PHOSPHATE INVENTORY: NORTHEASTERN BRITISH COLUMBIA*

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KEYWORDS: Economic geology, phosphate, Kechika Formation, Road River Formation, Fantasque Formation, Sulphur Mountain Formation, Toad Formation, Grayling Formation, Fernie Formation, carbonatites.

INTRODUCTION

The study of phosphate deposits in British Columbia continued through 1987 with the fieldwork component concentrating on marine strata in the northeastern corner of the province. Triassic rocks between Kakwa Lake and the Alaska Highway west of Fort Nelson were the main focus of this work. Permian strata along this same trend, and Cambrian to Lower Ordovician rocks in the Mount Sheffield – Grey Peak area to the west, were also the subject of field reconnaissance. Twenty-seven sample sites representing 14 localities along this sedimentary belt were examined (Figure 3-7-1).

In the Wells-Barkerville area east of Quesnel, the Black Stuart Formation of Ordovician-Mississippian age and associated volcaniclastic rocks of the Waverly member of the Devonian Guyet Formation were also investigated for their phosphate potential. Locally these rocks contain anomalous phosphate concentrations. Ten localities were sampled in this area.

Two apatite-bearing carbonatite localities were also visited (Figure 3-7-1), the Aley carbonatite north of Mackenzie and the Verity carbonatite north of Blue River.

Samples collected during the field season are being analysed for phosphate, zinc, uranium, vanadium, yttrium, lanthanum and cerium. In addition, petrographic studies and whole-rock and trace-element analyses are being done on selected specimens. Samples from the Wells-Barkerville area will also be analysed for precious metals, base metals and barite.

This is the third in a series of reports on phosphate deposits in British Columbia. The reader is referred to *Geological Fieldwork, 1986*, Paper 1987-1 and Open File 1987-16 for descriptions of phosphate deposits in southeastern British Columbia.

Phosphate terminology used in this report is defined as follows:

Phosphorite: A sedimentary rock composed principally of phosphate minerals. In this report it is applied to those rocks having a pelletal texture and containing greater than 7 per cent P_2O_5.

Phosphatic: A sedimentary rock containing phosphate minerals and in which the phosphate content ranges from 2 to 5 per cent P_2O_5.

Pellet: Phosphate grain less than or equal to 2.0 millimetres in size.

Nodule: Phosphate grain greater than or equal to 1.0 centimetre in size.

REGIONAL GEOLOGY

Phosphate deposits in the Rocky Mountains of northeastern British Columbia occur in a sequence of marine strata ranging in age from Cambrian to Jurassic (Figure 3-7-2). These beds were deposited in a miogeosynclinal environment along the western edge of the stable craton. Depositional environments varied from platformal to basinal with phosphate occurring most often in a platformal or shelf-edge environment similar to that in southeastern British Columbia (Butrenchuk, 1987).

Cambrian to Mississippian strata consist of shallow-marine carbonate assemblages that pass westward into a more basinal limestone, shale and siltstone facies (Cecile and Norford, 1979; McMechan, 1987). These rocks are host to several stratabound lead-zinc-barite deposits. The upper Paleozoic sequence consists of chert and fine-grained clastic rocks that unconformably overlie the lower Paleozoic sequence.

Mesozoic strata, consisting dominantly of fine-grained clastic sediments, unconformably overlie the Paleozoic sequence. During the Early Triassic, there was a marine transgression over Paleozoic strata between the Liard and Peace rivers. Deposition was continuous through the Toad Formation and continued into the Liard Formation (Douglas *et al.*, 1970). South of Pine Pass, in the vicinity of Wapiti Lake (Figure 3-7-3), there appears to have been a disconformity of short duration between the Vega-Phroso and Whistler members of the Sulphur Mountain Formation, and phosphorite approaching economic grade was deposited above it.

Structurally this region of the province is characterized by broad open folds and westerly dipping thrust faults. There is also a general thinning of stratigraphic units eastward.

STRATIGRAPHY: PHOSPHATIC UNITS IN THE ROCKY MOUNTAINS

CAMBRIAN-ORDOVICIAN

UPPER CAMBRIAN

Investigation of Upper Cambrian strata was restricted to the Mount Sheffield area. Lithologies consist of fine-grained sandstone, shale and siltstone. These strata are thin to medium bedded and weakly calcareous. Present at this locality is a grey calcareous siltstone that contains lenses of phosphatic material. The stratigraphic position of this unit may be in the uppermost section of the Upper Cambrian sequence or in the lower part of the Kechika Formation.

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British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1987, Paper 1988-1.

Age	Formation (Thickness, Metres)		Lithology	Phosphate
Cretaceous	Monteith (700)		Sandstone, minor shale; marine	
Jurassic	Fernie (350)		Shale, siltstone, minor limestone and sandstone; marine Unconformity	As phosphatic limestone of the Nordegg member of Sinemurian age – reported as far north as Wapiti River (Irish, 1970)
Upper Triassic	Baldonnel (155)		Limestone, dolomite, siltstone, sandstone; marine	
	Charlie Lake (290)		Silty dolomite, dolomitic siltstone, sandstone; marine	
Middle and Upper Triassic	Ludington (400)		Dolomitic to calcareous siltstone, limestone; marine	
	Liard (450)		Dolomitic to calcareous sandstone and siltstone, dolomite, limestone; marine	
Lower and Middle Triassic	Toad (300) (Sulphur Mountain Formation)	Llama member (60-350) Whistler member (30)	Calcareous siltstone, silty limestone, silty shale, siltstone, minor sandstone; carbonaceous siltstone and shale; marine	1-1.5-metre-thick pelletal and nodular phosphorite bed at base of Whistler; also phosphatic limestone and siltstone
			Local disconformity at base of Whistler	Phosphate nodules in beds 1-3 metres thick over stratigraphic intervals of 20-200 metres; also phosphatic siltstone and shale; minor pelletal phosphate north of Richards Creek
	Grayling (75) (Sulphur Mountain Formation)	Vega-Phroso member (50-250)	Unconformity	Minor phosphate in the upper part of the Vega-Phroso member and lower part of the Llama member; minor phosphate in upper part of Grayling Formation
Permian	Fantasque (10-40)		Chert, phosphatic chert, siltstone	Phosphatic nodules in siltstone (1 metre thick) near top of formation Cherts are weakly phosphatic
Pennsylvanian	Kindle Fm. (70)		Argillaceous limestone, shale, calcareous siltstone Unconformity	Phosphatic lenses in shale along the Alaska Highway
Mississippian Devonian	Flume		Limestone	30-centimetre-thick phosphate bed reported near Kakwa Lake
Lower Ordovician	Road River		Black shale, siltstone, limestone, minor dolomite; marine	Phosphatic siltstone in basal part of formation; also thin phosphatic shale beds higher in section
Lower Ordovician – Upper Cambrian	Kechika (1500)		Argillaceous, nodular limestone, minor shale; banded limestone; marine	Thin beds (5 centimetres) containing phosphatic fossil debris, pellets and microcrystalline phosphate (phosphate pavements) Parts of the nodular limestone phosphatic; thin veneer of phosphatic shale or limestone around nodules
Upper Cambrian			Shale, siltstone, argillaceous limestone	Thin beds containing phosphate lenses or nodules

Figure 3-7-2. Stratigraphy of phosphate-bearing formations in the Rocky Mountains of northeastern British Columbia.

KECHIKA FORMATION

Investigation of the Kechika Formation was restricted to the Grey Peak area. Previous work by Cecile and Norford (1979) has documented the presence of phosphate at various intervals in the upper part of the formation. Work was restricted to the uppermost unit (Unit OK4 of Cecile and Norford) of the Kechika Formation and lower units of the Road River Formation (Plate 3-7-1).

Cecile and Norford divided the Kechika Formation into five units. The lower two units consist of platy and arenaceous limestones and a putty grey-weathering, nodular, argillaceous limestone. A banded limestone overlies these units and is in turn overlain by a thick sequence of argillaceous, nodular calcilutite which is in excess of 500 metres thick in the Grey Peak area. This nodular unit can be traced southward into the Mount Selwyn area (MacIntyre, 1981, 1982; McMechan, 1987). The uppermost unit of the Kechika Formation consists of yellowish orange-weathering limestones. It was not observed at Grey Peak.

Cecile and Norford (1979) postulate that the Kechika Formation was deposited in a shelf-margin environment. From east to west, deposition took place at the edge of a subtidal carbonate platform, in a shelf facies, and in a deeper part of a shelf facies at Grey Peak. There is a corresponding increase in thickness of this formation westerly, toward the basin.

ROAD RIVER FORMATION

The Early to Late Ordovician Road River Formation consists primarily of black siltstone and shale, calcareous shale and minor limestone. In the Grey Peak area, fine siltstone and graptolitic shale conformably overlie nodular limestone of the Kechika Formation (Plate 3-7-1). The lowermost unit is approximately 60 metres thick and phosphatic throughout (Unit OR1 of Cecile and Norford). Locally, it contains glauconite. It is overlain by a nonphosphatic carbonate sequence which in turn is overlain by siltstone and shale. Phosphate occurs in thin (1-centimetre) beds throughout the basal portion of this upper clastic unit (Unit OR3 of Cecile and Norford).

The Road River Formation was deposited in a basinal environment. The basal Road River represents a period of slow sedimentation as evidenced by the presence of phosphate and glauconite.

PERMIAN

KINDLE FORMATION

The Kindle Formation outcrops in a belt along the western Rocky Mountains from the Halfway River northwards to the Toad River. Better exposures occur between the Racing and Toad rivers (Taylor and Stott, 1973). The formation also crops out along the Alaska Highway near Summit Lake.

This formation, comprising a sequence of siltstone, shale, siliceous limestone and chert, unconformably overlies older strata and is unconformably overlain by the Fantasque Formation. It is 90 to 205 metres thick, with the variation in thickness being due to erosion prior to deposition of the overlying Fantasque Formation.

FANTASQUE FORMATION

The Fantasque Formation of Permian age outcrops in a discontinuous band from north of Kakwa Lake into the Yukon Territory. It disconformably overlies younger Permian strata and is unconformably overlain by Triassic rocks. It consists primarily of chert with minor interbedded siliceous mudstone and siltstone. The chert is medium to dark grey in colour, locally pyritic, contains sponge spicules and very often is weakly phosphatic. The top of the formation is marked by a siltstone bed, approximately 1 metre thick, containing phosphate nodules. This phosphate-bearing bed was not observed at all Permian localities investigated.

In the Wapiti Lake area, McGugan and Rapson assign the chert to the Ranger Canyon Formation and the overlying sandstone to the Mowitch Formation. It is this sandstone bed that contains the phosphate nodules. The depositional environment is considered to be shallow water near the eastern shoreline of the basin (McGugan and Rapson, 1964).

TRIASSIC

Triassic strata in northeastern British Columbia outcrop in a north-northwest-trending belt from north of Kakwa Lake into the Yukon Territory (Figure 3-7-3). Fieldwork in 1987 focused on Lower and Middle Triassic rocks in which phosphate has been reported by Gibson (1971, 1972, 1975) and Pelletier (1961, 1963, 1964). The Sulphur Mountain Formation south of Pine Pass and the Toad and Grayling formations north of Pine Pass were of particular interest.

Triassic sedimentation took place on a stable shelf characterized by a pattern of embayments and platforms (McCrossan and Glaister, 1964). A minor embayment, flanked to the south by the Wapiti platform and to the north by the Nig Creek platform, developed south of Fort St. John during the Early Triassic (McCrossan and Glaister, 1964) (Figure 3-7-4). These conditions prevailed into the early Middle Triassic and probably exerted some control on phosphate deposition.

SULPHUR MOUNTAIN FORMATION

The Early to Middle Triassic Sulphur Mountain Formation is subdivided into the Vega-Phroso, Whistler and Llama members. The formation consists of shale, siltstone and limestone and exhibits a general thickening westward. The Whistler member is absent in southeastern British Columbia.

Vega-Phroso Member

The Vega-Phroso member of Early Triassic age unconformably overlies Permian strata. It is typically a flaggy, brownish weathering unit consisting of grey siltstone and calcareous siltstone with minor shale and bioclastic limestone. Thin phosphatic beds (10 to 20 centimetres) occur locally in the upper part of the section. The unit varies from 80 to 270 metres in thickness.

Whistler Member

The Whistler member, which overlies the Vega-Phroso member disconformably, is a recessive unit, 20 to 85 metres thick, consisting of grey-weathering, dark grey siltstone,

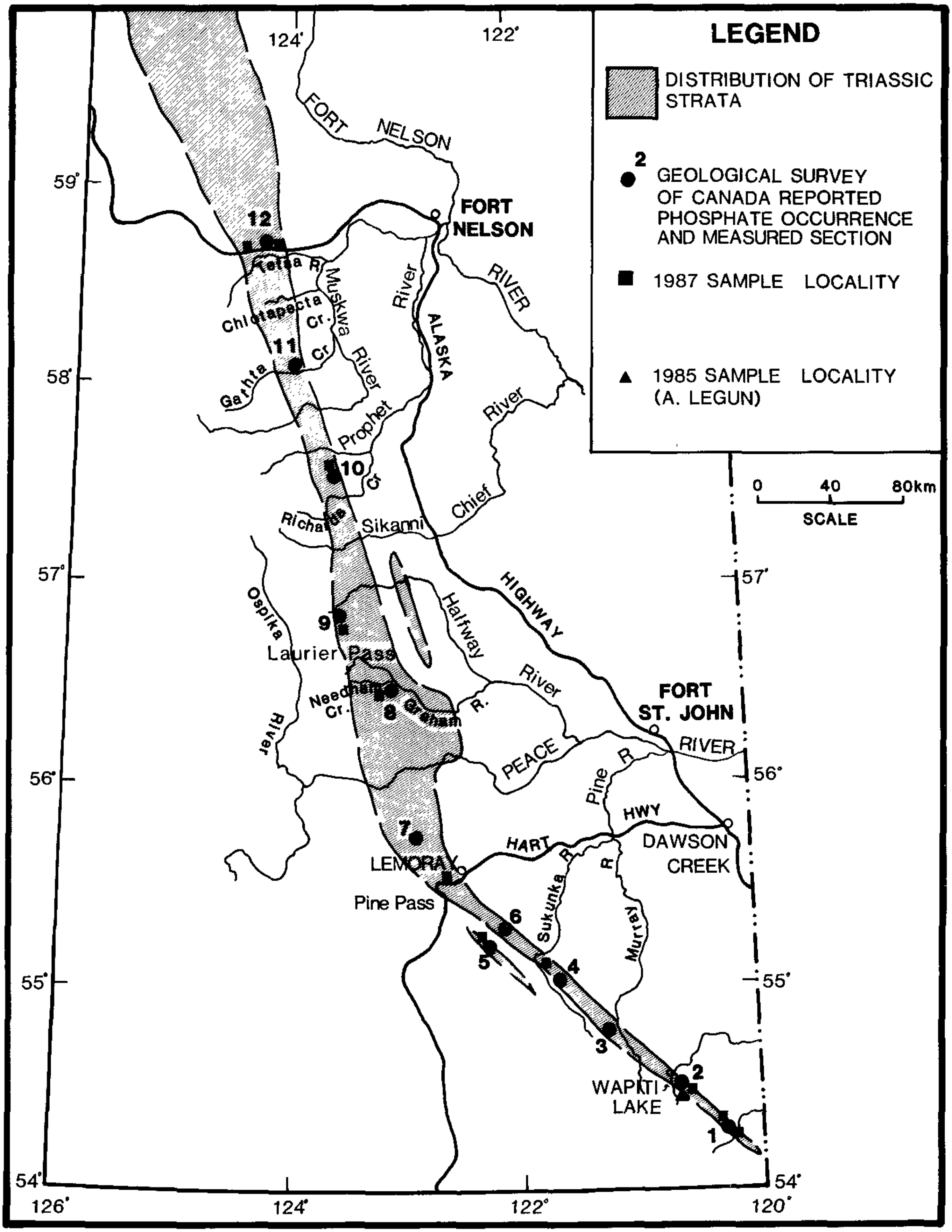

Figure 3-7-3. Distribution of Triassic strata in northeastern British Columbia.

shale and limestone. At most localities its lower contact is marked by the presence of a thin phosphorite bed that may contain a thin basal phosphatic conglomerate. This basal conglomerate was not observed in sections measured at Meosin Mountain but was observed in the Wapiti Lake area. Gibson (1975) suggests that the better phosphate occurrences are associated with "shelf" or thinning trends. These thinning trends may reflect areas of nondeposition or extremely slow sedimentation where phosphate deposition was not diluted by detritus. There may also have been some winnowing of detrital material resulting in higher phosphorite concentrations.

Llama Member

The Llama member is a resistant sequence of dolomitic quartzitic siltstone and limestone with minor sandstone and dolostone conformably overlying the Whistler member. It varies in thickness from 60 to 360 metres. Phosphate is reported in the lower part of this unit from a single section measured at Meosin Mountain (Gibson, 1972).

Grayling Formation

The Grayling Formation comprises strata of Early Triassic age north of Pine Pass and is correlatable with the lower part of the Vega-Phroso member of the Sulphur Mountain Formation. It consists of recessive, flaggy argillaceous siltstone, dolomitic siltstone and silty shale. Locally, strata containing phosphate nodules are present in the upper part of the formation. The Grayling Formation unconformably overlies strata of Permian or Mississippian age and is conformable with the overlying Toad Formation, but is not always present.

Toad Formation

The Toad Formation comprises Early to Middle Triassic strata north of Pine Pass. It is correlatable with the upper Vega-Phroso, Whistler and lower Llama members of the Sulphur Mountain Formation. Typically this formation consists of grey to dark grey-weathering, generally dark grey siltstone, shale, calcareous siltstone and silty limestone, most of which are weakly to moderately carbonaceous. The unit varies in thickness from 155 to 820 metres with an average thickness slightly in excess of 300 metres.

Phosphate occurs in numerous beds throughout the middle part of the Toad Formation. The phosphate-bearing interval varies in thickness from a few tens of metres to approximately 290 metres. The basal part of the phosphatic section generally contains calcareous, ovoid concretions several centimetres in diameter. Phosphate is present as nodules, phosphatic lenses, phosphate cement and occasionally as pellets and phosphatized fossil debris. Phosphorite is rare or absent.

Overlying the Toad Formation are clastic and carbonate strata of the Liard Formation or carbonate and fine-grained clastic strata of the Ludington Formation (Plate 3-7-2).

JURASSIC

Fernie Formation

The outcrop of Jurassic Fernie Formation parallels Triassic strata from the Kakwa Lake area to the Sikanni Chief River where it pinches out. Exposures are restricted to the foothills area. North as far as Wapiti River the basal sequence (Nordegg member) consists mainly of black phosphatic limestone. These strata are of Sinemurian age, similar to those in the Fernie Basin of southeastern British Columbia (Butrenchuk, 1987). In the Halfway River area, equivalent strata consist of recessive, fissile, dark grey to black calcareous shale (Irish, 1970) with no reported phosphate occurrences.

PHOSPHATE DEPOSITS

Unlike the southeastern corner of the province, there has been little exploration for phosphate in the Rocky Mountains of northeastern British Columbia. In 1967, KRC Inc. did some work on a phosphate occurrence at Lemoray in the Pine Pass area. Esso Minerals Canada carried out an extensive reconnaissance of the area between 1978 and 1980. In 1980 Esso completed an exploration program, including diamond drilling, on its Wapiti claim group southeast of Wapiti Lake. A. Legun investigated this property in 1985 on behalf of the Ministry of Energy, Mines and Petroleum Resources.

While phosphate occurs at several stratigraphic horizons, from early Paleozoic to Mesozoic, only Triassic occurrences appear to have possible economic significance.

CAMBRIAN-ORDOVICIAN

At Mount Sheffield, strata of Late Cambrian age contain nodular phosphate beds varying in thickness from 1 to 5 centimetres. The nodules are black, irregular to ovoid, 3 to 5 millimetres in size and constitute 20 to 80 per cent of the rock by volume. Cecile and Norford (1979) report the presence of phosphate nodules as large as 0.5 to 1.0 centimetre. Their work indicated that the phosphate horizons lie 220 to 120 metres below the base of the Kechika Formation.

A siltstone unit containing the phosphatic lenticles occurring higher in the sequence and not previously documented was also observed at this locality. The lenticles are 5 to 20 centimetres thick and black in colour, in contrast to the grey calcareous siltstone host. Bedding planes are often marked by pyrite bands, 1 to 2 millimetres thick. This unit is located either immediately below or in the basal part of the Kechika Formation.

Thin phosphate beds occur at five horizons in the upper 100 metres of the nodular limestone unit of the upper Kechika Formation in the vicinity of Grey Peak. Phosphate is present as microcrystalline coatings, 1 to 10 millimetres thick, around limestone nodules, and as phosphatized fossil debris in beds 5 to 50 centimetres thick. Some pelletal and oolitic phosphate is also present. The phosphatic beds are recognized by their blue-weathering surfaces and black colour contrasting with the pale grey of the host limestone. Also present, but not obvious, are thin phosphatic coatings,

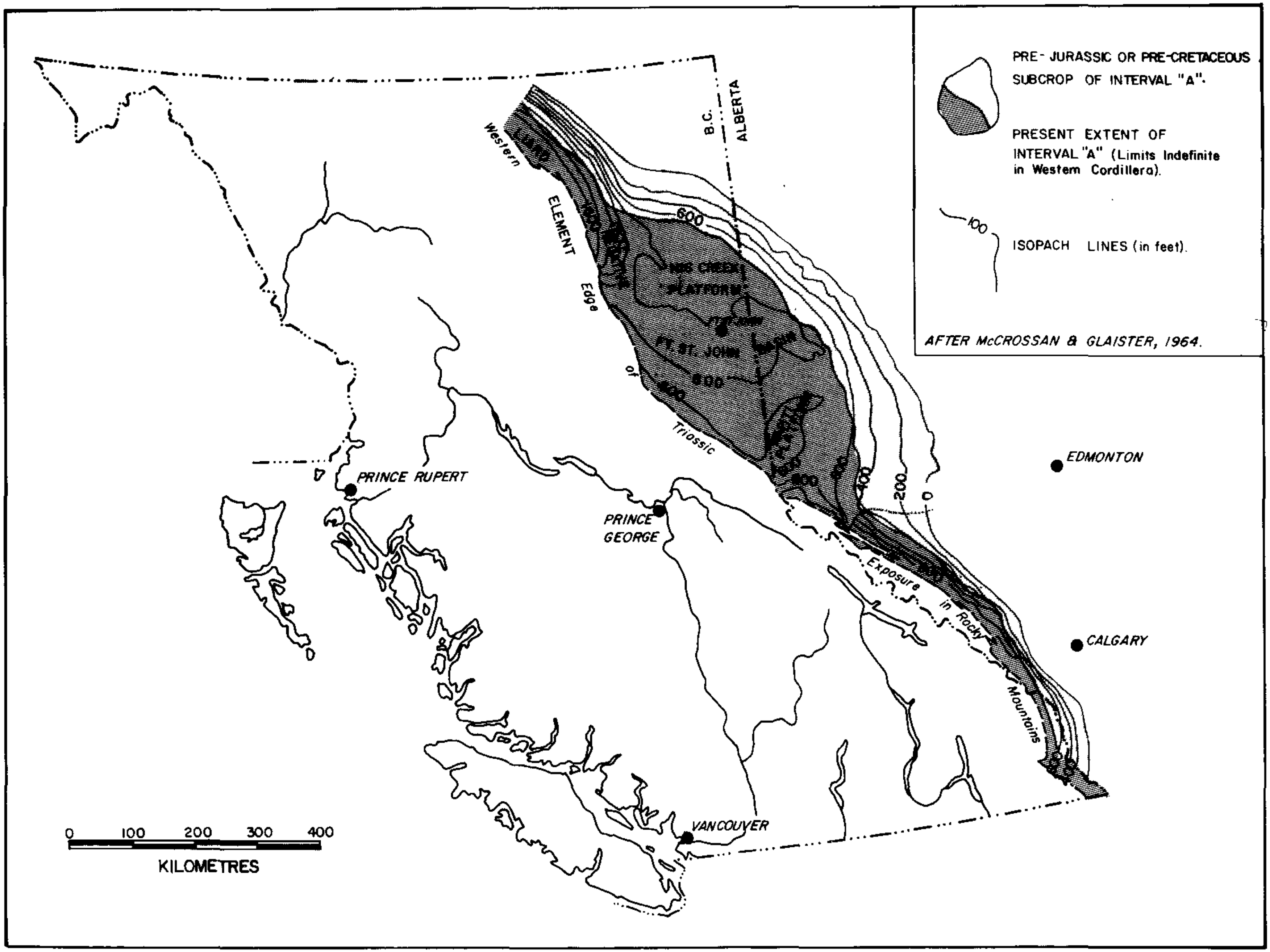

Figure 3-7-4. Interpretative map of the Early Triassic.

Plate 3-7-1. Section through Upper Kechika Formation (K) and Lower Road River Formation (RR) at Grey Peak in Kwadacha Park.

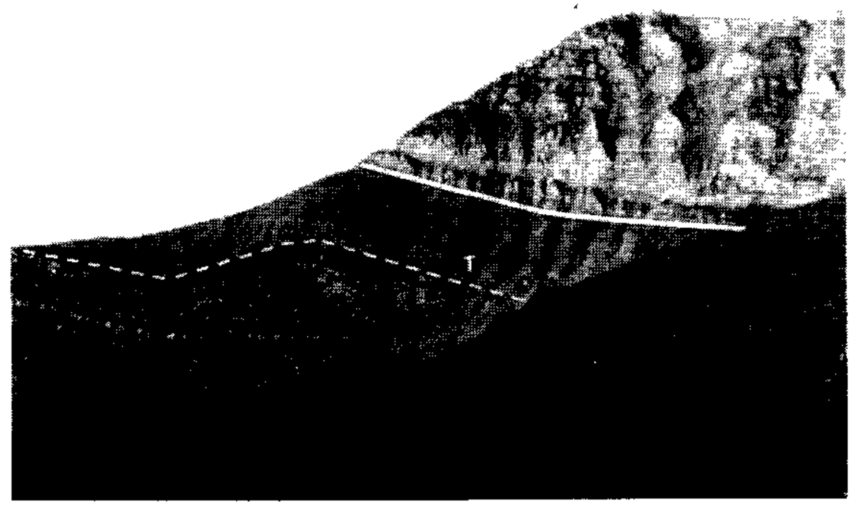

Plate 3-7-2. Section through Upper Toad Formation (T) and Lower Ludington Formation (Lud) at Mount Ludington . Dashed line marks the top of the phosphatic sequence.

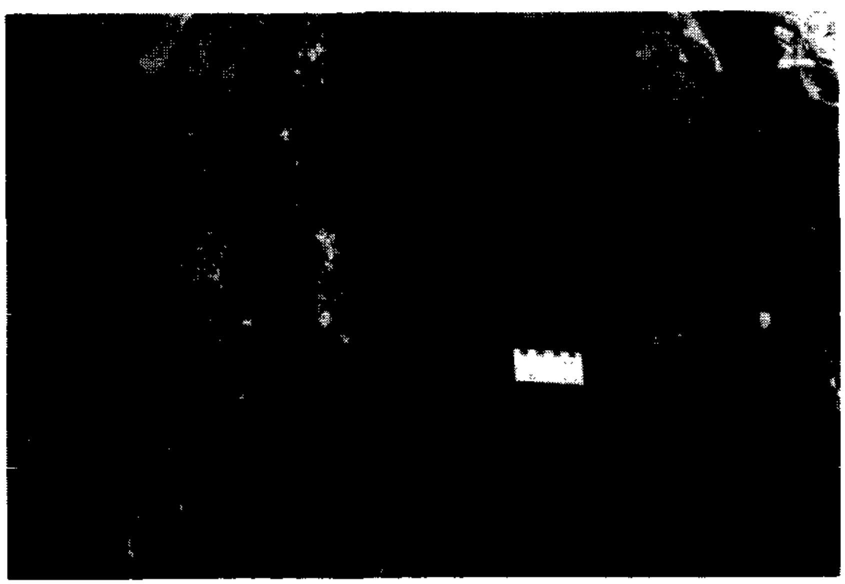

Plate 3-7-3. Phosphate nodules and lenses in phosphatic siltstone of the Toad Formation north of Laurier pass.

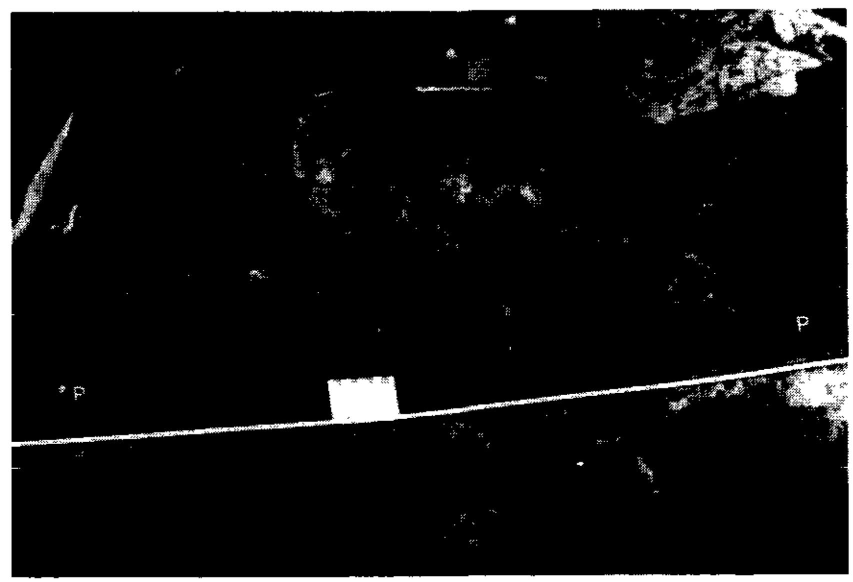

Plate 3-7-4. Phosphorite bed (P) in Toad Formation along the Alaska Highway north of the Tetsa River.

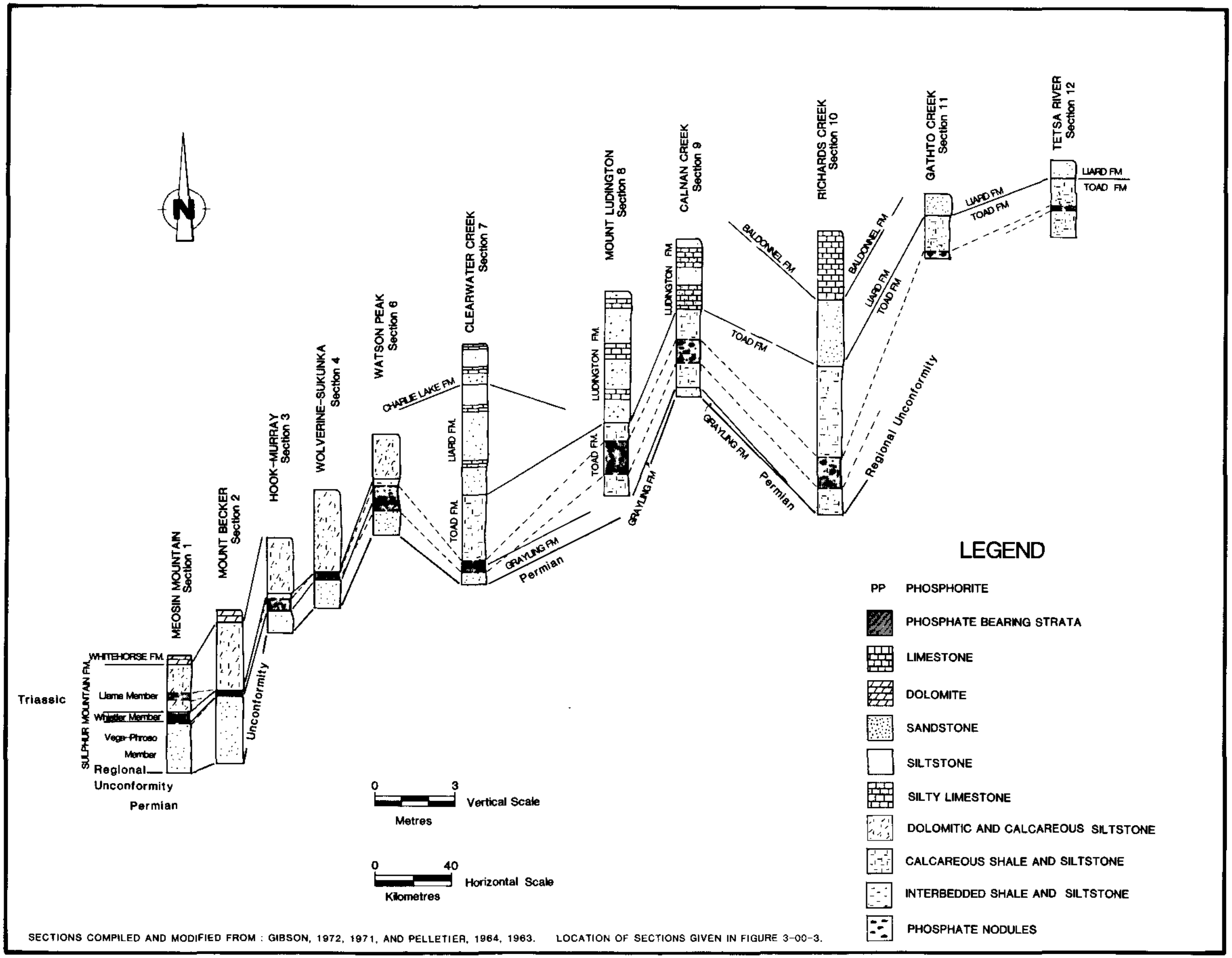

Figure 3-7-5. Stratigraphic correlation of phosphate-bearing strata in the Triassic of northeastern British Columbia.

1 millimetre or less in thickness, surrounding limestone nodules in beds 2 or more metres thick. Phosphate also occurs at several horizons in the lower banded limestone unit. Cecile and Norford (1979) describe these lower phosphate occurrences as "sea floor pavements or lag deposits".

Very fine-grained phosphate clasts, sometimes associated with glauconite, are disseminated throughout the shale and fine siltstones of the Road River Formation.

PERMIAN

Phosphate nodules occuring in a siltstone bed at the top of the Fantasque Formation were observed in the Burnt River area, south of Wapiti Lake and at Meosin Mountain. This siltstone bed is approximately 1 metre thick and contains 10 to 40 per cent nodules by volume. A. Legun (personal communication, 1987) obtained values of 6.8 and 16.2 per cent P_2O_5 across thicknesses of 63 and 34 centimetres respectively from samples collected from this bed in the Wapiti Lake area. This horizon was not observed at Richards Creek nor along the Alaska Highway. The author interprets this horizon to be correlative with a similar bed occurring at the top of the Ranger Canyon Formation in the vicinity of Connor Lakes (Butrenchuk, 1987).

Locally, along the Alaska Highway immediately east of Summit Lake, phosphate is present in the Kindle Formation. The phosphate is present as black, wispy lenses and laminations in a dark grey siliceous shale. Phosphatic chert is also present within the sequence which is restricted to the upper part of the formation.

At Mount Greene, north of the Peace River, phosphatic horizons were noted in strata underlying the Ranger Canyon Formation (McGugan, 1967). These rocks are tentatively correlated with the Kindle Formation (Bamber *et al.*, 1968) and are lithologically similar to the Johnson Canyon Formation that is host to several phosphate occurrences in southeastern British Columbia (Butrenchuk, 1987).

TRIASSIC

The majority of the known phosphate occurrences and phosphatic sediments occur in the Whistler member of the Sulphur Mountain Formation and in correlative rocks of the Toad Formation (Figure 3-7-5), both Anisian age. Phosphate is present in the Vega-Phroso and Llama members in only very minor amounts at a few localities. It is present in a variety of forms that include pelletal phosphorite, nodules, phosphate cement, phosphatic fragments or clasts and phosphatized fossil debris.

A phosphorite bed, occurring at or near the base of the Whistler member, extends from Meosin Mountain (Figure 3-7-5) to Watson Peak. At Meosin Mountain this phosphorite bed is 1.3 metres thick (Figure 3-7-6) and consists of both pelletal and nodular phosphate. South of Meosin Mountain this phosphorite passes into phosphatic, bioclastic and silty limestone and phosphatic calcareous siltstone (Figure 3-7-7). A single thin section of limestone from this location revealed that phosphate pellets 0.1 to 0.35 millimetre in size are dispersed throughout abundant fossil debris. Many of the pellets contain carbonate cores. North of Watson Peak, at Lemoray, a 1 to 2-centimetre phosphorite bed is present, but its exact stratigraphic position is uncertain.

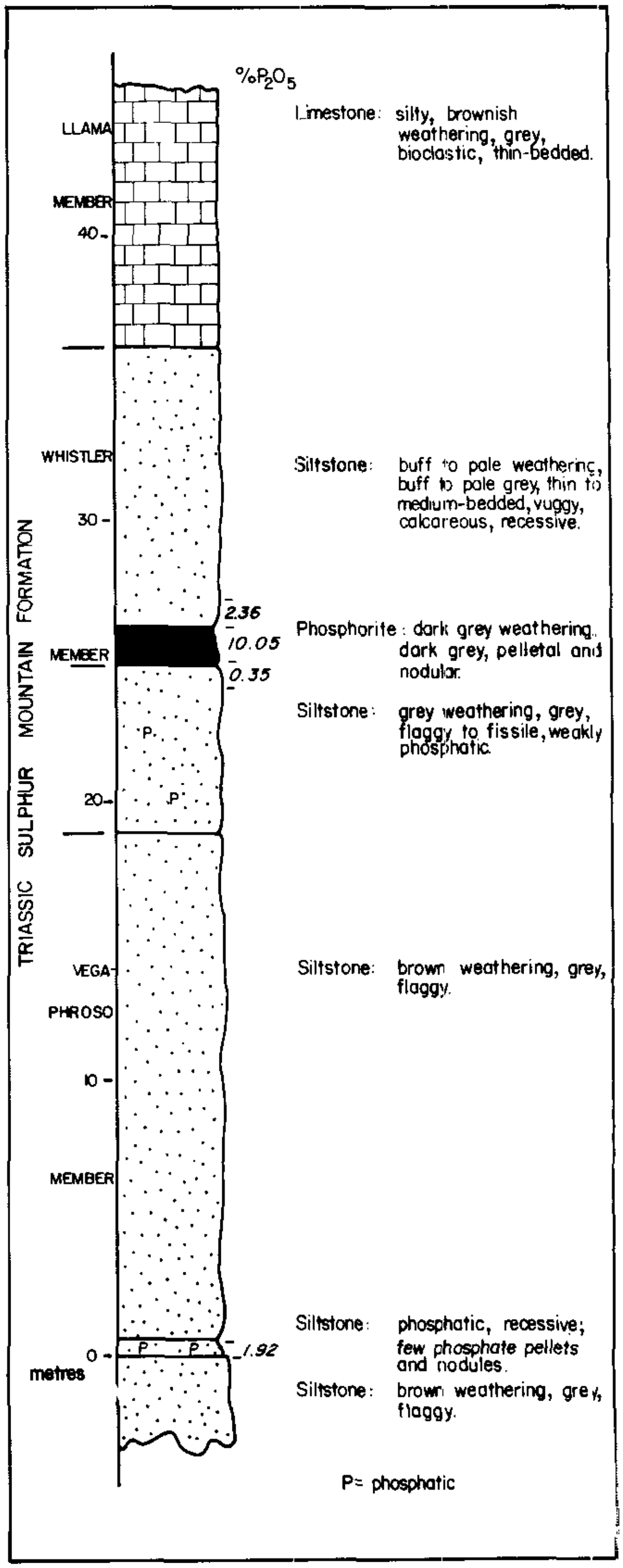

Figure 3-7-6. Section 87-6: Meosin Mountain north.

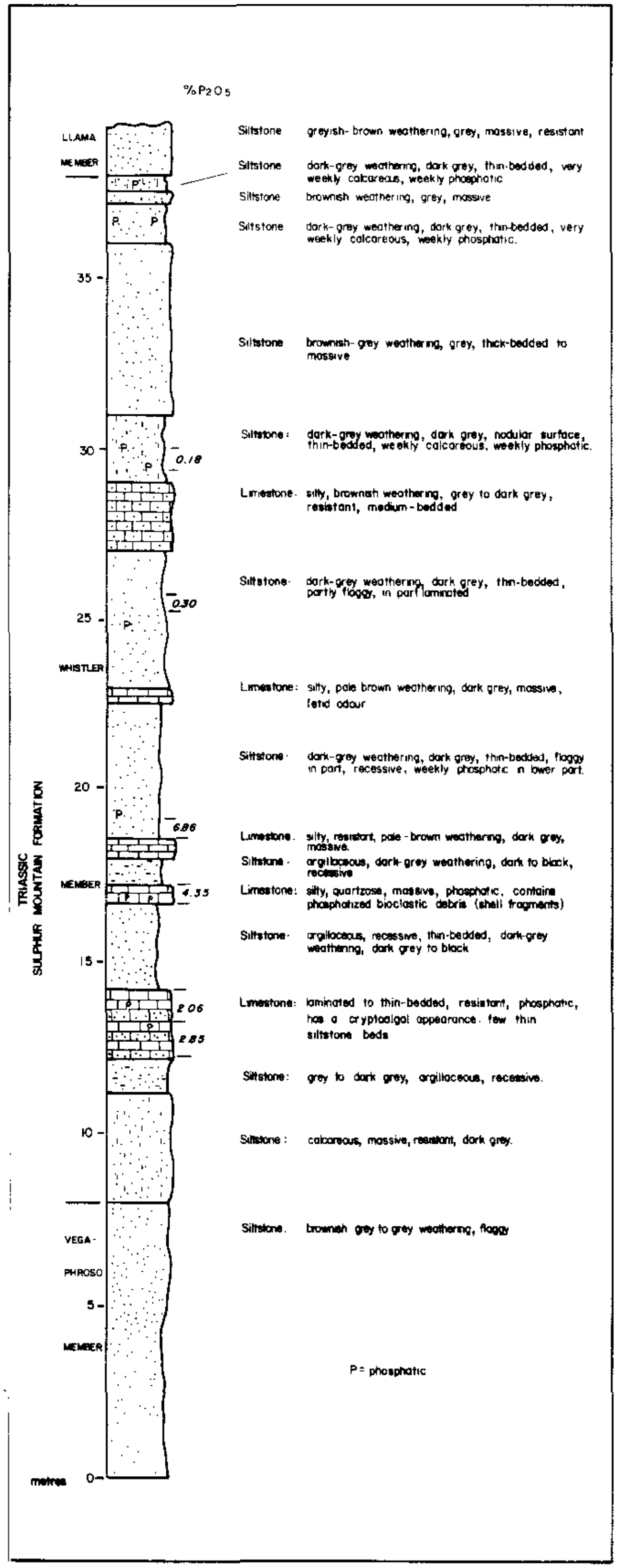

Figure 3-7-7. Section 87-7: Meosin Mountain south.

Near Wapiti Lake the Triassic sequence containing phosphorite has been folded into series of plunging folds. Here the phosphorite ranges in thickness from 0.8 to 3.2 metres with assays varying 11.9 to 23.7 per cent P_2O_5 (Heffernan, 1980; A. Legun, personal communication, 1987). The phosphorite which outcrops on a dip slope on the eastern limb of the Wapiti syncline, represented by an apparent exaggerated thickness of the phosphate horizon in Figure 3-7-8, is of particular significance. Mining of this bed could conceivably be done by open-pit methods with a relatively low stripping ratio. The base of the phosphorite bed is marked by a thin phosphatic conglomerate that varies in thickness from 5 to 20 centimetres. Analytical results are given in Tables 3-7-1 and 3-7-2 and sample locations are shown in Figure 3-7-8.

The phosphorite consists of pellets, together with a few oolites and nodules, in a carbonate-quartz matrix. Many of the pellets have an irregular carbonate core suggesting replacement of carbonate by phosphate. The cores also contain quartz, feldspar, shell fragments and rarely pyrite.

In contrast to the Wapiti Lake area, Triassic strata between Lemoray and the Alaska Highway do not contain any well-defined phosphorite beds. Phosphate is generally of the nodular type with phosphatic lenticles and sediments also present. Some pelletal material was observed immediately north of Richards Creek (*see* Figure 3-7-3).

TABLE 3-7-1
PHOSPHATE VALUES, WAPITI LAKE AREA

Sample No.	Average per cent P_2O_5	Thickness (metres)
TE-06	15.3	1.40
	or 11.9	or 3.19
TE-05	22.0	1.20
	or 18.6	or 1.56
TE-07	22.8	0.66
TE-01	21.4	0.73
85-26/2	14.8	0.94
85-23/3	20.9	0.94
85-23/1	6.8	0.63
TE-02	21.0	1.64
85-26/3	20.3	1.37
85-26/1	16.2	0.34
85-21/3	22.4	1.04
85-21/4	20.3	0.81
TL02	20.3	1.39
TL01	23.7	0.84
TG01	22.2	0.93
	or 14.4	or 1.84
TG02	23.6	0.99
	or 16.6	or 1.72
TR03	21.2	1.08
TR04	20.0	0.90
85-24/2	19.9	1.04
85-25/1	17.8	0.97
85-25/2	15.5	0.76
T6-03	17.9	1.42
85-23/4	14.8	0.46
TL-03	21.3	0.50
DDH 6-11,12	19.1	0.98
DDH 3-5,6	16.6	1.70

Note:

(1) All samples are Triassic Whistler member except 23/1 and 26/1 which are from Permian Mowitch Formation.

(2) Samples prefixed TE, TL, TG and TR are from Heffernan (1980); samples prefixed 85 are from Legun (personal communication, 1987).

(3) Thicknesses are those calculated by A. Legun.

TABLE 3-7-2.
WHOLE ROCK ANALYSES, WAPITI LAKE (A. LEGUN, 1985)
(Values in % unless otherwise indicated)

Sample Number	P_2O_5	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	S	F	Cd (ppm)	Pb (ppm)
85-21-3	22.33	8.17	0.80	0.39	0.56	49.40	0.34	0.35	0.09	0.018	0.34	2.31	14	15
85-21-4	20.29	9.31	1.00	0.52	0.64	48.72	0.40	0.40	0.08	0.021	0.33	2.49	10	15
85-23-1	6.83	76.13	0.88	1.26	0.14	10.87	0.08	0.29	0.06	0.008	0.08	0.56	3	8
85-23-3	20.30	16.32	2.09	1.06	1.07	42.82	0.54	0.80	0.21	0.020	0.36	2.12	3	12
85-23-4	14.81	18.16	2.14	0.82	2.11	40.73	0.48	0.84	0.18	0.024	0.28	1.62	1	0
85-24-2A	19.79	16.50	1.98	1.24	0.57	43.45	0.54	0.78	0.18	0.018	0.34	1.93	1	12
85-24-2B	20.08	11.13	1.11	0.45	1.21	45.96	0.36	0.43	0.11	0.014	0.42	2.19	21	12
85-24-2C	3.28	38.46	6.57	3.00	4.56	18.55	0.62	2.75	0.46	0.027	0.25	0.55	10	14
85-25-1A	17.82	15.28	1.78	0.99	0.93	45.17	0.52	0.66	0.16	0.019	0.37	1.78	12	13
85-25-1B	8.24	12.70	1.71	1.26	2.31	44.60	0.23	0.77	0.10	0.029	0.19	1.04	4	8
85-25-2	15.52	10.69	1.04	0.69	0.60	48.32	0.31	0.44	0.10	0.015	0.23	1.53	13	11
85-26-1	16.22	52.77	0.83	0.79	0.14	25.32	0.13	0.26	0.04	0.016	0.22	1.51	2	13
85-26-2	14.77	16.48	2.04	0.94	2.36	42.51	0.46	0.79	0.13	0.025	0.59	1.67	8	10
85-26-3	20.33	22.15	2.90	1.26	0.57	38.32	0.67	1.15	0.27	0.033	0.46	2.02	6	12
85-21-3D	22.54													

Localities at Mount Ludington, north of Laurier Pass, and Richards Creek were investigated. At Mount Ludington phosphate occurs over a stratigraphic interval of 150 metres in the middle Toad Formation (Plate 3-7-2) as nodules, phosphate-cemented siltstone, phosphatic lenticles and phosphatic fossil debris in a sequence of dark grey, weakly carbonaceous, calcareous siltstone and shale. Phosphate nodules are black, ovoid to spherical, 1 to 3 centimetres in size and comprise 5 to 20 per cent of the rock by volume. On weathered surfaces they stand out in relief. The lower part of the phosphate-bearing sequence is marked by the presence of large calcareous concretions and the upper limit by a change to less carbonaceous and more calcareous strata.

At a locality north of Laurier Pass and southeast of Calnan Creek, phosphate occurs over a stratigraphic interval of at least 100 metres. As at Mount Ludington, the dominant form of phosphate is nodular. Calcareous concretions occur in the lower part of the phosphatic sequence together with an abundance of phosphatic lenticles (Plate 3-7-3).

At Richards Creek the phosphatic section is 290 metres thick with phosphate nodules occurring in several beds over an interval of 220 metres. Unlike the previous two localities, calcareous concretions occur in the middle portion of the phosphatic sequence. Nodules remain the dominant form of phosphate, but thin beds of pelletal phosphate were also observed. These beds lie stratigraphically above strata containing the calcareous concretions. The pellets occur in a carbonate-rich matrix, with 10 to 20 per cent of the pellets containing either a quartz or carbonate core.

The northernmost Triassic exposures investigated are located along the Alaska Highway north of the Tetsa River. The presence of pelletal material and a thin phosphorite bed (Plate 3-7-4) within the Toad Formation is significant in this area. No nodules were observed at the phosphorite locality but were seen in outcrops to the west.

CARBONATITES

Carbonatites and related alkaline intrusives are the second most important source of phosphate worldwide, accounting for approximately 20 per cent of world reserves. In British Columbia phosphate-bearing carbonatites, two of which are the Aley and Verity, occur at a number of localities. In addition to phosphate these carbonatites represent potential sources of niobium, tantalum and rare earth elements.

The Aley carbonatite complex is described as an oval-shaped body, 3 to 3.5 kilometres in diameter, consisting of a dolomite-calcite carbonatite core with an outer ring of metasomatically altered syenite (Mäder, 1987). Apatite is present as fine-grained crystals and aggregates in both phases of the core but is more abundant in the calcite carbonatite. K.R. Pride (personal communication, 1987) suggests that the average grade of the carbonatite is approximately 5 per cent P_2O_5 representing approximately 10 per cent apatite. If the entire carbonatite core contains this amount of apatite then the Aley deposit may have a resource potential exceeding 15 billion tonnes at this grade.

Unlike the Aley complex, the Verity carbonatite is a tabular body that has undergone intense structural deformation (J. Pell, personal communication, 1987). Exploration of this deposit by Anschutz (Canada) Mining Limited (Aaquist, 1981) has indicated grades of 2 to 5 per cent P_2O_5 in the carbonatite. Apatite, occuring as subrounded grains 1 to 4 millimetres in diameter and in amounts up to 10 per cent by volume, is disseminated throughout the rock. The resource potential of this carbonatite is only a few million tonnes.

DISCUSSION

Phosphatic and associated siliceous sediments have generally been deposited at the structural hinge line between cratons and geosynclines (Sheldon, 1987). Deposition is episodic and generally takes place at paleolatitudes lower than 30 degrees (Christie, 1980). Sheldon postulates that there is an association between chert and phosphorite. This association is not necessarily one of coincidence but may be a geographic one.

An association between chert and phosphorite, although not always readily apparent, can be demonstrated for all the major phosphate occurrences in British Columbia. For the Permian this association is well documented both in the Phosphoria Formation of the Western United States and throughout the Ishbel Group in southeastern British

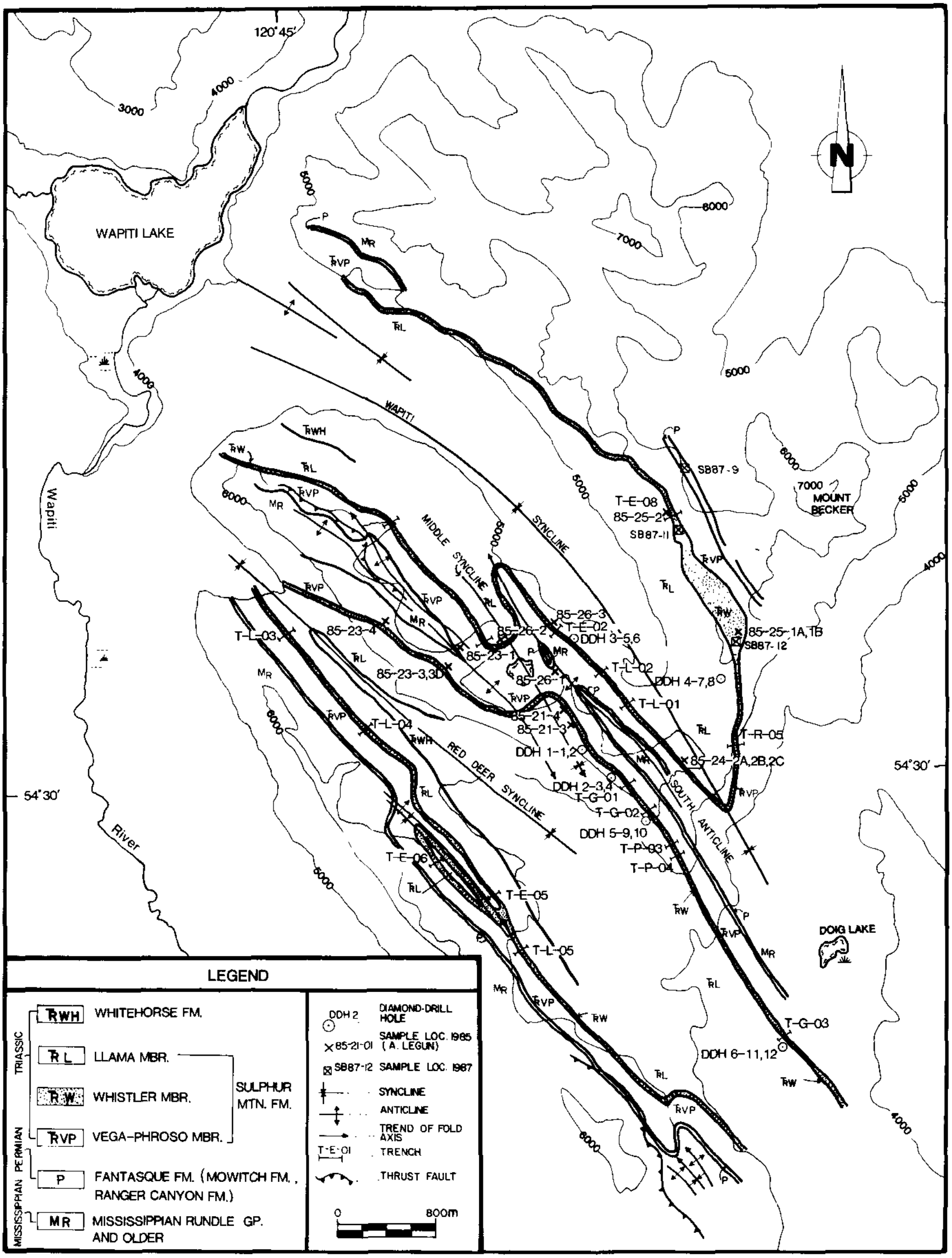

Figure 3-7-8. Geology of the Wapiti Lake area (modified from Hefferman, 1980 and Legun and Elkins, 1986.

Columbia and the Fantasque Formation in northeastern British Columbia. Similarly, both chert and phosphorite are present in the basal section of the Fernie Formation. In southeastern British Columbia the association between chert and phosphate is not readily apparent as chert was not observed during our study of this area. However, chert is present in equivalent strata of the Nordegg member of Sinemurian age in the northeast and in Alberta (MacDonald, 1985). MacDonald reports that phosphate is present below the Nordegg member and sporadically within it. In the Triassic, thin chert-pebble beds are reported along the eastern edge of the Doig Formation (McCrossan and Glaister, 1964). In thin section, minor chert is seen to be present in some of the siltstones of the Toad Formation.

Phosphate deposition is best developed in stable environments where the rate of sedimentation is very low. Thus telescoped stratigraphic sections often typify areas of good phosphorite. In British Columbia the majority of significant phosphorite deposits appear to have developed above unconformities during periods of marine transgressions.

In northeastern British Columbia significant phosphorite is restricted to Triassic strata between Lemoray and Meosin Mountain, north of the Wapiti platform. Here a small disconformity exists between the Vega-Phroso and Whistler members, while to the north deposition was continuous throughout the equivalent stratigraphic interval. A transgression began in early Whistler time and was accompanied by very slow sedimentation, allowing the development of the phosphorite bed. Paleogeographic reconstruction indicates that the Whistler member was deposited within 30 degrees of the paleoequator (Irving, 1979; MacDonald, 1985) while Triassic strata north of Lemoray were deposited further to the north. Theoretically we should not expect these more northerly exposures to contain extensive phosphorite deposits. However, although not abundant, phosphate deposits have also developed in more temperate climates. Phosphorite in the Jurassic Fernie Formation is an example of such a deposit. There are extensive nodular phosphate beds in the Toad Formation and the occasional thin phosphorite bed north of the Tetsa River. These occurrences also are interpreted to have formed in a temperate climate.

This study indicates that the area with the best phosphate potential is between Watson Peak and Meosin Mountain in strata of Middle Triassic (Anisian) age. There may also be some potential north of the Alaska Highway where thin phosphorite beds appear that are not present or only poorly developed to the south. Another potentially economic source of phosphate is the Aley deposit. Although it is presently being evaluated for its niobium potential it does contain a very large phosphate resource. In terms of contained P_2O_5 it may represent the second most important phosphate resource in British Columbia after the Fernie Formation.

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