British Columbia Geological Survey
Geological Fieldwork 1986

PHOSPHATE INVENTORY* (82G and J)

By S. B. Butrenchuk

INTRODUCTION

During the summer of 1986 the author began an investigation of phosphate deposits in southeastern British Columbia. Fieldwork consisted of examining approximately 80 phosphate localities in the area bounded by the Alberta-British Columbia boundary on the east, Fernie on the west, Kananaskis Lakes on the north and the Canada-United States border on the south. Samples were collected from 59 localities (Figure 4-6-1). Individual phosphate beds were chip sampled in intervals of 1 metre or less and strata above and below the phosphate were also sampled. Where outcrop was insufficient to permit chip sampling, grab samples of the phosphate were taken. Specimens were obtained from most localities for petrographic work and whole rock analyses. Stratigraphic sections were measured where there was sufficient exposure of the phosphate and enclosing strata.

Samples collected in the field are being analysed for phosphate copper, lead, zinc and arsenic at the Ministry of Energy, Mines and Petroleum Resources laboratory facilities in Victoria using X-ray fluorescent techniques and for phosphate using wet chemical techniques. In addition these samples will be analysed for uranium, vanadium and a number of rare earth elements.

REGIONAL GEOLOGY

Phosphate deposits in southeastern British Columbia occur in a sequence of marine strata ranging in age from Devonian to Jurassic (Figure 4-6-2). These strata lie within the thrust and fold belt of the Rocky Mountains and have generally been thrust eastward onto the craton. They have a complex depositional history that is recorded by a number of unconformities. Older strata in the sequence are primarily platformal carbonates of Devonian-Mississippian age, conspicuous by the their resistant cliff-forming appearance. During the Pennsylvanian-Permian, deposition of shallow marine fine clastic and carbonate strata took place under quiescent conditions (Douglas *et al.*, 1970). In this time period there were a number of marine transgressions and regressions. Triassic sediments are postulated to have been laid down during minor marine transgressions and regressions in a deltaic environment (Douglas *et al.*, 1970). A regional unconformity marks the contact between the Triassic and Jurassic. Jurassic shales were deposited in a moderately deep marine environment. Sedimentation gradually became nonmarine at the end of the Jurassic. The phosphate-bearing sequence is overlain by nonmarine Cretaceous strata that are host to extensive coal measures.

The geological structure of southeastern British Columbia is characterized by a number of southwest-dipping thrust faults that have displacements of up to 165 kilometres (MacDonald, 1985; Benvenuto and Price, 1979). These thrusts extend for many kilometres in a north-south direction. Folding in the area can be related to thrust faulting and stratigraphic sequences are often overturned. Much of the deformation has been absorbed by the Fernie Formation. Areas where phosphate beds have been thickened by repetitive thrust faulting are of particular significance.

STRATIGRAPHY: PHOSPHATIC UNITS

EXSHAW FORMATION

Exposures of Exshaw Formation are restricted to a narrow band in the Highrock Ranges north and south of Crowsnest Pass and locally southwest of Fernie. This is a distinctive, black shale unit that forms an excellent marker. Strata include black, thin-bedded to massive shale, limestone, phosphatic shale and phosphate. The thickness of this unit varies from 6 metres to 30 metres (Christie and Kenny, 1984).

Phosphate occurs at four horizons within the Exshaw Formation (MacDonald, 1985). A basal phosphate unit is present in sandstone overlying the top of the Palliser Formation. Three other phosphate horizons occur within the Exshaw section. They consist of pelletal and nodular phosphate and a fine-grained phosphorite and are best developed in the region north of the Crowsnest Pass (MacDonald, 1985; Kenny, 1977). Much of this section is located along the Alberta-British Columbia boundary or in Alberta.

ISHBEL GROUP

The Ishbel Group is comprised of four formations containing a number of phosphatic horizons. Phosphate is present in the Johnson Canyon, Ross Creek and Ranger Canyon Formations. The Telford Formation is nonphosphatic except for phosphate laminae and rarely a very thin phosphate bed.

This sequence of strata, consisting of fine-grained siltstone and sandstone, chert, carbonate and minor shale (McGugan and Rapson, 1962, 1964) increases in thickness from east to west. It is best developed in the Telford thrust plate where all four formations are present. Elsewhere only the Johnson Canyon and/or Ranger Canyon Formations are present.

JOHNSON CANYON FORMATION

The Johnson Canyon Formation, which unconformably overlies Kananaskis or Tunnel Mountain strata, consists of a series of thin to medium-bedded siltstones and sandstones with minor shale and chert. A phosphatic chert pebble conglomerate, a few centimetres thick, marks its base (MacRae and McGugan, 1977). Phosphate is present as black ovoid nodules or distinct horizons within sandstone or siltstone beds (Plate 4-6-1) as phosphate-cemented sandstone or in pelletal form. Phosphatic intervals range in thickness from less than 1 metre to a maximum of 22 metres in the Mount Broadwood area (Figure 4-6-3).

TELFORD FORMATION

The Telford Formation comprises a thick sequence of carbonates and sandy carbonates. These strata are resistant cliff-forming units that are preserved only in the Telford thrust plate (MacRae and McGugan, 1977). Phosphate is absent in the Telford Formation except for a few phosphatic laminae and a single phosphatic coquinoid bed (Plates 4-6-2 and 4-6-3).

* This project is a contribution to the Canada/British Columbia Mineral Development Agreement.

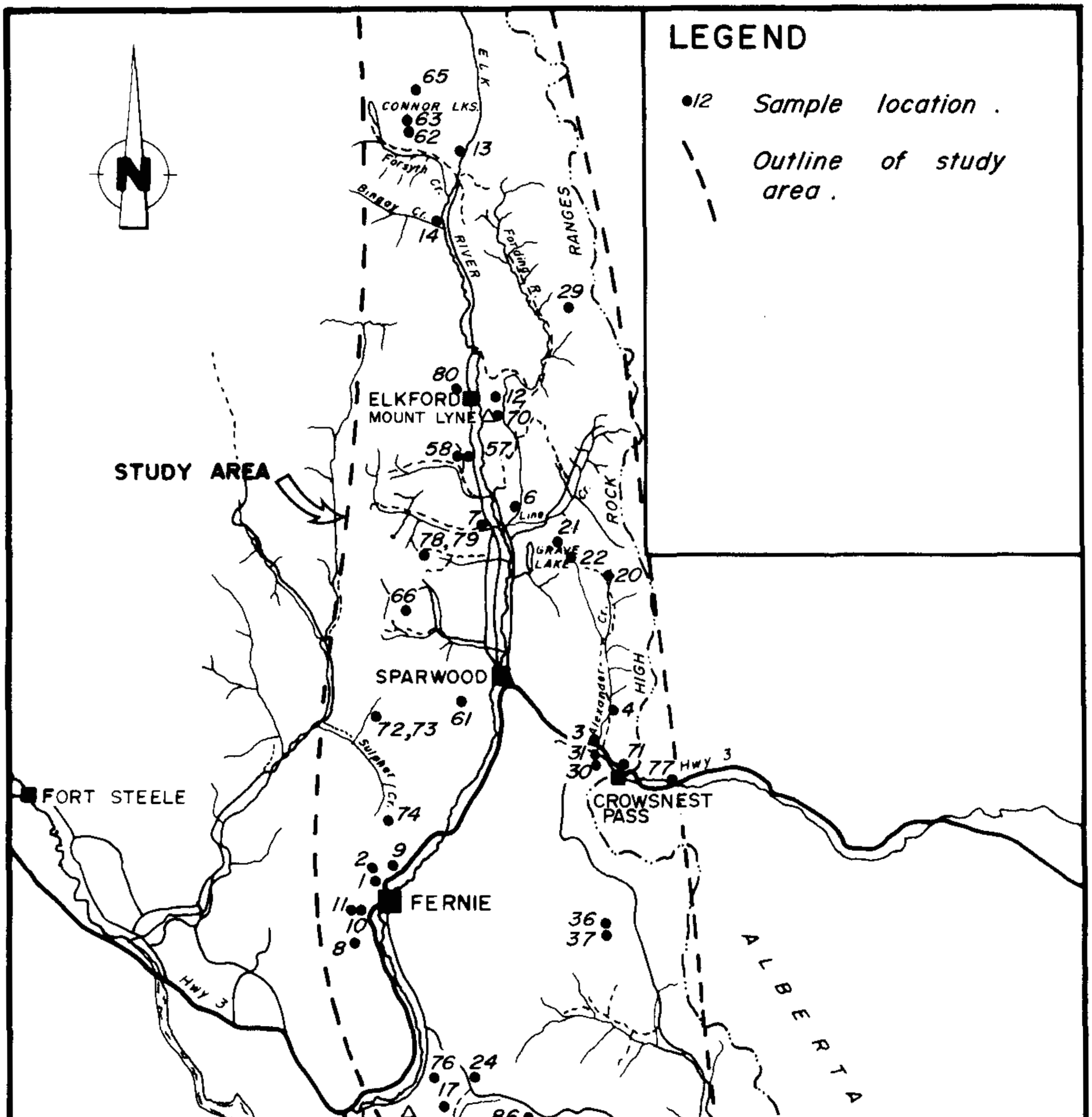

Figure 4-6-1. Sample location map.

Age	Group/ Formation (Thickness, Metres)		Lithology	Phosphate
Cretaceous	Kootenay Fm.		• grey to black carbonaceous siltstone and sandstone; nonmarine; coal	
Jurassic	Fernie Fm. (±244)		• black, shale, siltstone, limestone; marine to nonmarine at top • glauconitic shale in upper section • belemnites common fossil • rare calcareous sandstone • thin conglomerate may be present at base	• basal phosphate in Sinemurian strata; general pelletal/oolitic; rarely nodular; 1 to 2 metres thick; locally two phosphate horizons; top of phosphate may be marked by a yellowish-orange-weathering marker bed • approximately 60 metres above base — low-grade phosphate-bearing calcareous sandstone horizon or phosphatic shale
Triassic	Spray River Group	Whitehorse Fm.	• dolomite, limestone, siltstone	
	Spray River Group	Sulphur Mountain Fm. (100-496)	• grey to rusty brown-weathering sequence of siltstone, calcareous siltstone and sandstone, shale, silty dolomite and limestone	• nonphosphatic in southeastern British Columbia
Permian	Ishbel Group	Ranger Canyon Fm. (1-60)	• sequence of chert, sandstone and siltstone; minor dolomite and gypsum; conglomerate at base • shallow marine deposition	• basal conglomerate-chert with phosphate pebbles present (≤1 metre) • upper portion — brown, nodular phosphatic sandstone; also rare pelletal phosphatic sandstone (few centimetres to +4 metres)
	Ishbel Group	Ross Creek Fm. (90-150)	• sequence of siltstone, shale, chert, carbonate and phosphatic horizons areally restricted to Telford thrust sheet • west of Elk River, shallow marine deposition	• phosphate in a number of horizons as nodules and finely disseminated granules within the matrix • phosphatic coquinoid horizons present
	Ishbel Group	Telford Fm. (210-225)	• sequence of sandy carbonate containing abundant brachiopod fauna; minor sandstone • shallow marine deposition	• rare, very thin beds or laminae of phosphate; rare phosphatized horizon
	Ishbel Group	Johnson Canyon Fm. (1-60)	• thinly bedded, rythmic sequence of siltstone, chert, shale, sandstone and minor carbonate; basal conglomerate • shallow marine deposition	• basal conglomerate (maximum 30 centimetres thick) contains chert and phosphate pebbles • phosphate generally present as black ovoid nodules in light-coloured siltstone; phosphatic interval ranges in thickness from 1 to 22 metres • locally present as a black phosphatic siltstone
Pennsylvanian	Kananaskis Fm. (±55)		• dolomite, silty, commonly contains chert nodules or beds	
Mississippian	Rundle Group (±700)		• limestone, dolomite; minor shale, sandstone and cherty limestone	
Mississippian	Banff Fm. (280-430)		• shale, dolomite, limestone	
Devonian-Mississippian	Exshaw Fm. (6-30)		• black shale, limestone • areally restricted in southeastern British Columbia	• basal phosphate less than 1 metre thick; pelletal • phosphatic shale and pelletal phosphate 2 to 3 metres above base • an upper nodular horizon
Devonian	Palliser Fm.		• limestone	

Figure 4-6-2. Stratigraphy of phosphate-bearing formations in southeastern British Columbia.

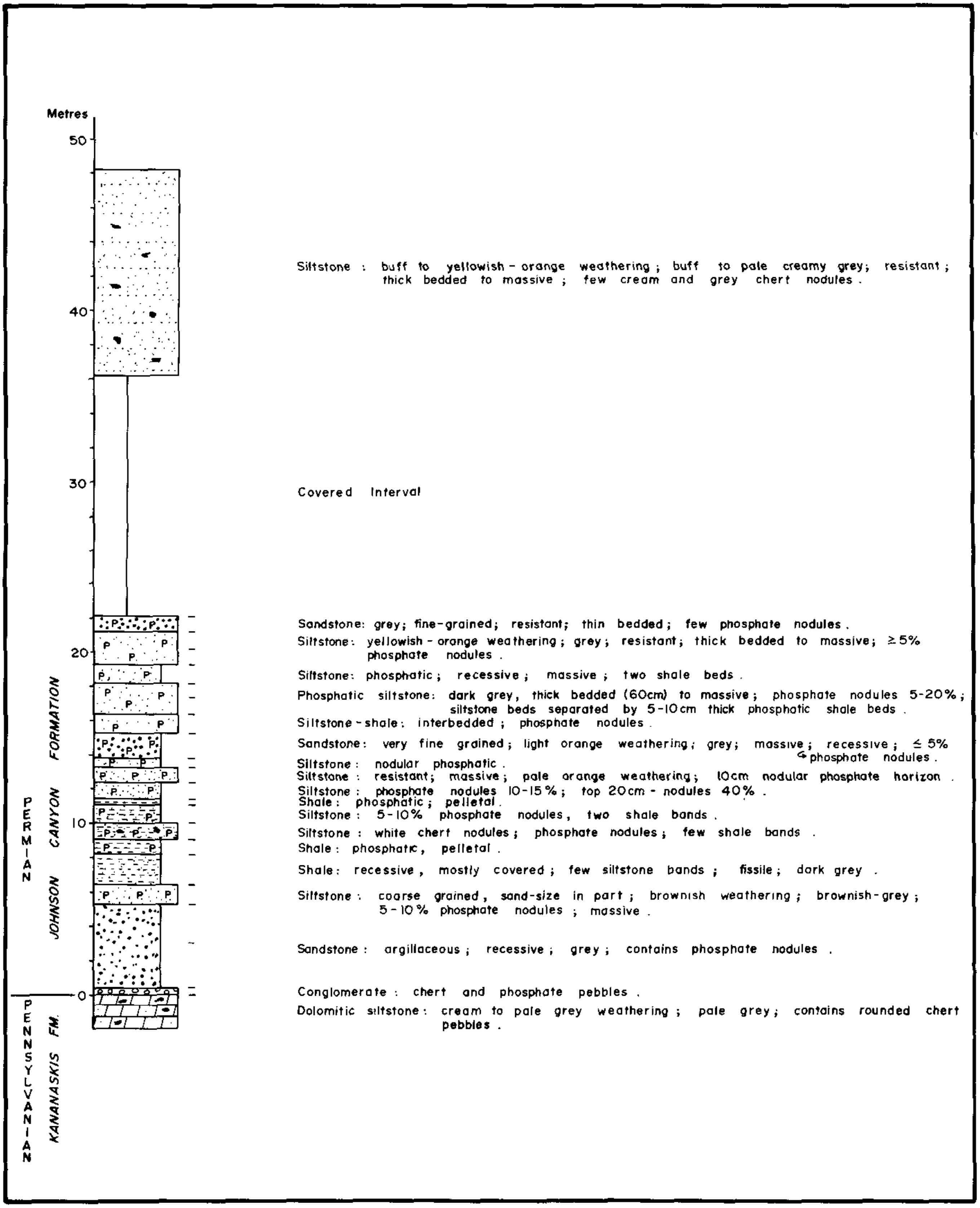

Figure 4-6-3. Stratigraphic Section 17, Mount Broadwood.

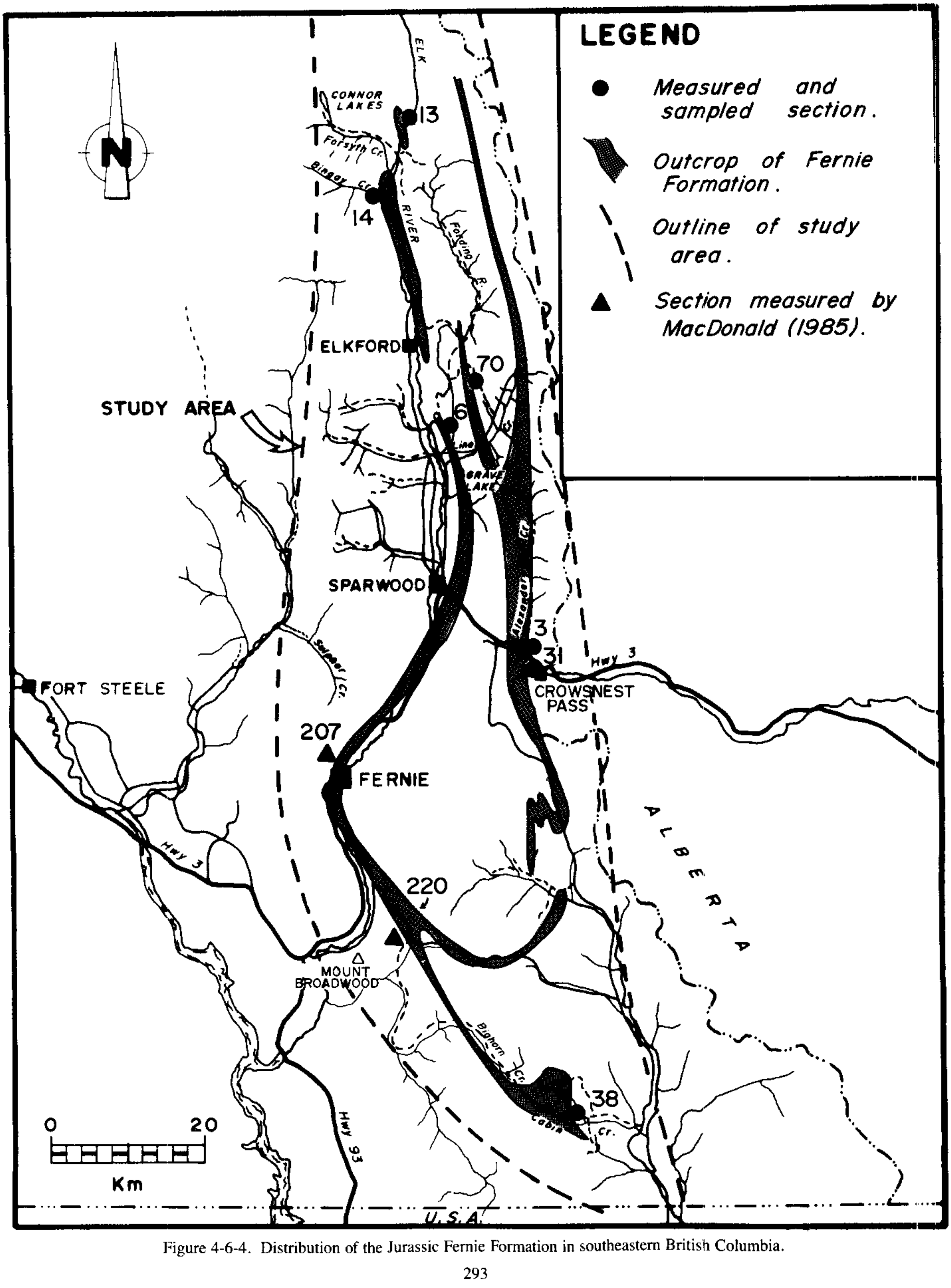

Figure 4-6-4. Distribution of the Jurassic Fernie Formation in southeastern British Columbia.

ROSS CREEK FORMATION

The Ross Creek Formation, preserved only in the Telford thrust plate, consists of a sequence of recessive thin-bedded siltstone, argillaceous siltstone, minor carbonate and chert (MacRae and McGugan, 1977), Pelletal and nodular phosphate layers occur in the upper portion together with relatively thin coquinoid horizons that contain phosphate nodules (Plate 4-6-4).

RANGER CANYON FORMATION

The Ranger Canyon Formation unconformably overlies the Ross Creek Formation and consists of resistant cliff-forming chert, cherty sandstone and siltstone. Minor gypsum and dolomite are also present (MacRae and McGugan, 1977).

The base is marked by a phosphate-cemented chert-pebble conglomerate that also contains massive phosphate intraclasts, nodules and pebbles. This conglomerate is well exposed in the Cabin Creek area (Plate 4-6-5). Phosphate also occurs in a brown sandstone in the upper part of the formation. It is typically nodular with nodules ranging in size from 1 to 6 centimetres. Phosphatic horizons range in thickness from a few centimetres at Mutz Creek to 4 metres at Fairy Creek, north of Fernie. Phosphate is also present as phosphatic chert, in pelletal form or as the matrix in fine-grained sandstones or siltstones (Plate 4-6-6).

SPRAY RIVER GROUP

There are no known phosphate deposits in the Triassic Spray River Group in southeastern British Columbia, although Telfer (1933, page 599) does report some samples assaying up to 6 per cent P_2O_5 in Triassic shales.

The Whitehorse Formation is present in the area north of Elkford, but is very thin; elsewhere in the region the Spray River Group contains only strata of the Sulphur Mountain Formation. Although they contain no phosphate, they do provide a useful marker sequence as phosphate occurs in the stratigraphic interval immediately above and below.

FERNIE FORMATION

Triassic strata are unconformably overlain by dark grey to black shales, minor limestone, siltstone and sandstone of the Jurassic Fernie Formation (Freebold, 1957, 1969). This formation thickens from east to west. A persistent phosphorite bed 1 to 2 metres thick occurs at the base of the Fernie in strata of Sinemurian age (Plate 4-6-7). It is typically black and pelletal; phosphate nodules and bioclastic debris are occasionally present. Limonitic blebs, interpreted to represent oxidized pyrite grains, are common. Generally this phosphate rests directly on strata of Triassic age, with a thin conglomerate (+ 5 centimetres) at its base. The phosphate interval may be present as two phosphorite beds separated by phosphatic shale. Thicknesses in excess of 2 metres are attained locally, as at Mount Lyne where 4 metres of phosphatic rock are present (Plate 4-6-8). The top of the phosphate may be marked by a yellowish-orange calcareous marker bed 2 to 5 centimetres thick.

A second phosphate horizon lies approximately 60 metres above the base of the Fernie. It is low grade and may be associated with a belemnite-bearing calcareous sandstone horizon. This upper horizon was only observed on the railroad tracks south of the Highway 3 roadcut at Alexander Creek and in a poorly exposed outcrop north of Mount Lyne, where it occurs in shale rather than sandstone.

PHOSPHATE DEPOSITS

Early this century Telfer (1933), while working for The Consolidated Mining and Smelting Company of Canada, Limited (Cominco Ltd.), recognized a number of distinct stratigraphic intervals containing phosphate. Since this early work a number of authors have recorded the presence of phosphate in southeastern British Columbia. MacDonald (1985), in the course of his study of phosphate deposits in Alberta, also completed a cursory evaluation of the phosphate potential of southeastern British Columbia and a number of companies have explored for phosphate in the region. However, there has been no broad assessment of these data. This study attempts to synthesize the data, determine the most favourable stratigraphic intervals for phosphate and evaluate the economic potential of the various phosphate deposits. It makes it clear that in southeastern British Columbia only the Jurassic Fernie Formation and the Permian Ishbel Group contain phosphate deposits of some significance.

FERNIE FORMATION

The Fernie Formation occupies a broad syncline known as the Fernie basin. This structure is canoe-shaped and covers an area that extends 100 kilometres in a north-south direction and has an average width of approximately 20 kilometres. Pelletal phosphorite and phosphatic shale occur at the base of the formation in strata that unconformably overlie the Triassic Sulphur Mountain Formation. This contact can be traced for approximately 310 kilometres (Figure 4-6-4) although it is not everywhere exposed.

During Sinemurian time there was a rapid marine transgression. Phosphate was deposited as a single bed, or as two beds separated by phosphatic shale, during a period of very slow clastic sedimentation. This phosphatic unit extends throughout the basin and is consistently 1 to 2 metres thick (Figure 4-6-5). We estimate that 8.4 billion tonnes of phosphatic rock may have been deposited, but less than 5 per cent of this can be considered as a potential resource. The resource potential is estimated to be 400 million tonnes with a phosphate content of 15 to 25 per cent P_2O_5. A downdip extension of 300 metres has been used in the above calculation to represent a practical mining depth.

Surface exposures are invariably weathered and may be enriched in phosphate as a result of the leaching of carbonates. The presence of blebs of limonite replacing pyrite grains provides evidence of oxidation, but thin-section studies indicate that weathering has not affected the phosphate pellets. As we were only able to sample surface exposures we could not determine the depth to which the phosphate has been weathered or how much the grade has been affected.

The southernmost exposures of the basal phosphate of the Fernie Formation occur in the Cabin Creek area. Exploration by First Nuclear Corp. Ltd. (Hartley, 1982), Imperial Oil Ltd. (Van Fraassen, 1978) and the author has demonstrated that a phosphate bed averaging 1.5 metres in thickness occurs along a strike length of 27 kilometres. Phosphate is present in a broad synclinal structure modified by a number of thrust faults and smaller folds. Thrust faulting has thickened the phosphate bed at some localities. Elsewhere, the phosphate has been remobilized into the axial portions of folds (Hartley, 1982). Phosphate content is in the range of 13 to 20 per cent P_2O_5. Less silty varieties contain better than 20 per cent P_2O_5 (Hartley, 1982).

North of Crowsnest, at the Crow mine, a phosphate bed 1.5 metres thick has been thickened by repetitive thrust faulting (Telfer, 1933). Individual phosphate beds are thrust one upon another at some localities and faulted out at others along strike. Our work in this area was confined to the examination of one trench and a small surface exposure. The phosphate beds are repeated four times in the trench, increasing the width of the phosphate section to 16 metres. The phosphate content of these beds averages 26 per cent P_2O_5.

In the west Line Creek area the basal phosphate horizon can be traced for a strike length of 15 kilometres. The strata dip 40 to 75 degrees easterly. The phosphate bed varies in thickness from less than 1 metre south of Line Creek, to in excess of 3 metres at Mount

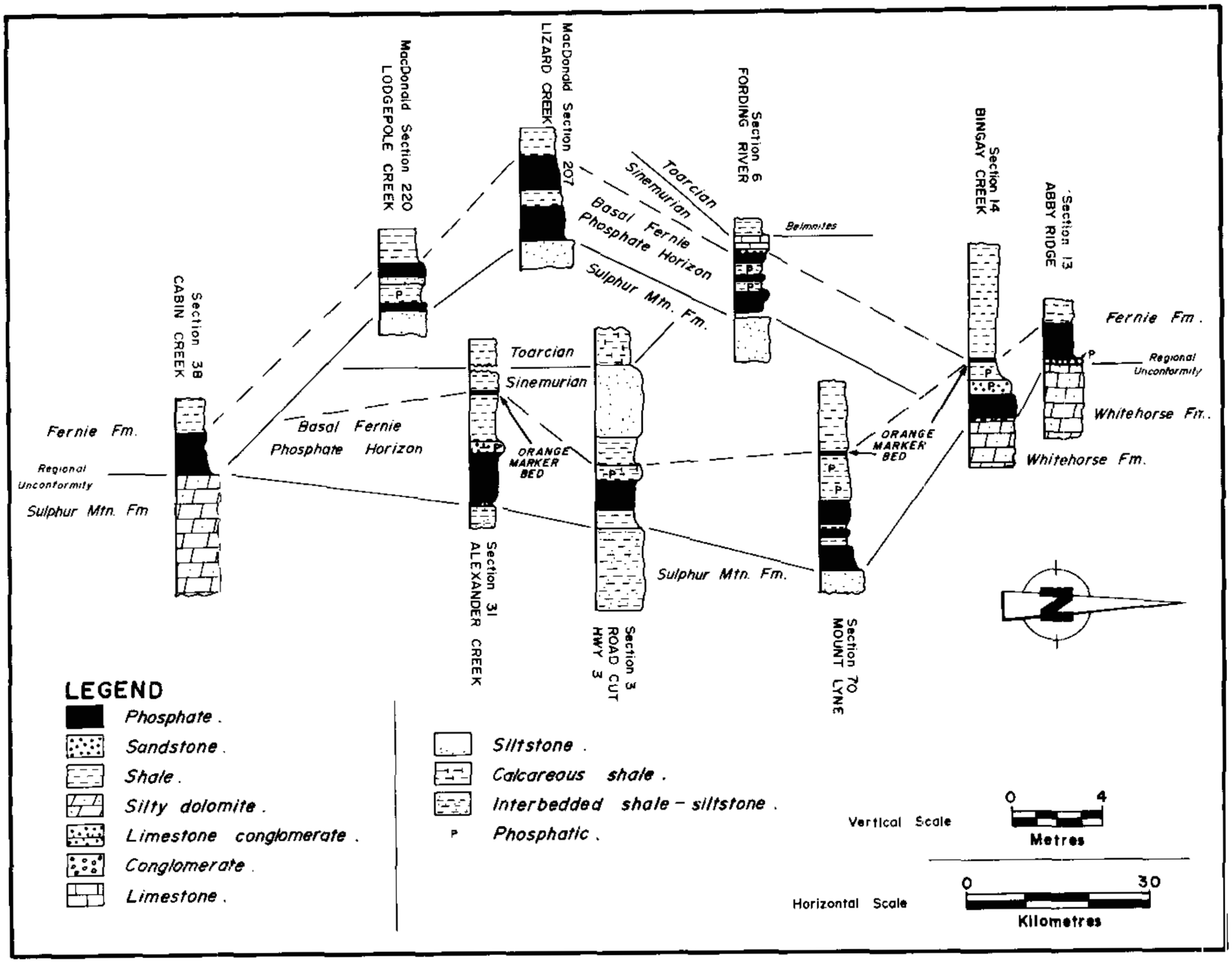

Figure 4-6-5. Stratigraphic correlation of the basal Fernie phosphate in southeastern British Columbia.

Lyne. Phosphate content ranges from a low of 3.7 per cent P_2O_5 in a diamond-drill hole (Hannah, 1980) to a high of 23.7 per cent P_2O_5 across 1.6 metres in a back-hoe trench (Hannah, 1980).

ISHBEL GROUP

Pennsylvanian-Permian strata occur extensively throughout southeastern British Columbia (Figure 4-6-6) but exposures of the Permian Ishbel Group are restricted to a narrow stratigraphic interval. The best development of the Ishbel Group is in the Telford thrust plate west of the Elk River and north of Sparwood (MacRae and McGugan, 1977). The Ishbel Group has been correlated with the Phosporia Formation of the western United States which contains extensive phosphate deposits

The Permian phosphate deposits in southeastern British Columbia occur at several stratigraphic intervals; most important appear to be the Johnson Canyon and the Ranger Canyon Formations. Phosphate is also present in the Ross Creek Formation but its distribution is restricted and exposures are rare. Deposition of the phosphate appears to have taken place in a shallow shelf environment with the eastern sequence being deposited close to a hingeline parallel to a shoreline trend (MacRae and McGugan, 1977). Host lithologies vary from conglomerate to fine-grained sandstone, siltstone and shale. Phosphatic intervals vary considerably in thickness and grade.

Phosphate occurs in a number of forms but nodular varieties are the most common. Phosphate nodules may comprise anywhere from 5 per cent of the rock by volume to almost the entire rock and contain up to 32 per cent P_2O_5 (Telfer, 1933). The best exposures of this nodular variety occur in an outcrop of Johnson Canyon Formation near Mount Broadwood and in the Ranger Canyon Formation north of Forsyth Creek, in the Connor Lakes area.

Several exposures of the Johnson Canyon Formation were examined in the Bighorn-Cabin Creek area at the southeastern limit of Permian strata. Phosphate is commonly present as subrounded nodules 1 to 2 centimetres in diameter in the lower part of the formation. Phosphatic intervals vary considerably, ranging in thickness from less than 5 metres in the southeast to 22 metres at Mount Broadwood (Figure 4-6-7). Phosphate content is exceedingly low, averaging less than 2 per cent P_2O_5 across widths of 1 metre. Northwesterly along the same trend, in the vicinity of the Fernie ski hill, phosphatic intervals are 1 metre thick or less. In two of the three sections measured a basal conglomerate 25 to 30 centimetres thick contains chert and phosphate pebbles and has a phosphate content averaging 3.9 per cent P_2O_5. In the area of the Fernie ski hill this conglomerate is only 2 centimetres thick.

North of Forsyth Creek, in the Connor Lakes area, several exposures of phosphate are present in the Ranger Canyon Formation. In this area a resistant chert horizon is overlain by a sandstone bed

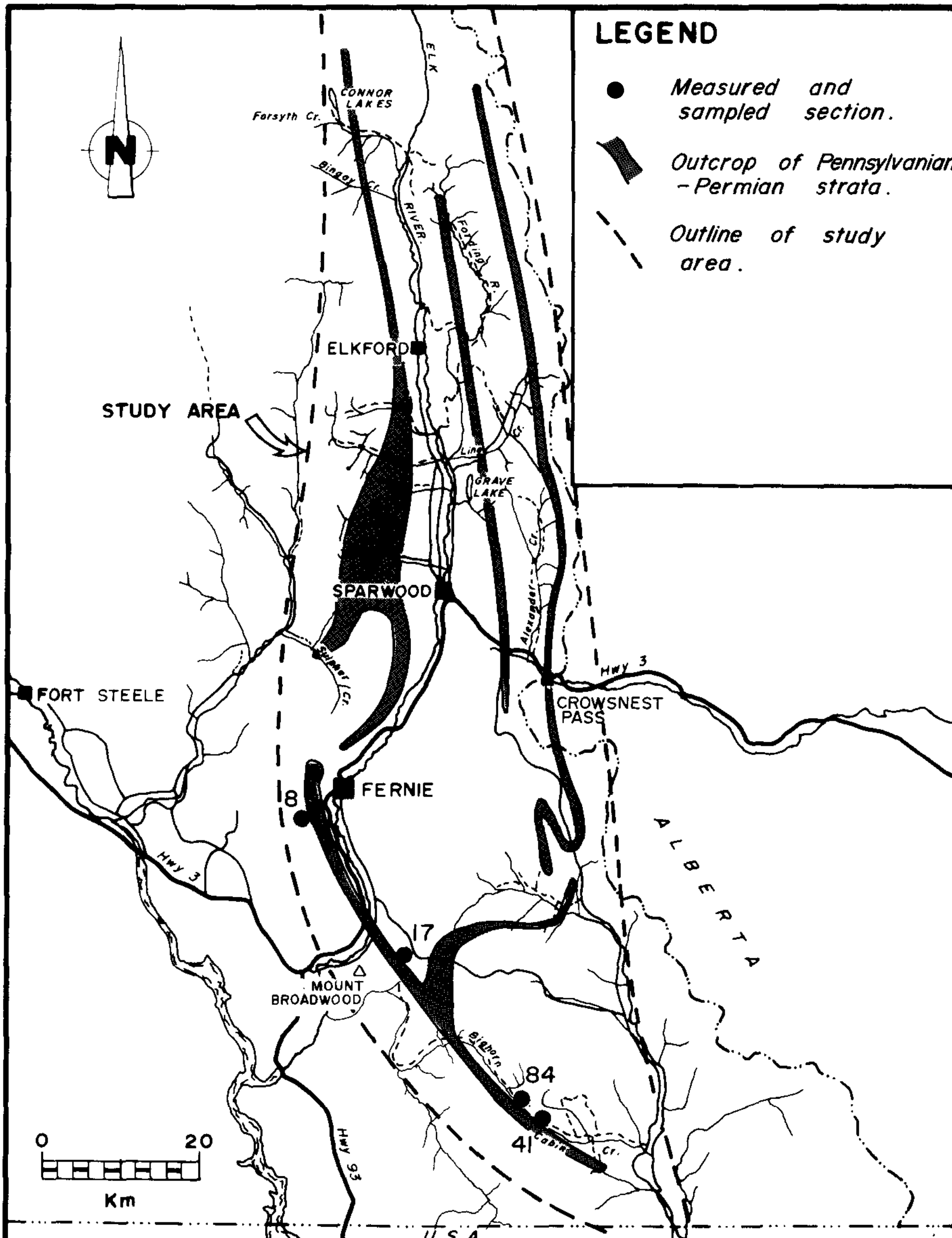

Figure 4-6-6. Distribution of Pennsylvanian-Permian strata in southeastern British Columbia.

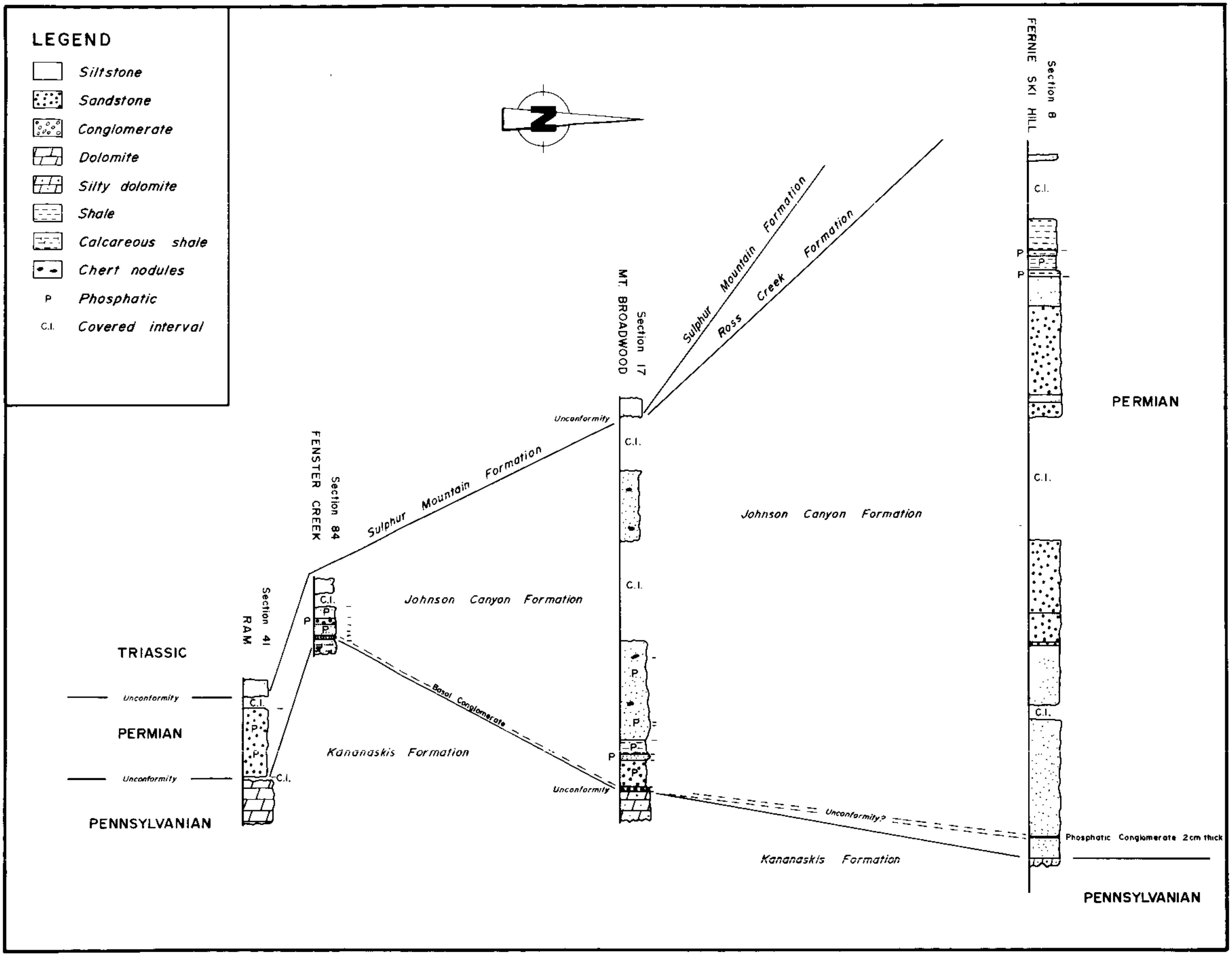

Figure 4-6-7. Stratigraphic correlation of phosphate-bearing strata, Johnson Canyon Formation, Fernie Cabin Creek area.

1 metre thick containing 10 to 15 per cent phosphate nodules by volume. The nodules are black, subrounded, and average 5 centimetres in diameter. They contain 23 to 28 per cent P_2O_5 but samples of the sandstone assayed only 1.6 percent P_2O_5. The geology of this area is complicated by a number of steeply dipping normal faults which have caused a thickening of the section; fault repetitions can be seen in outcrop, especially in the beds below the chert horizon. At one locality we were able to measure a phosphatic interval of 10 metres below the chert horizon. Throughout this section the phosphate content was generally less than 5 per cent P_2O_5 except for a bed 50 centimetres thick, at the base of the chert, which assayed 16.5 per cent P_2O_5.

On the eastern margin of the study area the Permian section is only a few metres thick. Exposures examined consisted of nodular phosphate in a sandstone matrix. A sample of nodules from an outcrop in the Crowsnest area, north of Highway 3, assayed 24.0 per cent P_2O_5. A sample of sandstone from the same locality had a phosphate content of 12.3 per cent P_2O_5. This phosphate horizon, which is approximately 1 metre thick, can be traced as far south as Flathead Pass and as far north as Todhunter Creek.

DISCUSSION

Phosphate exposures of are not very distinctive. Phosphate beds are generally thin and good exposures are rare. The basal phosphate of the Fernie Formation is typicaly pelletal, dark grey to black and recessive. Permian strata generally contain black ovoid phosphate nodules, although pelletal varieties are also present. Phosphate may also occur as a cement in fine clastic rocks and as cement or pebbles in conglomerates.

Several criteria can be used to recognize phosphate in the field. On weathered surfaces it may exhibit a pale bluish coloration and will give off a distinct bituminous odour when struck by a hammer. Chemical tests are available for qualitative determination of phosphate in the field. A spectrometer is an invaluable tool; phosphatic sections in the Permian give readings in the range of 150 to 400 counts per second compared to a background of less than 100 counts. Readings for the Fernie phosphate are in the range of 500 to 900 counts per second as compared to a background generally less than 200 counts.

The best potential for phosphate in southeastern British Columbia occurs at the base of the Fernie Formation. The phosphate content averages 15 to 25 per cent P_2O_5 across a thickness of 1 to 2 metres. Locally there has been some thickening of the phosphatic unit. At the present time a grade of approximately 30 per cent P_2O_5 is required for processing. Fernie phosphate would therefore require beneficiation. Metallurgical tests to date have been unsatisfactory (Kenny, 1977) but recent metallurgical work in the United States (Rule, *et al.*, 1982 ; Judd, *et al.*, 1986) may offer some encouragement for the future recovery of phosphate from the Fernie Formation.

The phosphate potential of the Ishbel Group is more difficult to assess. Phosphatic intervals at several localities exceed 5 metres in thickness but grades are less than 5 per cent P_2O_5. Most of this phosphate occurs as nodules having phosphate contents in excess of 23 per cent P_2O_5. These nodular varieties may present a potential phosphate resource if an inexpensive method can be found to separate the nodules from the fine clastic matrix.

ACKNOWLEDGMENTS

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Plate 4-6-1. Phosphate nodules (N) in sandstone in Johnson Canyon Formation, Cabin Creek area.

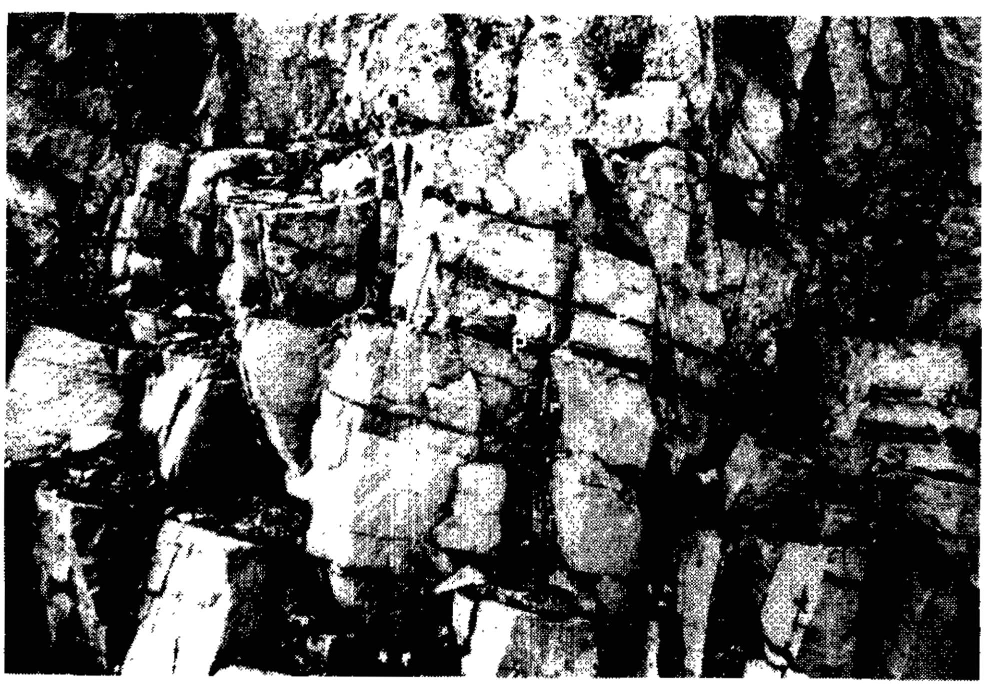

Plate 4-6-2. Phosphate laminae (P) in Telford Formation, Telford Creek area.

Plate 4-6-3. Phosphatic coquinoid bed (P) in Telford Formation, Telford Creek area.

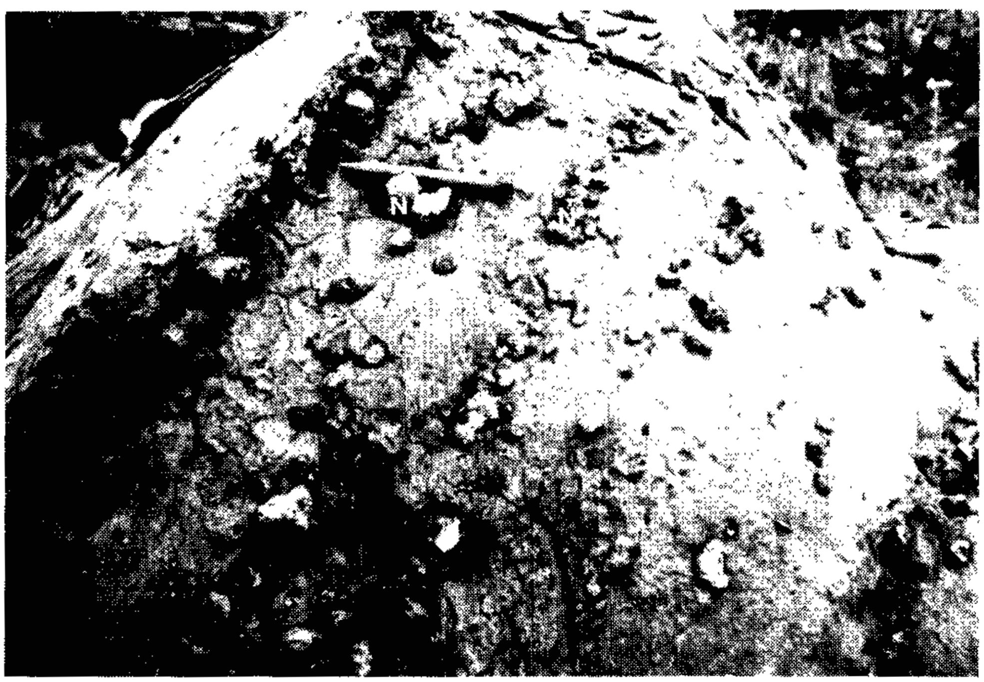

Plate 4-6-4. Phosphate nodules (N) in a coquinoid bed, Ross Creek Formation.

Plate 4-6-5. Basal conglomerate with phosphate cement (P); Ranger Canyon Formation, Cabin Creek area.

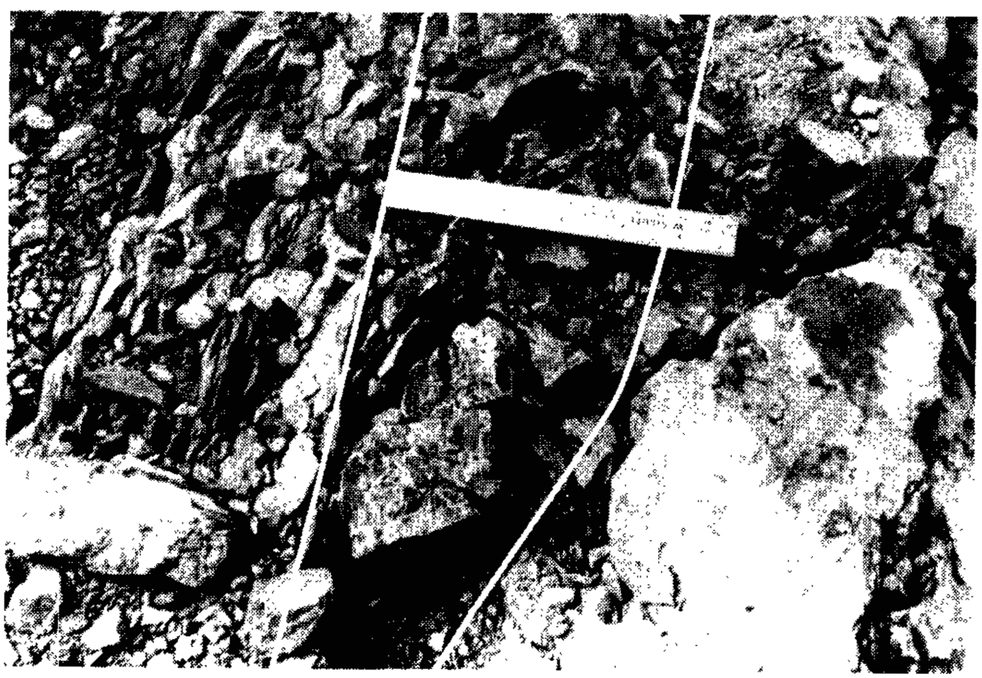

Plate 4-6-6. Phosphate bed at top of Ranger Canyon Formation, Fernie ski hill.

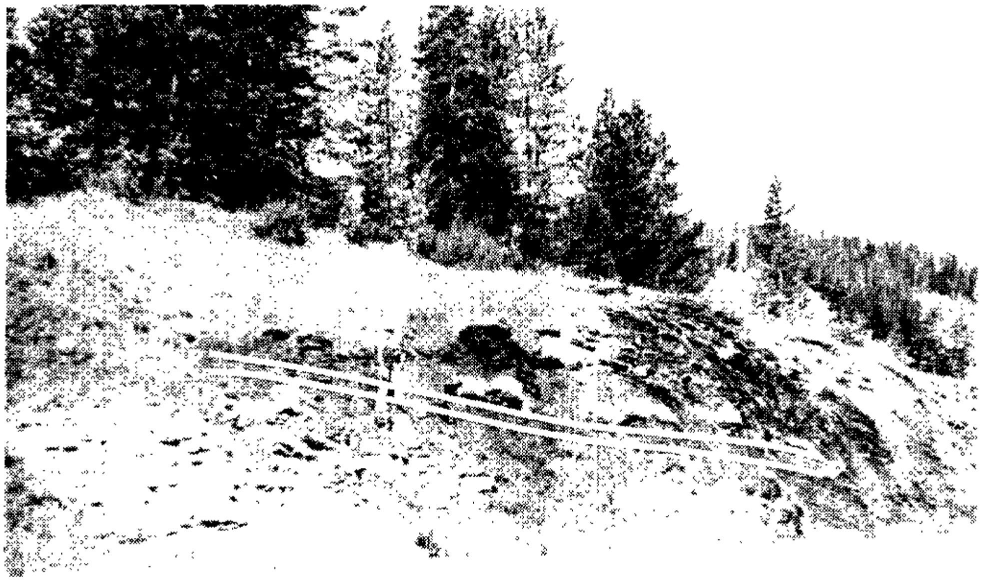

Plate 4-6-7. Basal phosphorite bed (P) in Fernie Formation shale (JF) overlying siltstone of the Sulphur Mountain Formation (Tsr), Highway 3 roadcut at Alexander Creek.

Plate 4-6-8. Basal phosphate horizon (P) in Fernie Formation shale (JF) overlying siltstone of the Sulphur Mountain Formation (Tsr), Mount Lyne, top of the phosphate marked by yellow-orange limestone bed (Y).