feet (0.3-0.5 m) locally. The significance and extent of this unit, which appears to represent an intraformational disconformity, is unknown.

Stratigraphic relationships

As noted previously, disconformities separate the Hanington Formation from the underlying and overlying formations. At the type section (Fig. 1, Loc. 8), where the basal conglomeratic beds rest on Viséan dolomite of the Rundle Group, the lower contact shows vertical relief of 4 to 6 inches (10-15 cm). Pebbles of chert within this conglomerate resemble chert found in underlying Rundle Group strata. The lower contact is not exposed at locality 2 (Fig. 1), where the Hanington Formation rests on the Besa River Formation, the uppermost part of which is probably of Viséan age. At localities 2 and 8, relief of up to 6 inches (15 cm) has been observed at the contact between the Hanington Formation and the overlying basal conglomerate of the Belcourt Formation (Lower Permian).

The conglomeratic unit (unit 1), 10.25 feet (3 m) below the top of the type Hanington, contains Lower Permian fusulinacean foraminifers (schwagerinids) in the sediment-filled fissure noted above. Limestone adjacent to the "veinlet" contains abundant lower Moscovian fusulinaceans, as do the underlying and overlying limestone beds. The Permian fusulinaceans presumably were derived, during Early Permian time, from sediments of the overlying Belcourt Formation, which contain the genus *Schwagerina*. Thus, a weathered surface, with fissures at least 10 feet (3 m) in depth at the top of the Hanington Formation is indicated. The single known fissure was later filled with Permian sediments. Disconformable relationships between the Belcourt and Hanington Formations are emphasized further by the discontinuous distribution and general absence of the Hanington (Fig. 4).

Fauna and age

Lower Moscovian foraminifers belonging to the genera *Profusulinella*, *Eoschubertella*, and *Pseudoendothyra* have been reported from the Hanington Formation by Ross and Bamber (1978). They are abundant throughout the type section (Loc. 8) and occur in the lower 82 feet (25 m) of the formation at the West Sukunka section (Loc. 2). The rugose coral genera *Bothrophyllum*, *Kleopatrina* (*Porfirievella*), and ?*Amplexizaphrentis* also are represented. Brachiopods, including *Echinoconchus*, *Neospirifer*, *Linoproductus*, and other unidentified genera, are abundant at several levels in the lower 50 feet (15 m) of the unit at locality 2. *Schwagerina* sp. cf. *S. emaciata* Beede, of Early Permian age, occurs 10.25 feet (3 m) below the top of the type section in fissure fillings.

Middle Pennsylvanian (lower Moscovian) fusulinacean foraminifers indicate that the lower 82 feet (25 m) of the Hanington at the West Sukunka section (Loc. 2) are the same age as the Hanington at its type section (Loc. 8).

Depositional and diagenetic environments

The predominence of skeletal wackestone and packstone in the Hanington at its type section indicates accumulation under shallow, subtidal marine conditions. The abundance of lime-mud and pelletoid grains further suggests an environment of low tidal and wave energy, perhaps analogous to modern carbonate environments in Florida Bay (Bathurst, 1971, p. 147), or on the west side of the Qatar Peninsula in the Persian Gulf (*ibid.*, p. 209).

The ?hydrozoan *Palaeoaplysina* and the rugose coral genera noted above are the only probable *in situ* organisms known; these and echinoderm and mollusc debris and ostracodes all suggest normal salinity, Patchy dolomitization present within the Hanington at the type section is of macrodolomite type (Illing *et al.*, 1967), and does not indicate supratidal dolomitization, which might be expected in such a peritidal carbonate sequence. Scattered chert pebbles and granules in the lower few feet of the type section probably represent a basal lag deposit derived from older Lower Carboniferous units. Some transport of the chert by waves or currents is indicated, because the pebbles and granules are matrix-supported (skeletal lime-packstone or wackestone). Chert pebbles and cobbles represent the only facies that might be expected in a transgressive sequence.

Microspar and single crystals of calcite (Fig. 6) are abundant throughout the Hanington Formation at the type section. The resultant fabric resembles fabrics described by Steinen (1974) from Pleistocene limestone of Barbados, in which microspar and moldic porosity (later to be filled by calcite spar?) are both abundant. Steinen postulated that zones rich in microspar and moldic porosity represent zones that were bathed in phreatic (below the ground water table) fresh water during lowest sea level stands of the Pleistocene. The development of moldic porosity and microspar was more complete and considerably more rapid (105 000 years) in the phreatic zone than in the fresh water vadose zone (Steinen, *ibid.*). Such a process may account for the microspar and single crystals of calcite abundant in Hanington limestone at the type section, or Hanington beds could well have been bathed in fresh water prior to transgression and deposition of the overlying Permian sequence.

The ages of the uppermost Hanington and overlying basal Belcourt are not known precisely. A rough estimation based on recent time scales (Ross, 1970) suggests that youngest Moscovian rocks may be approximately 293 million years old, whereas oldest Asselian rocks may be approximately 280 million years old. Thus, the minimum interval of time represented by the disconformity between the Hanington and Belcourt Formations is on the order of 13 million years, more than adequate to accomplish major diagenetic changes related to fresh-water flushing in Hanington rocks. The length of time during which the preserved Hanington was subaerially exposed, however, is unknown. More textural evidence from modern and ancient settings is necessary for closer comparison. Relationships between microspar development, chert replacement, and dolomitization are unclear.

Sediments at the West Sukunka locality appear to represent a deep-water, open-marine setting, whereas sediments of the Hanington type section represent extremely shallow water, muddy, lagoonal environments close to sea level, within which local skeletal sands,

Figure 16

Figure 17

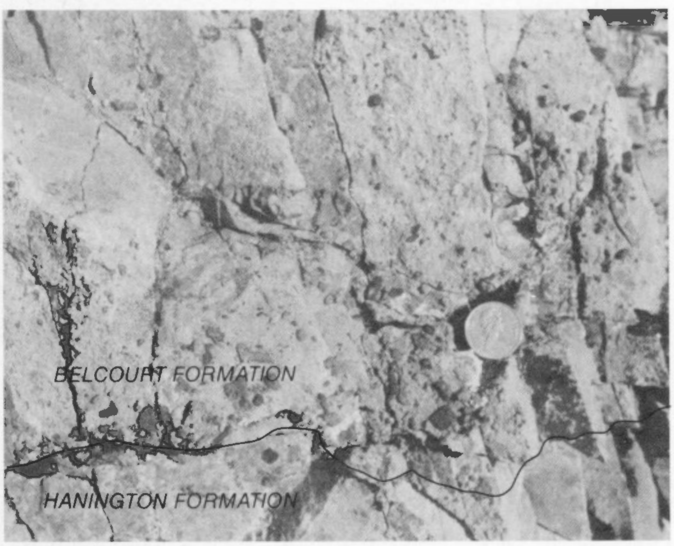


Figure 18

rugose corals, and *Palaeoaplysina* banks developed. The rare packstone and grainstone in the West Sukunka sequence (Fig. 4) show less development of microspar, suggesting a different diagenetic environment (?limited fresh-water flushing, or perhaps a shorter time interval). The absence of the Hanington Formation from intervening measured sections (Fig. 4) obscures lateral relationships between the contrasting carbonate facies present at Mount Hanington and West Sukunka.

Unfortunately, we do not know the thickness of Hanington carbonates removed during the erosional interval represented by the disconformity separating the Hanington Formation from the Belcourt Formation. Such information would be of interest in assessing the former lateral distribution of the Hanington, facies changes within it, and the timing and degree of diagenetic alteration.

PERMIAN

Belcourt Formation

Type section

Approximately 4 miles (6.5 km) south of Belcourt Lake, Latitude 54°20'30"N, Longitude 120°24'30"W, Monkman Pass (NTS 93I) 1:250 000 map-sheet; McGugan and Rapson (1963, p. 55-57), section 4 of Forbes and McGugan (1959, p. 39).

Distribution and thickness

The Belcourt Formation is present in most sections examined within the study-area (Figs. 1, 4). It is thickest in the northwest, where it is up to 452 feet (138 m) thick at the Mountain Creek section (Fig. 1, Loc. 1), and thins to 12.5 feet (4 m) at Mount Hanington (Loc. 8) in the southeast. This apparent regional trend is broken in the central part of the area, however, where the thickness decreases to 11 feet (3 m) at Hook Creek (Loc. 3). The formation is absent, as is most of the remaining Permian succession, from stratigraphic sections exposing the Paleozoic-Mesozoic boundary in the Burnt River-Sukunka River area, east and north of locality 2. There, Triassic strata rest disconformably on Mississippian carbonates of the Rundle Group.

FIGURE 16. Contact between Hanington Formation (Moscovian) and underlying Rundle Group (Lower Carboniferous, Viséan). Knife on contact provides scale. Mount Hanington (Loc. 8). GSC 199340.

FIGURE 17. Chert pebble conglomerate in lower part of Pennsylvanian Hanington Formation (unit 3). West Sukunka section (Loc. 2). GSC 199344.

FIGURE 18. Detail of contact between Belcourt Formation (Permian) and underlying Hanington Formation (Carboniferous, Moscovian). Note angular chert pebbles and granules in basal bed of Belcourt. Twenty-five cent coin provides scale. Mount Hanington (Loc. 8). GSC 199339.

Lithology and facies variation

Skeletal wackestone and packstone, non-skeletal oolitic grainstone, and very finely to finely crystalline dolomite make up much of the Belcourt Formation. A basal conglomerate or conglomeratic carbonate, ranging in thickness from less than 2 inches to 19 feet (5 cm-6 m), is present in all sections measured through the Belcourt Formation (Figs. 18, 20, 33-36). This conglomerate commonly consists of well-rounded chert pebbles and cobbles up to 4 inches (10 cm) across, derived from underlying Mississippian formations (Prophet, ?Besa River). Carbonate pebbles and cobbles are present but less common. The matrix of the conglomerate unit may be grainstone with pelletoid grains, ooids and brachiopods (Loc. 2), or it may be sparry calcite only (e.g. Loc. 3, Hook Creek). Locally, carbonate pebbles and cobbles may predominate, as at the Hook Creek section (Loc. 3, unit 1 of Belcourt Formation, Appendix). Reworked Lower Carboniferous corals also are present locally (Fig. 1, Loc. 4, Fellers Creek section). At some localities, chert and carbonate clasts are set in a matrix of dolomite or calcareous dolomite with the original matrix texture obscured (Locs. 5-7, Wapiti Lake, Mount Becker, and Belcourt Creek). The conglomerate or conglomeratic carbonate at the base of the Belcourt Formation is everywhere in sharp and disconformable contact with older rocks of the Hanington Formation or Rundle Group.

Beds of the Belcourt Formation, above the basal conglomerate, exhibit considerable variation in lithology. Two main, laterally equivalent facies can be distinguished: one comprising brachiopod-bearing mudstone or wackestone, and very finely to finely crystalline dolomite in thicker sections to the north and west; and another consisting of fusulinacean- and coral-bearing packstone and grainstone in thinner sections to the south and east. There appears to be a vertical trend in lithologic variation from skeletal grainstone or packstone at the base (above the conglomerate or conglomeratic carbonate) to wackestone and rare mudstone in higher parts of the unit - an apparent upward decrease in grain size within the Belcourt on a large scale. In terms of sedimentary environments, this probably indicates deposition in progressively deepening water (transgression), with the basal conglomeratic beds representing shoreline or beach deposits composed of eroded chert and carbonate clasts and overlying beds representing somewhat deeper, more open marine conditions with local or widespread echinoderm shoals (Figs. 29, 30) and ooid-fusulinacean shoals (Fig. 31).

Stratigraphic relationships

A sub-Permian disconformity of regional extent, marked by basal conglomerate or conglomeratic carbonates, separates the Belcourt Formation from underlying older rocks (Figs. 18, 23, 25). The conglomerate contains abundant pebbles and cobbles derived from the underlying Rundle Group and Prophet Formation, and the lower contact shows relief ranging from 3 inches (8 cm) to more than 3 feet (1 m).

Age relationships of fusulinaceans occurring within and just above the basal conglomerate (Ross and Bamber, 1978) demonstrate that the lower Belcourt Formation is older in the northwest at the Fellers Creek section (Loc. 4), where it is early to middle Asselian (earliest Permian) in age, than in the southeast at the Belcourt Creek section (Fig. 1, Loc. 7), where late Sakmarian (middle Early Permian) fusulinaceans occur in the matrix of the basal conglomerate. The persistence of this diachronous conglomerate at the base and the change in facies from wackestone and mudstone in the northwest to packstone and grainstone in the southeast indicate onlap, in an easterly direction, of Viséan and Moscovian units by sediments of the Belcourt Formation.

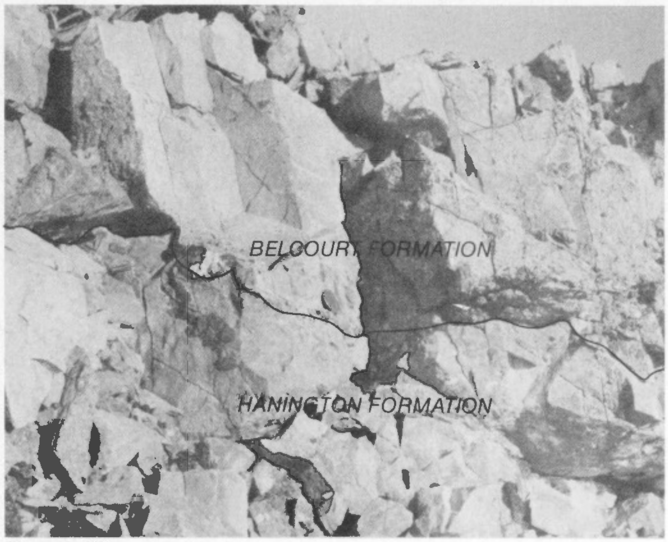
Where Permian rocks younger than the Belcourt Formation are preserved, they commonly are separated from the latter by a thin, cherty and phosphatic basal conglomerate containing abundant quartz sand, which marks the regional disconformity beneath the Ranger Canyon (McGugan and Rapson, 1963, p. 59) and Fantasque Formations. In the Hook Creek section (Fig. 1, Loc. 3), younger Permian units are absent beneath the sub-Triassic disconformity and only the basal conglomerate of the Belcourt Formation remains, overlain directly by Triassic rocks (Fig. 24). It appears that the Belcourt carbonates above the basal conglomerate have been removed from the area immediately southwest of the Wapiti Lake section (Fig. 1, Loc. 5), as well. There, McGugan and Rapson-McGugan (1976, p. 200, Secs. CDP 12, 14, 16) have recorded the Belcourt Formation in a conglomeratic facies with a thickness of only 3 m or less. In these sections, however, the Ranger Canyon and Mowitch Formations are present above the conglomerate. As noted above, the Belcourt Formation is absent from sections in the Burnt River-Sukunka River area north and east of the West Sukunka section (Loc. 2). Thus, the formation is very thin or absent in a narrow, linear belt extending from the Burnt River-Sukunka River area southeast through the Hook Creek section (Loc. 3), to the area southwest of the Wapiti Lake section (Fig. 1, Loc. 5).

Fauna and age

Lower Permian rugose corals and fusulinacean foraminifers are abundant at some levels in the formation in the southeast (Locs. 4-8; also McGugan and Rapson, 1963, p. 55) whereas brachiopods, such as *Waagenoconcha, Spiriferella, Yakovlevia,* and *Neospirifer,* dominate the fauna in the northwestern sections (Locs. 1, 2). The Early Permian (early or middle Asselian to late Sakmarian) age assignment is based mainly on foraminiferal studies by Forbes and McGugan (1959) and by Ross (*in* Ross and Bamber, 1978), who described eleven species of the genera *Schwagerina, Pseudofusulina, Schubertella*?, *Staffella*?, and *Pseudofusulinella.* These taxa are associated with the coral genera *Durhamina, Heintzella,* "*Thysanophyllum*", *Stylastraea,* and *Fomichevella.* Diachronism at the base of the Belcourt Formation, as reported by Ross and Bamber (1978), is discussed above.

Depositional and diagenetic environments

Belcourt carbonates represent shallow-shelf sedimentation. The Belcourt is thickest in the northern and western part of the area (Fig. 4), where it is composed of lime-mudstone and wackestone and their dolomitized equivalents. These rocks appear to represent open-marine conditions, dominated by water depths above, but perhaps approaching, wave-base. In contrast, the thinner sections of the southern and eastern part of the area consist of grainstones bearing fusulinaceans, ooids, and corals, and must have accumulated as shoals or banks of skeletal and oolitic sands close



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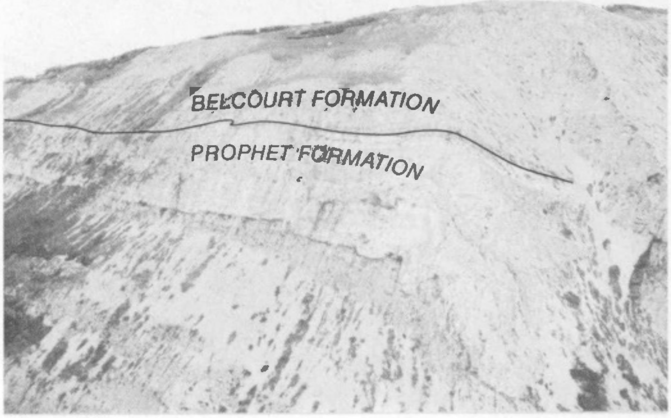

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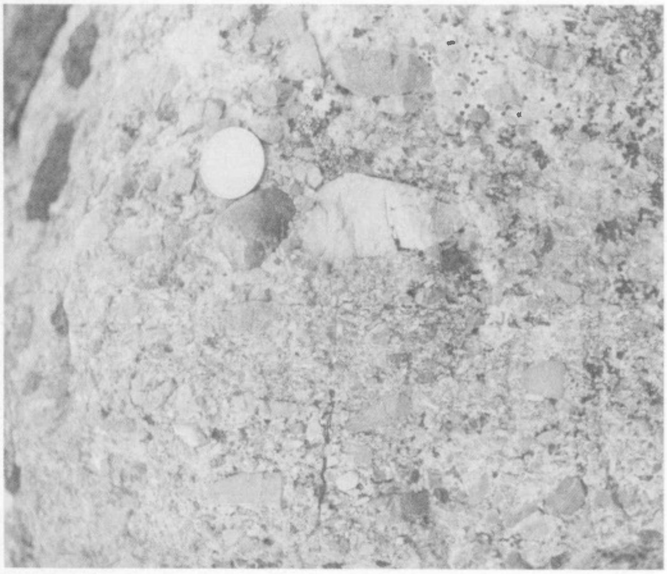
Figure 20

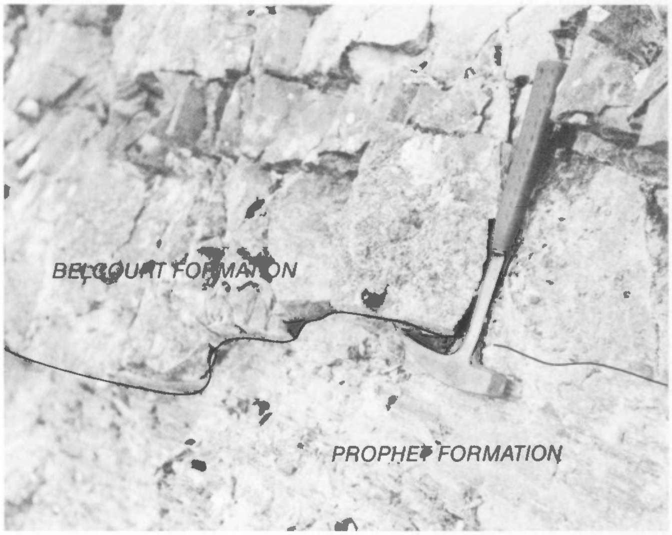

Figure 23


Figure 21

Figure 24

FIGURE 19. Contact between Belcourt Formation (Permian) and underlying Hanington Formation (Carboniferous, Moscovian), showing conglomerate at base of Belcourt Formation. Twenty-five cent coin provides scale. Mount Hanington (Loc. 8). GSC 199338.

FIGURE 20. Basal conglomerate of Belcourt Formation (Permian), unit 1. Pebbles and cobbles of chert and limestone in a lime-grainstone matrix, including pelletoid grains, ooids, and brachiopods. Five-cent coin provides scale. West Sukunka section (Loc. 2). GSC 199341.

FIGURE 21. Conglomerate within lower part of Belcourt Formation (Permian), showing large, angular clasts and the contact between unit 3 (conglomeratic) and unit 2 beneath. Twenty-five cent coin provides scale. West Sukunka section (Loc. 2). GSC 199342.

FIGURE 22. Mountain Creek section (Loc. 1), showing eastward truncation of Prophet Formation (Lower Carboniferous, Viséan) beneath the sub-Permian disconformity at the base of the Belcourt Formation (Permian). GSC 157632.

FIGURE 23. Detail of contact between Belcourt Formation (Permian) and Prophet Formation (Lower Carboniferous, Viséan), shown in Figure 21. Mountain Creek section (Loc. 1). GSC 157628.

FIGURE 24. Basal conglomerate of Belcourt Formation (Lower Permian) separated by disconformities from underlying Rundle Group (Lower Carboniferous, Viséan) and overlying Spray River Group (Triassic). Hook Creek section (Loc. 3). View to northwest. GSC 159123.

FIGURE 25. Detail of basal conglomerate of Belcourt Formation, shown in Figure 23. Hook Creek section (Loc. 3). GSC 159122.

FIGURE 26. Chert and carbonate pebble and cobble conglomerate within unit 3 of the Belcourt Formation (Permian). Twenty-five cent coin provides scale. West Sukunka section (Loc. 2). GSC 199343.

FIGURE 27. View to west of upper part of the Belcourt Creek section (Loc. 7), showing Permian Belcourt Formation (foreground) and Mowitch Formation overlain by Spray River Group (Triassic). GSC 15911.

Figure 25

Figure 26

Figure 27

Figure 28

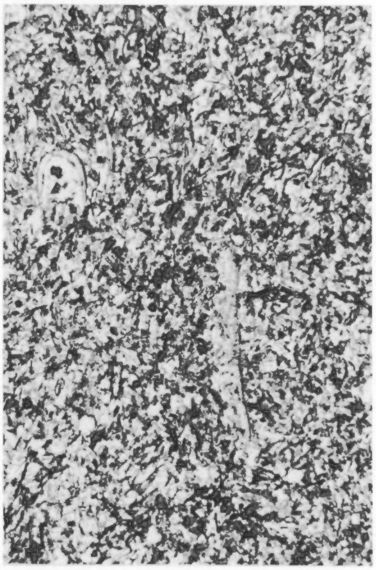

Figure 29

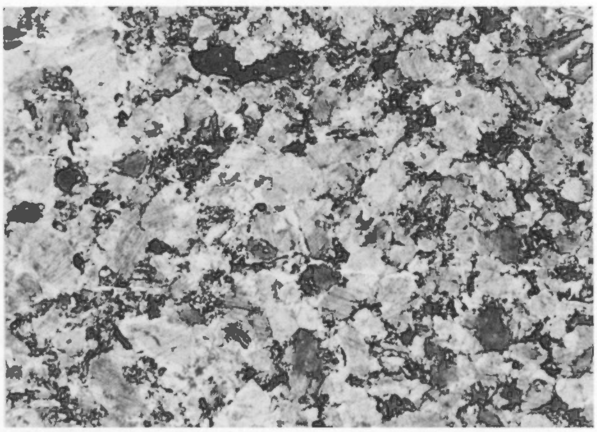

Figure 30

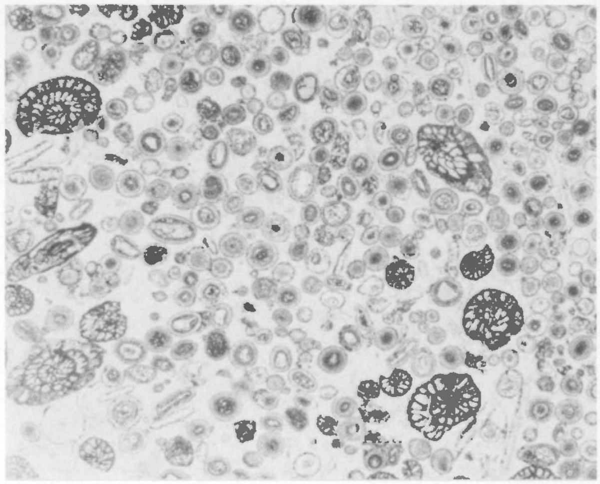

Figure 31

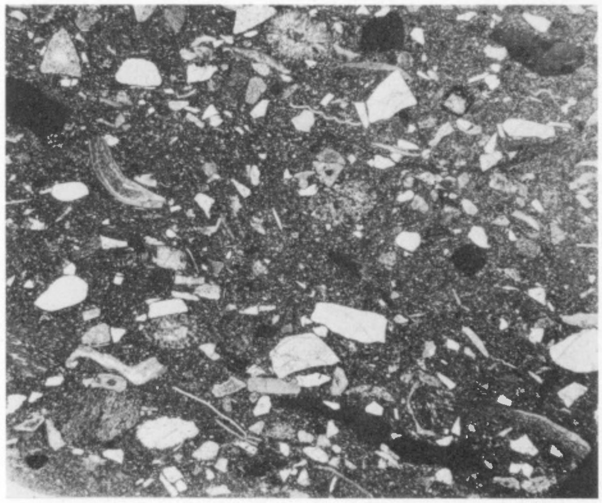

Figure 32

Figure 33

FIGURE 28. Skeletal packstone, fine to coarse grained, with bryozoan, mollusc, brachiopod and echinoderm material and scattered calcispheres; poorly sorted. Thin section, plane light. Belcourt Formation, unit 6; 80-100 feet (24-30.5 m) below top of unit, Mountain Creek section (Loc. 1) (GSC loc. C-39025). Bar scale 1 mm.

FIGURE 29. Skeletal, pelletoid grain, and echinoderm grainstone, very fine to fine grained, with delicate molluscan material, in sparry calcite cement; moderately well sorted. Thin section, plane light. Belcourt Formation, unit 7; 0-31 feet (0-9.5 m) below top of formation, Fellers Creek section (Loc. 4) (GSC loc. C-39144). Bar scale 1 mm.

FIGURE 30. Echinoderm grainstone-packstone, very coarse grained, matrix partly dolomitized, with syntaxial sparry calcite overgrowths (white), rare foraminifers. Dark grey areas are micrite, partly replaced by dolomite. Thin section, plane light. Belcourt Formation, unit 6; 31-51 feet (9.5-15.6 m) below top of formation, Fellers Creek section (Loc. 4) (GSC loc. C-39145). Bar scale 1 mm.

FIGURE 31. Oolitic and foraminiferal grainstone; well sorted, sparry calcite cement. Thin section, plane light. Belcourt Formation, lower part, unit 2; 19-49 feet (5.8-14.9 m) above base of formation, Fellers Creek section (Loc. 4) (GSC loc. C-39149). Bar scale 1 mm.

FIGURE 32. Conglomeratic packstone-wackestone with angular granules of chert "floating" in a pasty carbonate matrix with brachiopod, bryozoan and indeterminate skeletal detritus, partly dolomitized. Many sand-size single crystals of calcite, probably detrital. Intraformational conglomeratic unit of unknown extent. Thin section, plane light. Belcourt Formation, unit 3; 34-38 feet (10.4-11.6 m) above base of formation, West Sukunka section (Loc. 2) (GSC loc. C-39083). Bar scale 2 mm.

FIGURE 33. Basal conglomerate of Belcourt Formation with angular to rounded chert granules and pebbles, some showing poorly preserved skeletal material, and rimmed and initially cemented by a delicate fringe of drusy quartz crystals (white rims). Remainder of pore space cement is dolomite with minor amounts of polycrystalline calcite spar. Thin section, plane light. Top part of basal Belcourt conglomerate, unit 1; 3 feet (0.9 m) above base of formation, Mountain Creek section (Loc. 1) (GSC loc. C-39034). Bar scale 2 mm.

FIGURE 34. Basal conglomerate of Belcourt Formation with rounded chert pebbles and cobbles (?lag deposit), set in a matrix (?depositionally infilled) of medium- to fine-grained grainstone with echinoderm, brachiopod, mollusc and bryozoan material and scattered foraminifers. Matrix and skeletal material locally silicified. Thin section, plane light. Basal bed of formation, unit 1; West Sukunka section (Loc. 2) (GSC loc. C-44596). Bar scale 5 mm.

FIGURE 35. Basal conglomerate of Belcourt Formation with angular chert pebbles and cobbles, and rare limestone pebbles. Matrix is carbonate clast, skeletal grainstone; carbonate clasts have foraminifers; clasts and skeletal material cemented with sparry calcite. Thin section, plane light. Basal bed of Belcourt Formation, unit 1; Fellers Creek section (Loc. 4) (GSC loc. C-39360). Bar scale 5 mm.

FIGURE 36. Basal conglomerate of Belcourt Formation with angular chert pebbles and cobbles (?lag deposit) in a skeletal and pelletoid grain packstone, partly dolomitized (?depositionally infilled). Chert pebbles contain Carboniferous foraminifers and may be derived from Prophet Formation (Lower Carboniferous). Thin section, plane light. Basal bed of Belcourt Formation, unit 1; Mount Hanington section (Loc. 8) (GSC loc. C-39318). Bar scale 5 mm.

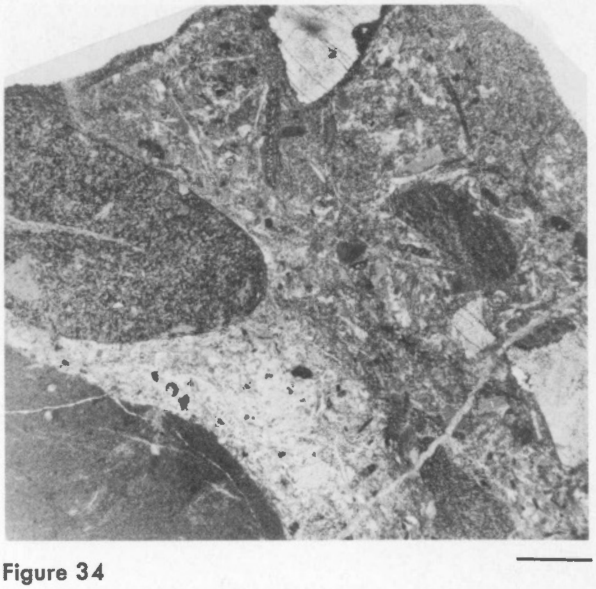

Figure 34

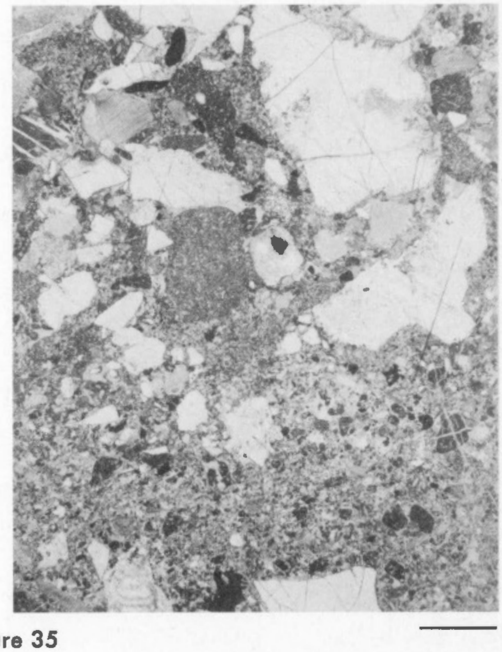

Figure 35

Figure 36

to sea level. Age relationships within the Belcourt sequence (Fig. 5) indicate easterly directed depositional transgression over Carboniferous rocks during Early Permian time, as outlined previously. At all sections, the lowest sediments consist of conglomeratic carbonates, probably lag deposits representing the more durable and, hence, residual lithologies of the underlying, eroded Rundle Group, and Prophet, Besa River, or Hanington Formation.

Dolomitization within the Belcourt is clearly of secondary or macrodolomite type, after pre-existing limestone. The presence of minor amounts of disseminated quartz silt and local burrow mottling in some dolomite beds (e.g. Loc. 1) suggests that the dolomitized beds initially were muddy carbonate sediments - wackestone or packstone - in which larger surface areas of silt- and clay-size carbonate facilitated solution and replacement by dolomite, probably during early diagenesis. None of the dolomite appears to be of the sabkha or supratidal type (microcrystalline), associated with evaporites or evaporite pseudomorphs, algal mats, desiccation cracks, etc. The chert present appears to represent diagenetic replacement of limestone. The local presence of pseudomorphic granular fabrics (?pelletoid grains) within chert nodules in dolomite beds demonstrates that chert replacement occurred prior to dolomitization.

In contrast to the limestones of the underlying Hanington Formation, those of the Belcourt Formation generally do not show features suggestive of freshwater diagenesis (microspar, caliche, non fabric-selective cavities, etc.). This may indicate a relatively short time of exposure between erosion of the Belcourt and deposition of the overlying, younger Permian sediments.

Ranger Canyon Formation

Type section

West flank of Mount Ishbel, Sawback Range, Banff area, Alberta (McGugan and Rapson, 1963, p. 56; 1961, p. 90).

Distribution and thickness

The Ranger Canyon Formation extends from its type area in the southern Canadian Rocky Mountains, north through the Jasper area, to Wapiti Lake (McGugan and Rapson, 1963). The name has been used farther north, from Pine Pass to the southern Mackenzie Mountains (McGugan *et al.*, 1964; McGugan, 1967) for dark grey chert and shale previously referred to the Fantasque Formation (Harker, 1961; Bamber *et al.*, 1968). In the present paper, the name Fantasque Formation is retained for the 102 to 109 feet (31-33 m) of chert, siltstone, and minor amounts of shale capping the upper Paleozoic succession at the Mountain Creek and West Sukunka sections (Fig. 1, Locs. 1, 2). The Fantasque Formation in these two sections appears to be a western facies equivalent of the Ranger Canyon Formation, which is absent from the Hook Creek and Fellers Creek sections (Locs. 3, 4), but occurs in several measured sections to the southeast (Locs. 5, 6; Sections 1, ?3 of Forbes and McGugan, 1959), where the thickness ranges from 6 to 18 feet (2-5.5 m).

Lithology and facies variation

The Ranger Canyon Formation was described by McGugan and Rapson (1963, p. 57) as "a complex deposit of phosphatic chert and siltstone with smaller amounts of sandstone and silicified carbonate". It was pointed out by these authors (*ibid.*, p. 60; McGugan *et al.*, 1964, p. 107) that, north of Jasper, variations in the amount of sandstone and chert within this formation and the overlying Mowitch Formation cause difficulty in separating the two units. Within the study-area, the Ranger Canyon Formation, as recognized in this paper, was examined at Wapiti Lake and Mount Becker (Fig. 1, Locs. 5, 6). At Wapiti Lake the formation consists of a single, resistant, light grey bed of chert, 6 feet (2 m) thick, with local irregular zones of dolomite containing molds of echinoderm columnals and indeterminate skeletal debris. The diagenetic sequence appears to be: 1) limestone (?skeletal packstone or grainstone), 2) dolomitization, 3) extensive (incomplete) replacement by chert. At the Mount Becker section (Fig. 1, Loc. 6) the formation consists of 20 feet (6 m) of chert with minor amounts of fine-grained sandstone as interbeds. Again the chert appears to be a replacement of pre-existing carbonate; thin-sections show poorly preserved but recognizable pelletoid grains, ooids (rare), and spicules. The chert is light grey, weathering white to light grey.

The amount of quartz sandstone in the post-Belcourt interval increases from the Mount Becker section (Loc. 6), where several thin beds occur, toward Mount Hanington (Loc. 8), where the entire post-Belcourt Permian interval consists of sandstone with local lensing chert beds present only in the basal 2 feet (0.5 m) (Fig. 4). This sandstone succession at Mount Hanington (and at Belcourt Creek, Loc. 7) is referred to the Mowitch Formation, discussed below.

At most sections where the contact is exposed, the Belcourt Formation is separated from the overlying Ranger Canyon or Mowitch Formation by a thin, widespread conglomerate (McGugan and Rapson, 1963), consisting of chert granules, pebbles, and cobbles in a sandstone matrix, which commonly is partly silicified and phosphatized.

Stratigraphic relationships

The conglomerate at the base of the Ranger Canyon Formation and its lateral equivalents mark a regional disconformity of great lateral extent (McGugan and Rapson, 1963; McGugan *et al.*, 1964; McGugan, 1965). Lack of precise ages within the study-area, for beds immediately above and below the conglomerate, prevents estimation of the amount of time represented by the disconformity. Relief of no more than a few centimetres has been observed on the top surface of the underlying Belcourt Formation within the study-area. McGugan and Rapson (1963, p. 59), however, reported relief of at least 5 feet (1.5 m) at the base of the conglomerate to the south of the area, near Jasper.

The chert and interbedded sandstone of the Ranger Canyon Formation grade upward into sandstone assigned to the Mowitch Formation. Also, the Ranger Canyon may, in part, grade laterally into the Mowitch as sandstone increases in abundance between Wapiti Lake and Mount Hanington (Loc. 8) to the southeast. Biostratigraphic control, however, is insufficient for verification of the time equivalence of the two units.

At the Wapiti Lake section, the Ranger Canyon is overlain directly by a covered interval that is assigned tentatively to the Triassic Spray River Group because of its recessive nature. McGugan and Rapson-McGugan (1976, Fig. 4) show the Mowitch Formation overlying the Range Canyon Formation in a composite section for Wapiti Lake. Three miles (4.8 km) northwest of Wapiti Lake, Forbes and McGugan (1959, Sec. 1, p. 38) indicated the presence of a 20-foot (6 m) unit of sandstone with some nodular chert, and an underlying 14-foot (4 m) unit of interbedded chert and sandstone, overlying carbonates now assigned to the Belcourt Formation. It is probable that the 20-foot (6 m) unit represents the Mowitch, and that the underlying 14-foot (4 m) unit represents the Ranger Canyon. Farther northwest at the Hook Creek and Fellers Creek sections (Fig. 1, Locs. 3, 4), the Ranger Canyon is absent beneath the sub-Triassic disconformity. Sedimentary environments and lateral relationships for the Ranger Canyon and Fantasque Formations are discussed below in the section dealing with the Fantasque Formation.

Fauna and age

No identifiable fossils were collected by the authors from the Ranger Canyon Formation. A Late Permian (Guadalupian or younger) age has been assigned (McGugan and Rapson, 1963, p. 59; McGugan *et al.*, 1964, p. 107; McGugan, 1965, p. 125; Logan and McGugan, 1968) on the basis of brachiopod occurrences within the study-area and near Jasper, and also on the basis of the stratigraphic position of the Ranger Canyon Formation above a regional disconformity truncating beds as young as early Guadalupian (Ross Creek Formation, southeastern British Columbia). The vertebrate *Helicoprion*, which is found toward the top of the Lower Permian elsewhere in North America (Nassichuk, 1971, p. 87), occurs in the conglomerate at the base of the formation near Banff, Alberta (McGugan *et al.*, 1964, p. 107).

Fantasque Formation

Type section

North side of Beaver River, south of Mount Merill, Latitude 60°02'N, Longitude 124°42'W, La Biche River (NTS 95C) 1:250 000 map-sheet, southeastern Yukon Territory (Harker, 1961).

Distribution and thickness

The Fantasque Formation is restricted to the northeastern part of the area (Figs. 1, 4). At localities 1 and 2, it has thicknesses of 102 and 109 feet (31 and 33 m), respectively, but is only 9 feet (2.5 m) thick approximately 8 miles (12.9 km) north of locality 2, northeast of Burnt River (Fig. 1). The formation thins toward the southeast and is absent from sections at Hook Creek and Fellers Creek (Locs. 3, 4).

Lithology and facies variation

Most of the Fantasque Formation consists of grey, medium- to thick-bedded chert. Minor amounts of shale and fine- to coarse-grained siltstone occur locally as lenses within the chert of the lower third of the formation at the Mountain Creek section (Fig. 1, Loc. 1). Thin sections of chert commonly show skeletal and other granular material, including spicules, pelletoid grains, and intraclasts, indicating carbonate precursors for much of the chert (Fig. 40). Associated siltstone is composed mainly of quartz with minor amounts of carbonate and chert grains. The fact that the siltstone occurs commonly as lenses suggests that significant amounts of siltstone also have been incorporated (or replaced) by chert. Several generations of chert are present. Near the top of the Fantasque at the West Sukunka section (Fig. 1, Loc. 2), scattered small vugs in the host chert are lined with at least three generations of almost white microcrystalline quartz, with drusy, pore-filling quartz as the last generation. The inaccessibility of the cliff-forming Fantasque Formation at the West Sukunka section prevented adequate sampling. Therefore, the degree of facies variation between this section and the Mountain Creek section could not be determined.

Fantasque chert lithologies compare closely with those of the Ranger Canyon Formation at Wapiti Lake and Mount Becker to the south (Fig. 1, Locs. 5, 6). At Wapiti Lake, actual lenses of skeletal carbonate (dolomite) occur; elsewhere, in both the Fantasque and Ranger Canyon, probably pre-existing carbonates appear to have been completely replaced by chert. In contrast to the light grey weathering, irregularly bedded Ranger Canyon Formation, however, the Fantasque Formation weathers dark grey and occurs in regular beds. It contains siltstone and shale as it does north of the study-area (Bamber *et al.*, 1968), rather than the sandstone that characterizes the Ranger Canyon Formation in the southern part of the area.

Stratigraphic relationships

Neither the lower nor the upper contact of the formation was observed in the area because of inaccessibility or lack of exposure. Relationships between the Fantasque and adjacent formations, however, indicate that both contacts are disconformable. The Fantasque Formation is overlain by Triassic rocks and underlain by the Belcourt Formation at the Mountain Creek and West Sukunka sections (Locs. 1, 2). Approximately 8 miles (12.8 km) north of locality 2, the Belcourt Formation is absent and the Fantasque Formation rests on Viséan carbonate rocks of the Rundle Group. Farther east and to the southeast, the Triassic rests directly on the Rundle Group, or on the Belcourt Formation at Hook Creek (Locs. 3) and Fellers Creek (Loc. 4). There is considerable variation in the thickness of the Fantasque Formation and its lateral equivalents to the south. These variations are controlled partly by the sub-Triassic disconformity but, for a complete understanding of their stratigraphic and sedimentological significance, accurate age relationships among the Mowitch, Ranger Canyon, and Fantasque Formations are required.

Fauna and age

No fossils, other than sponge spicules, were found in the Fantasque Formation. Bamber *et al.* (1968, p. 13) reported the occurrence of *Helicoprion*, of probable Artinskian (late Early Permian) age, near the base of the formation on Dunedin River, approximately 250 miles (400 km) north of the area. Stratigraphic relationships suggest that the Fantasque Formation at localities 1 and 2 (Fig. 1) is equivalent in age to the Ranger Canyon Formation and possibly to part of the Mowitch Formation to the southeast (Fig. 4).

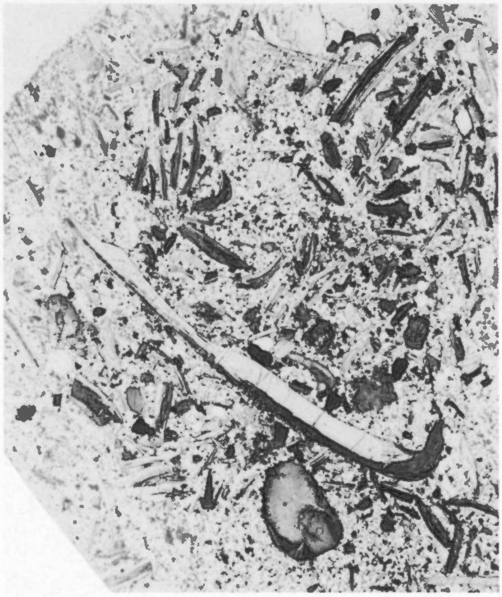

Figure 37

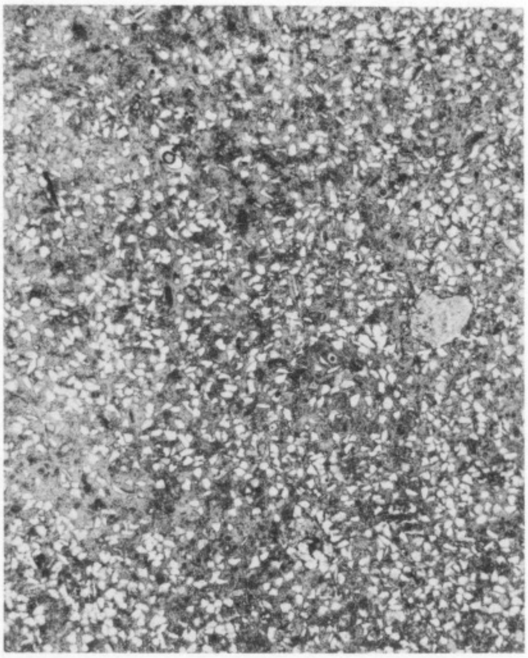

Figure 38

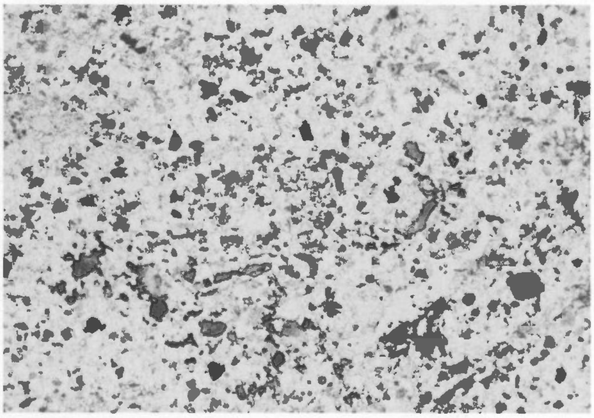

Figure 39

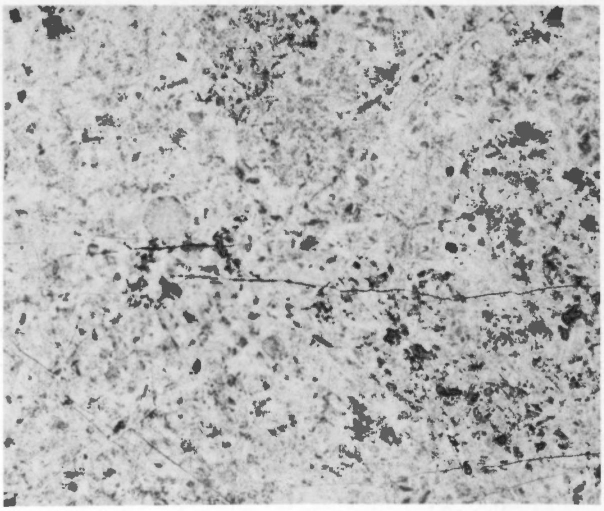

Figure 40

FIGURE 37. Sandstone, fine to medium grained with abundant silicified and partly phosphatized lamellar skeletal fragments probably derived from brachiopods and molluscs; scattered phosphate and chert grains of coarse sand to granule size. Quartz sand is subrounded, well-sorted and mature. Thin section, plane light. Mowitch Formation, unit 3; 34-46 feet (10.4-14 m) above base of formation. Belcourt Creek section (Loc. 7) (GSC loc. C-39220). Bar scale 2 mm.

FIGURE 38. Sandstone, fine grained; subangular quartz grains "floating" in cement and matrix of microcrystalline quartz and phosphate; matrix consists of dense, dark grey grains of phosphate (?formerly quartz) and lighter grey mixture of silica and phosphate. Thin section, plane light. Mowitch Formation, unit 1; basal conglomeratic bed, Mount Hanington section (Loc. 8) (GSC loc. C-39315). Bar scale 1 mm.

FIGURE 39. Sandstone, fine to medium grained, poorly sorted, with phosphate occurring both as grains and irregular matrix "patches" (black in photomicrograph). Thin section, plane light. Mowitch Formation, unit 2; 2-12 feet (0.6-3.7 m) above base of formation, Mount Hanington section (Loc. 8) (GSC loc. C-39314). Bar scale 2 mm.

FIGURE 40. Chert with incompletely replaced spicules, foraminifers, ?echinoderm ossicles, and indeterminate skeletal material; between crossed nicols many grains are cryptocrystalline quartz, whereas cement is microcrystalline quartz with local finely to medium crystalline and polycrystalline quartz filling pore space. Spicules, however, are microcrystalline quartz similar to, but coarser than, quartz of cement. In plane light, skeletal grains (excluding spicules) are dusky brown in colour; matrix is pale brown. Thin section, plane light. Fantasque Formation, unit 1; 29-49 feet (8.8-14.9 m) above base of formation, West Sukunka section (Loc. 2) (GSC loc. C-39349). Bar scale 1 mm.

Depositional and diagenetic environments

The thin, distinctive, widespread interval that includes the Ranger Canyon and Fantasque Formations was studied in detail by Rapson-McGugan (1970; also *see* McGugan and Rapson-McGugan, 1976). South of the study-area, she demonstrated that it originally included lag deposit phosphatic conglomerates, as well as siltstone, carbonates, evaporites, and phosphates. Rapson-McGugan (1970) interpreted this distinctive and somewhat bewildering succession of rocks to be: (a) initial deposits of peritidal clastics and carbonates, widely developed along the shores of an early Permian sea, and (b) the product of extensive solution and replacement processes that took place in a chemically active, supratidal environment similar to modern coastal supratidal flats in Baja California and the Persian Gulf, but dominated by extensive processes of solution and precipitation of phosphate. The diagenetic environment she postulated entailed extensive replacement of preexisting sediments by quartz, chalcedony, dolomite, sulphate, and phosphate; all of these minerals also occur as cement within intergranular pore space and secondarily developed vugs. Perhaps the most distinctive attribute of these rocks on a regional scale is the common breccia texture that they display. Rapson-McGugan applied the name "corrosion breccia" and interpreted this texture to be the product of repeated and extensive solution and precipitation.

The results of detailed study of the Ranger Canyon and Fantasque Formations do not form part of this paper. The textures and fabrics observed in this stratigraphic interval, however, resemble those reported by Rapson-McGugan (1970). Fantasque chert at localities 1 and 2 (Fig. 1) includes scattered pelletoid grains, intraclasts, spicules (?monaxonid sponge spicules), and other skeletal detritus, suggesting replacement of pre-existing limestone. Siltstone and minor amounts of shale occur as discontinuous lenses; the original proportion of carbonate to siltstone is unknown. The unusual mixture of siltstone, sandstone, shale, chert, and (originally) carbonate appears to require unique depositional as well as diagenetic environments. As pointed out by Rapson-McGugan (1970) and others, a key factor in the preservation of this thin and unusual sequence has been the widespread, wholesale replacement of pre-existing ?carbonates by chalcedony and quartz, creating a durable unit resistant to erosion.

As stated previously, the present authors recognize the Ranger Canyon only in sections at Wapiti Lake and Mount Becker (Fig. 4). Chert lithologies similar to those of the Fantasque are present, but interbeds of fine-grained, partly silicified, calcareous sandstone at Mount Becker suggest a lateral transition to the Mowitch, as indicated in Figure 4. Spicules, pelletoid grains, and ooids, etc., replaced by chalcedony, also indicate silicification of pre-existing rocks, probably limestones.

Mowitch Formation

Type section

Ridge between Deer Creek and Mowitch Creek, approximately 42 miles (67.5 km) northwest of Jasper, Alberta; Mount Robson (1:250 000) map-sheet (McGugan and Rapson, 1963; McGugan *et al.*, 1964).

Distribution and thickness

The Mowitch Formation is present only in the southwestern part of the area. It is well developed in the Belcourt Creek section (Fig. 1, Loc. 7) and the Mount Hanington section (Loc. 8), and occurs in several sections described by Forbes and McGugan (1959) and McGugan and Rapson-McGugan (1976) near Belcourt and Wapiti Lakes. The thickness ranges from 9 feet (2.7 m) at Mount Becker (Loc. 6) to 71 feet (22 m) at Mount Hanington (Loc. 8). At Fellers Creek (Loc. 4), 3 feet (0.9 m) of sandstone are assigned tentatively to the Mowitch. This sandstone unit may, however, represent an erosional remnant of the Ranger Canyon Formation, which contains a variable amount of sandstone in the area to the southeast.

Lithology and facies variation

The Mowitch Formation is composed mainly of very fine to medium-grained sandstone, which is quartzose and commonly contains siliceous cement and less commonly carbonate cement. Chert and some carbonate lenses and beds occur in some sections (e.g. Belcourt Creek, Loc. 7), especially where Mowitch sandstone apparently intergrades with Ranger Canyon chert. Chert grains of sand and granule size appear to make up a few per cent to as much as 10 per cent of the formation at all localities; collophane grains and phosphatic nodules are present, but less common. At Belcourt Creek and Mount Hanington (Fig. 1, Locs. 7, 8), phosphate occurs as replacements of shell fragments, and as phosphate zones filling intergranular pore space on a hand-specimen scale (Figs. 37-39). Phosphate-pebble conglomerate occurs on the top surface of the formation in the Mount Becker section (Loc. 6). In thin sections, Mowitch sandstone commonly consists of a tightly interlocking pressure-welded mosaic of subangular quartz grains. A basal 0.5 to 1 foot (0.15-0.3 m) conglomerate or conglomeratic zone of chert pebbles and cobbles is present in several sections (Fig. 1; Belcourt Creek, Loc. 7; Mount Hanington, Loc. 8). Facies variations within the Mowitch Formation, in addition to its apparent lateral gradation into the Ranger Canyon Formation, include changes in the amount and type of occurrence of phosphate, variation in the amount of chert either as detrital grains or as *in situ* replacements or pore-fillings, and the presence or absence of basal conglomerate.

Stratigraphic relationships

The Mowitch Formation rests conformably on the Ranger Canyon Formation and the two units appear to interfinger and grade laterally into each other as sandstone becomes predominant in the interval above the Belcourt Formation toward the southeast (Fig. 4). The contact between the Mowitch Formation and carbonate rocks of the Belcourt Formation, where the Ranger Canyon Formation is absent (Locs. 7, 8), is sharp. Where observed, the Permian-Triassic contact at the top of the Mowitch Formation is sharp and disconformable, with little relief. A chert granule and pebble conglomerate bed commonly occurs immediately above the contact (Fig. 1, Loc. 7; McGugan and Rapson, 1963, p. 60; Forbes and McGugan, 1959, p. 38, 39).

Northwest of Wapiti Lake, Triassic siltstone rests disconformably on the Belcourt Formation at Hook Creek and Fellers Creek (Locs. 3, 4), and the Mowitch Formation is absent. Its relationship to the Fantasque Formation, which caps the Paleozoic succession farther to the northeast at the Mountain Creek and West Sukunka sections (Fig. 4, Locs. 1, 2), is uncertain.

Fauna and age

Fossils are rare in the Mowitch Formation. Fish fragments and very poorly preserved productoid brachiopods occur at localities 6 and 7. Northwest of Jasper, near the headwaters of Sulphur River, *Neospirifer* and *Lingula* were reported by McGugan and Rapson (1963, p. 60) and McGugan *et al.* (1964, p. 107, Section 120), who assigned a ?Late Permian age to the formation.

Depositional and diagenetic environments

The fine- to medium-grained sandstone of the Mowitch is partly a residual deposit derived from erosion of the underlying formations, as demonstrated by the variably abundant chert grains of sand and granule size. The basal conglomeratic bed developed at two of the three Mowitch sections examined appears to represent a lag gravel that marks the beginning of the Mowitch transgression. The basal conglomerate may have accumulated as a beach deposit, although evidence other than stratigraphic position is lacking. It is overlain by marginal marine sands within which penecontemporaneous diagenetic processes appear to have accomplished silicification and phosphatization, as outlined by Rapson-McGugan (1970). The problems of Mowitch sedimentation and diagenesis are the same as those of the Fantasque and Ranger Canyon Formations. The Mowitch, however, initially may have consisted largely of mature quartz sand that was less reactive under phosphate- and silica-rich diagenetic environments than were the probable carbonates and evaporites initially present in the Fantasque and Ranger Canyon Formations.

DISCONFORMITIES

Four major disconformities are recognized within the upper Paleozoic succession described in this report (Figs. 3, 4): a sub-Moscovian (Atokan) disconformity beneath the Hanington Formation; a sub-Permian disconformity beneath the Belcourt Formation; an intra-Permian disconformity beneath the Ranger Canyon and Fantasque Formations; and a sub-Triassic disconformity at the top of the succession. The sub-Moscovian disconformity is known only locally, but the upper three disconformities can be recognized widely in the eastern Cordillera and adjacent plains.

SUB-MOSCOVIAN DISCONFORMITY

Truncation of Lower Carboniferous rocks is greater in the Monkman Pass-Pine Pass area than in any other part of the Rocky Mountains. Lower Moscovian (Atokan) carbonates of the Hanington Formation rest disconformably on Lower to Middle Viséan carbonates and shale of the Rundle Group and the Besa River Formation (Fig. 4, Locs. 2, 8). At Mount Hanington (Fig. 7, Loc. 8), thin, chert-pebble conglomerate rests on the erosional surface, which shows relief of from 4 to 6 inches (10-15 cm). This disconformity has not been recognized previously in the area. Its lateral extent is unknown, because Upper Carboniferous rocks generally are absent beneath the sub-Permian disconformity in the Rocky Mountains and Plains of the Jasper area and northeastern British Columbia (Fig. 3). Disconformities have been reported by several authors (Sikabonyi and Rodgers, 1959; Halbertsma and Staplin, 1960; Bamber and Mamet, 1978) within the Stoddart Group in the subsurface of the northeastern British Columbia Plains. Faunal data (Bamber and Mamet, 1978) suggest, however, that most or all of the Stoddart Group is older than the Hanington Formation. South of Jasper, in southwestern Alberta and southeastern British Columbia, a sub-Atokan unconformity was reported by Scott (1964) between the Tobermory Formation and the underlying Lower Pennsylvanian (Morrowan) Storelk Formation (Fig. 3). In northern Yukon Territory, sedimentation continued without significant interruption from Namurian through Moscovian time, except in the northern Richardson Mountains, where Middle Pennsylvanian (upper Bashkirian to Moscovian) rocks rest unconformably on Middle Devonian carbonates of the Ogilvie Formation (Bamber and Waterhouse, 1971).

SUB-PERMIAN DISCONFORMITY

The Belcourt Formation is separated from older rocks by a widespread, regional, sub-Permian disconformity, which shows considerable relief, is consistently overlain by conglomerate, and has been traced from the southern Canadian Rocky Mountains to the northern Yukon (McGugan *et al.*, 1964; Bamber *et al.*, 1968; Bamber and Waterhouse, 1971). The magnitude of this disconformity varies considerably from area to area, as outlined below.

Within the study-area, carbonates of the lower part of the Belcourt, above the disconformity, range in age from early or middle Asselian (earliest Permian) to late Sakmarian (middle Early Permian), becoming younger in an easterly direction, as discussed previously (Fig. 5). Lower to Middle Viséan carbonates of the Rundle Group commonly underlie the disconformity, but the lower Moscovian (Atokan) Hanington Formation is present locally (Fig. 4, Locs. 2, 8). The nature and extent of the sub-Permian disconformity are unknown in the Jasper area to the south, where the ?Guadalupian Ranger Canyon Formation rests directly on the Viséan Rundle Group, and Lower Permian rocks are absent beneath the intra-Permian disconformity.

Part of the Lower Permian succession also is absent from southwestern Alberta and southeastern British Columbia. There, the upper Wolfcampian to Leonardian (Sakmarian to lower Artinskian) Johnson Canyon Formation rests disconformably on Atokan (lower Moscovian) carbonates of the Kananaskis Formation (Fig. 3).

North of the study-area, from Pine Pass to Liard Plateau (Fig. 3), the age of the basal Permian above the disconformity is not known accurately. Brachiopods of Asselian to early Artinskian (Wolfcampian to early Leonardian) age occur at several localities in the Kindle Formation (= Mount Greene Beds of McGugan, 1967) (Logan and McGugan, 1968; Bamber and Waterhouse, 1971). The top of the Carboniferous succession below the disconformity ranges in age from Early to Middle Viséan in the Pine Pass area (Rundle Group and Prophet Formation) to Early Namurian (Morrowan) near the Yukon-British Columbia border (Stoddart Formation) (McGugan, 1967; Bamber *et al.*, 1968).

Continuous sedimentation across the Carboniferous-Permian boundary was reported by Bamber and Waterhouse (1971, p. 42, 102) in western sections of the northern Ogilvie Mountains, northern Yukon Territory (Fig. 3). Where Permian rocks are preserved elsewhere in the northern Yukon, Asselian (lower Wolfcampian) or younger Permian units rest unconformably on Moscovian (Desmoinesian) or older rocks.

INTRA-PERMIAN DISCONFORMITY

The regional disconformity within the Permian succession, at the base of the Ranger Canyon and Fantasque Formations, has been traced from southeastern British Columbia to the southwestern District of Mackenzie (McGugan, 1965, 1967; Bamber *et al.*, 1968). A thin, phosphate-pebble conglomerate is associated consistently with this stratigraphic break, and the top surface of the underlying beds shows considerable relief locally (McGugan and Rapson, 1963). The amount of Permian time represented by this disconformity varies from area to area (Fig. 3). The age of the underlying strata is commonly Sakmarian to early Artinskian (late Wolfcampian to early Leonardian), but ranges from Viséan in the Jasper area to Leonardian or possibly early Guadalupian in southeastern British Columbia (Logan and McGugan, 1968, p. 1128). Meagre faunal evidence and stratigraphic relationships suggest a Guadalupian age for the Ranger Canyon and Fantasque Formations, above the disconformity. No stratigraphic break corresponding to the intra-Permian disconformity was reported for the northern Yukon Territory by Bamber and Waterhouse (1971, p. 42).

SUB-TRIASSIC DISCONFORMITY

No rocks of latest Permian age are known from the eastern Cordillera. Guadalupian and older Permian rocks are disconformably overlain by Lower Triassic rocks from southeastern British Columbia to the southeastern District of Mackenzie (Fig. 3). In some areas, however, such as the Burnt River-Sukunka River area (Fig. 1), the easternmost outcrops north of the Halfway River (Bamber *et al.*, 1968, p. 10), and locally in the subsurface to the northeast, the sub-Triassic disconformity truncates Permian and Upper Carboniferous units to rest directly upon Viséan carbonates. Within the study-area, little relief is present at the Paleozoic-Triassic contact, which commonly is overlain by a thin, chert and phosphate pebble conglomerate.

DEPOSITIONAL AND TECTONIC HISTORY

All of the Upper Carboniferous and Permian units of the Pine Pass-Kakwa River area are unconformity-bounded units in the sense of Chang (1975). As such, each of the formations discussed here represents only the preserved remnant of what was presumably a thicker and more extensive unit prior to widespread erosion associated with the four disconformities present (Figs. 2-4).

Age and stratigraphic relationships discussed previously and shown in Figures 3 and 4 indicate that uplift and erosional truncation of the underlying Lower Carboniferous succession was greater in the study-area than elsewhere in the Rocky Mountains. Preservation of the lower Moscovian Hanington Formation in this same area suggests that the major episode of uplift and erosional removal of older Carboniferous rocks took place in pre-Hanington (pre-Moscovian) time, rather than in pre-Belcourt (latest Carboniferous or earliest Permian) time. The same may be true of adjacent areas to the north and south (Fig. 3), where Permian rocks rest directly on the Lower Carboniferous and no record of intervening strata remains.

Shallow-water marine carbonates, such as those in the Hanington Formation and the underlying Rundle Group, commonly have extensive geographic distribution. For example, the Lower Carboniferous Pekisko, Shunda, and Turner Valley Formations are found from southwestern Alberta to northeastern British Columbia in both the plains and the outcrop belt (Macauley *et al.*, 1964, Fig. 7-1). Thus, there is reason to believe that Hanington sediments accumulated over a much larger area than they presently cover, and may have been continuous with their correlatives in the Kananaskis Formation of the Banff area and the Ettrain Formation of the northern Yukon Territory (Fig. 3). Previously described facies distribution within the Hanington Formation, although based on only two known stratigraphic sections (Fig. 1, Locs. 2, 8), indicates shoaling from west to east, but there is no suggestion of proximity to a shoreline.

The period of exposure, erosion, and development of relief associated with the sub-Permian disconformity was followed by renewed eastward Early Permian marine transgression and deposition of lower Belcourt sediments during Asselian and Sakmarian time. The age of the lower Belcourt ranges from early to middle Asselian in western sections to late Sakmarian in eastern sections (Figs. 4, 5). Thus, the maximum time required for the Early Permian transgression in this area was approximately 13 million years, according to absolute age data presented by Ross (1970, p. 11, Fig. 1). The minimum time interval is unknown.

On a regional scale, the sub-Permian disconformity is one of the most widespread disconformities in the Cordillera. The associated conglomerate (Figs. 3, 4) is equally widespread and distinctive, and appears to represent a well-developed residual deposit. Deposition of the basal deposit was followed, in the Pine Pass-Kakwa River area, by a period of carbonate sedimentation during which the Belcourt carbonate sediments remained relatively free from influx of terrigenous clastics. The original extent of Belcourt carbonates to the south is unknown because of the erosional removal of the Belcourt Formation in the Jasper area prior to deposition of younger Permian sediments. Judging by the nature of the carbonates and the facies distribution within the Belcourt Formation, however, it originally may have been considerably more widespread than at present. There is no indication of proximity to a shoreline near the southern margin of existing Belcourt outcrops.

A third episode of exposure and erosion, probably of limited duration, is marked by the widespread intra-Permian disconformity, which is well documented from southeastern British Columbia to the southern Mackenzie Mountains. The associated, equally widespread phosphatic conglomerate appears to represent a lag deposit that was the initial phase of renewed shallow-marine sedimentation of the Ranger Canyon, Fantasque, and Mowitch Formations. This conglomerate is similar to that at the base of the Belcourt Formation, with the important difference that phosphatization and silicification processes were extremely active in the younger sequence (Rapson-McGugan, 1970).

A final period of exposure and erosion terminated the upper Paleozoic sequence of the eastern Cordillera. Guadalupian beds are overlain directly by the Triassic in most of this area (Fig. 3). No rocks of latest Permian age are known. The deepest, well-documented sub-Triassic erosion in the Rocky Mountains occurred locally within the Pine Pass-Kakwa River area. There, Lower Triassic beds rest directly on the basal conglomerate of the Lower Permian Belcourt Formation in the Hook Creek section (Fig. 1, Loc. 3), and on Lower Viséan beds of the Rundle Group in the Burnt River-Sukunka River area, east of locality 2. Thus, the study-area, which was affected in late Paleozoic time by all four of the disconformities discussed above, was subjected to particularly deep erosion in pre-Moscovian (pre-Hanington) time and, on a local scale, in latest Permian to earliest Triassic time.

Locality Number	Section Name	Location of section (Fig. 1)			HANINGTON FORMATION	BELCOURT FORMATION	RANGER CANYON FORMATION	FANTASQUE FORMATION	MOWITCH FORMATION
		Latitude and Longitude	Airphoto Number	Airphoto Co-ordinates*					
1	Mountain Creek	55°21′30″N 122°29′W	BC. 2136:51	BASE X=+7.0 Y=+6.95 TOP X=+7.3 Y=+5.1		138 m (452 ft)		31 m (102 ft)	
2	West Sukunka	55°04′30″N 121°59′W	BC. 2136:35	BASE X=+9.3 Y=-1.9 TOP X=+8.8 Y=-1.8	67 m (220 ft)	44 m (143 ft)		33 m (109 ft)	
3	Hook Creek	54°48′N 121°19′W	BC. 2016:105	X=-6.5 Y=+1.7		3.4 m (11 ft)			
4	Fellers Creek	54°42′30″N 120°57′30″W	BC. 2017:12	BASE X=+1.9 Y=+3.3 TOP X=+1.65 Y=+3.3		51 m (167 ft)			0.9 m (3 ft)†
5	Wapiti Lake	54°34′N 120°43′30″W	BC. 2017:19	BASE X=+0.7 Y=-5.85 TOP X=+0.5 Y=-5.85		29 m (95 ft)	1.8 m (6 ft)		
6	Mount Becker	54°31′30″N 120°39′W	BC. 2017:23	BASE X=+0.55 Y=+0.8 TOP X=+0.4 Y=+0.9		30 m (98 ft)	6 m (20 ft)		2.7 m (9 ft)
7	Belcourt Creek	54°22′N 120°29′30″W	BC. 2016:77	BASE X=-5.75 Y=-7.1 TOP X=-5.9 Y=-7.1		10 m (34 ft)			14 m (46 ft)
8	Mount Hanington	54°07′N 120°12′30″W	BC. 2124:12	BASE X=-7.95 Y=+4.1 TOP X=-8.2 Y=+4.2	5 m (17 ft)	3.8 m (12.5 ft)			22 m (71 ft)

* Determined with respect to centre of aerial photo with millimetre grid overlay (D.K. Norris, 1972).

† Formational assignment tentative - may represent eroded Ranger Canyon Formation.

GSC

TABLE 1. Section locations and thickness of formations.

TABLE 2. Location and stratigraphic data for GSC locality numbers

GSC loc.	Section	Formation	Height above base Feet	Metres
C-4548	Mountain Creek (Loc. 1)	Belcourt	417-424	127.2-129.3
C-4549	Mountain Creek (Loc. 1)	Belcourt	382	116.5
C-4552	Mountain Creek (Loc. 1)	Belcourt	319	97.3
C-4553	Mountain Creek (Loc. 1)	Belcourt	254	77.5
C-4555	Mountain Creek (Loc. 1)	Belcourt	199	60.7
C-4575	West Sukunka (Loc. 2)	Hanington	18-21	5.5-6.4
C-4576	West Sukunka (Loc. 2)	Hanington	41-42	12.5-12.8
C-4577	West Sukunka (Loc. 2)	Hanington	44-46	13.4-14
C-7323	Hook Creek (Loc. 3)	Belcourt	5	1.5
C-7324	Fellers Creek (Loc. 4)	Belcourt	118	36
C-7325	Fellers Creek (Loc. 4)	Belcourt	92	28.1
C-7326	Fellers Creek (Loc. 4)	Belcourt	94	28.7
C-7327	Fellers Creek (Loc. 4)	Belcourt	94 (talus)	28.7
C-7328	Fellers Creek (Loc. 4)	Belcourt	44	13.4
C-7329	Fellers Creek (Loc. 4)	Belcourt	39	11.9
C-7331	Fellers Creek (Loc. 4)	Belcourt	2-17	0.6-5.2
C-7378	Mount Becker (Loc. 6)	Belcourt	51	15.6
C-7385	Belcourt Creek (Loc. 7)	Belcourt	29	8.8
C-7386	Belcourt Creek (Loc. 7)	Belcourt	18-19	5.5-5.8
C-7387	Belcourt Creek (Loc. 7)	Belcourt	15-16	4.6-4.9
C-7388	Belcourt Creek (Loc. 7)	Belcourt	12	3.7
C-7389	Belcourt Creek (Loc. 7)	Belcourt	8	2.4
C-7390	Belcourt Creek (Loc. 7)	Belcourt	6	1.8
C-7391	Belcourt Creek (Loc. 7)	Belcourt	4	1.2
C-7392	Belcourt Creek (Loc. 7)	Belcourt	2	0.6
C-7393	Belcourt Creek (Loc. 7)	Belcourt	8 (rubble)	2.4
C-7415	Mount Hanington (Loc. 8)	Belcourt	0.5-1.5	0.2-0.5
C-7416	Mount Hanington (Loc. 8)	Hanington	6	1.8
C-7417	Mount Hanington (Loc. 8)	Hanington	3.5	1.1
C-7426	Wapiti Lake (Loc. 5)	Belcourt	45	13.7
C-39025	Mountain Creek (Loc. 1)	Belcourt	239-259	72.9-79
C-39034	Mountain Creek (Loc. 1)	Belcourt	3	0.9
C-39073	West Sukunka (Loc. 2)	Hanington	37	11.3
C-39074	West Sukunka (Loc. 2)	Hanington	37-41	11.3-12.5
C-39076	West Sukunka (Loc. 2)	Hanington	48-100	14.6-30.5
C-39083	West Sukunka (Loc. 2)	Belcourt	34-38	10.4-11.6
C-39144	Fellers Creek (Loc. 4)	Belcourt	136-167	41.5-50.9
C-39145	Fellers Creek (Loc. 4)	Belcourt	116-136	35.4-41.5
C-39149	Fellers Creek (Loc. 4)	Belcourt	19-49	5.8-14.9
C-39220	Belcourt Creek (Loc. 7)	Mowitch	34-46	10.4-14
C-39314	Mount Hanington (Loc. 8)	Mowitch	2-12	0.6-3.7
C-39315	Mount Hanington (Loc. 8)	Mowitch	0-2	0-0.6
C-39318	Mount Hanington (Loc. 8)	Belcourt	0-1.5	0-0.46
C-39349	West Sukunka (Loc. 2)	Fantasque	29-49	8.8-14.9
C-39360	Fellers Creek (Loc. 4)	Belcourt	0-19	0-5.8
C-44553	Mount Hanington (Loc. 8)	Hanington	15-16	4.6-4.9
C-44555	Mount Hanington (Loc. 8)	Hanington	13-14	4-4.3
C-44556	Mount Hanington (Loc. 8)	Hanington	12-13	3.7-4
C-44560	Mount Hanington (Loc. 8)	Hanington	8-9	2.4-2.7
C-44562	Mount Hanington (Loc. 8)	Hanington	7	2.1
C-44563	Mount Hanington (Loc. 8)	Hanington	6.25	1.9
C-44564	Mount Hanington (Loc. 8)	Hanington	5.5	1.7
C-44565	Mount Hanington (Loc. 8)	Hanington	4-5	1.2-1.5
C-44566	Mount Hanington (Loc. 8)	Hanington	4	1.2
C-44567	Mount Hanington (Loc. 8)	Hanington	3-4	0.9-1.2
C-44568	Mount Hanington (Loc. 8)	Hanington	3.5	1.1
C-44570	Mount Hanington (Loc. 8)	Hanington	1-2	0.3-0.6
C-44591	West Sukunka (Loc. 2)	Hanington	0-5	0-1.5
C-44592	West Sukunka (Loc. 2)	Hanington	25-37	7.6-11.3
C-44594	West Sukunka (Loc. 2)	Hanington	64-82	19.5-25
C-44596	West Sukunka (Loc. 2)	Belcourt	0-1	0-0.3
C-44599	West Sukunka (Loc. 2)	Belcourt	19	5.8

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