SM-GENERAL INFORMATION 75(10)A

SIMILKAMEEN COALFIELDS

Dolmage Campbell & Assoc. Ltd.
1975

CONFIDENTIAL

SIMILKAMEEN COALFIELDS

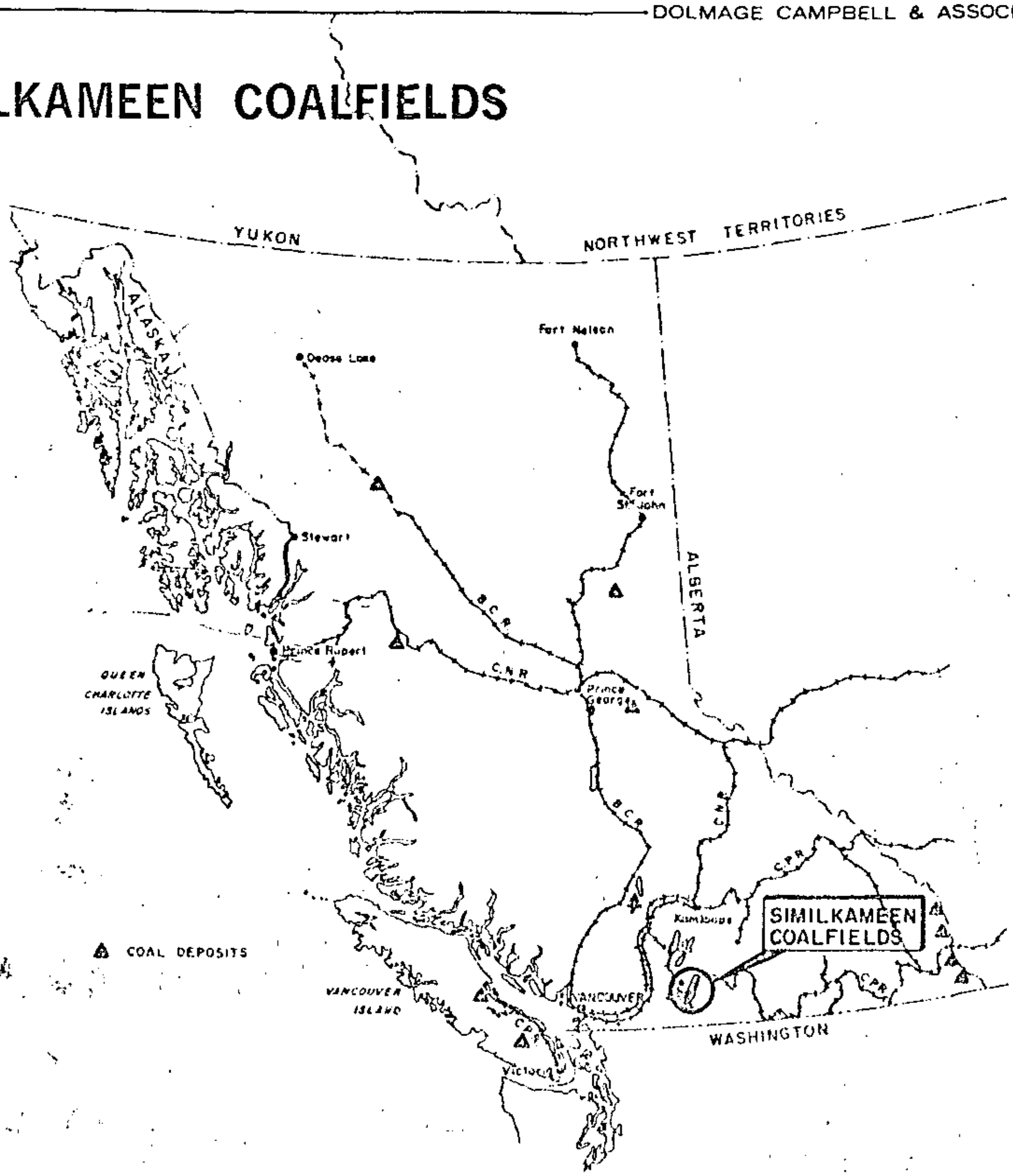

FIGURE 6-1

LOCATION SIMILKAMEEN DISTRICT

6.1 INTRODUCTION

LOCATION AND ACCESS (49° 30' N. Lat., 120° 30' W. Long) (Figure 6-1)

The Similkameen Coalfields in southern British Columbia lie at the southern extremity of the Interior Plateau, a short distance north of the International boundary. The district, centred on the confluence of the Tulameen and Similkameen Rivers, embraces an area of remnant basins of Tertiary sedimentary rocks which comprise the coalfields.

The region is well serviced by road and rail. The all-weather Southern Transprovincial Highway provides road access from east and west. Highway 5 from Merrit and Kamloops to the north joins the Southern Transprovincial

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at Princeton. The Kettle Valley branch of the Canadian Pacific Railway connects Princeton with Vancouver on the coast, via Spences Bridge, a distance of 275 miles by rail.

PHYSIOGRAPHY AND CLIMATE

The Similkameen district lies, for the most part, in the Interior Plateau, but abuts the Cascade Mountains on its western and southern borders. The Tulameen and Princeton basins are situated in the transition zone separating these two physiographic regions. Hence the terrain comprises rolling hills and ridges dissected sharply by numerous streams and two large rivers, the Similkameen and the Tulameen. Glaciation has mantled most of the areas of Tertiary rocks with deposits ranging up to fifty feet in depth.

Vegetation varies markedly from west to east, consistent with rapidly diminishing precipitation eastward. Firs and balsam predominate to the west, whereas pines become more plentiful to the east. Precipitation averages 13.1 inches per year. Temperatures range from an average of 16° in the winter to 63° in the summer.

HISTORY

Coal has been mined more or less continuosly in the Similkameen district since the early part of the century. To 1961, when the last production was recorded, 4,429,551 short tons were extracted; approximately one-half, (2,364,561 tons), coming from a single seam in the Tulameen basin, the remainder from several operations from possibly four separate seams in the Princeton basin.

Production from the Tulameen area by Coalmont Colleries and predecessor companies began in 1919 and continued until 1940. The peak year was 1928 when 184,594 tons were extracted. In recent years the entire Tulameen basin has been acquired through licenses and option by Imperial Metals and Power Ltd. The company has carried out extensive exploratory work with a view to defining sufficient quantities of coal that would be amendable to open cast mining methods and would support an iron mining and smelting operation in the area.

Mining in the Princeton area, unlike that of the Tulameen basin, comprised short-lived and discontinuous operations from several small underground mines; the maximum daily tonnage from any one mine rarely exceeded 500 tons. Extending intermittently from 1909 to 1961, mining operations were terminated or restricted in most cases when unfavourable underground support conditions, consisting of squeezing and crumbling of the roof and pavement caused by swelling bentonitic clays, were encountered at depth. The maximum annual output from the Princeton basin was 125,288 tons in 1942, most of which came from three mines. The most recent exploratory work in the Princeton basin has been by Bethlehem Copper Corporation Ltd. In 1971 this company drilled 12 surface boreholes, (9,852 feet), in the southwestern portion of the basin in a search for coking-quality coal.

AVAILABLE DATA

The data upon which this report is based have been derived essentially from the available government literature on the area as well as from various reports by mining companies who have operated in the district. The district's lengthy production history has been documented, more or less regularly, in the annual Minister of Mines reports. Three public companies, Imperial Metals and Power Ltd., Granby Mining Company Ltd. and Bethlehem Copper Corporation Ltd. have made their file data and reports available.

The following reports comprise the most comprehensive published documents available on the coal deposits of the district.

1952 Shaw, W. S. - "Princeton Coalfield", Geological Survey of Canada, Paper 52-12.

1952 Shaw, W. S. - "Tulameen Coalfield", Geological Survey of Canada, Paper 52-19.

Other published data reviewed are documented in Part 4 of this report.

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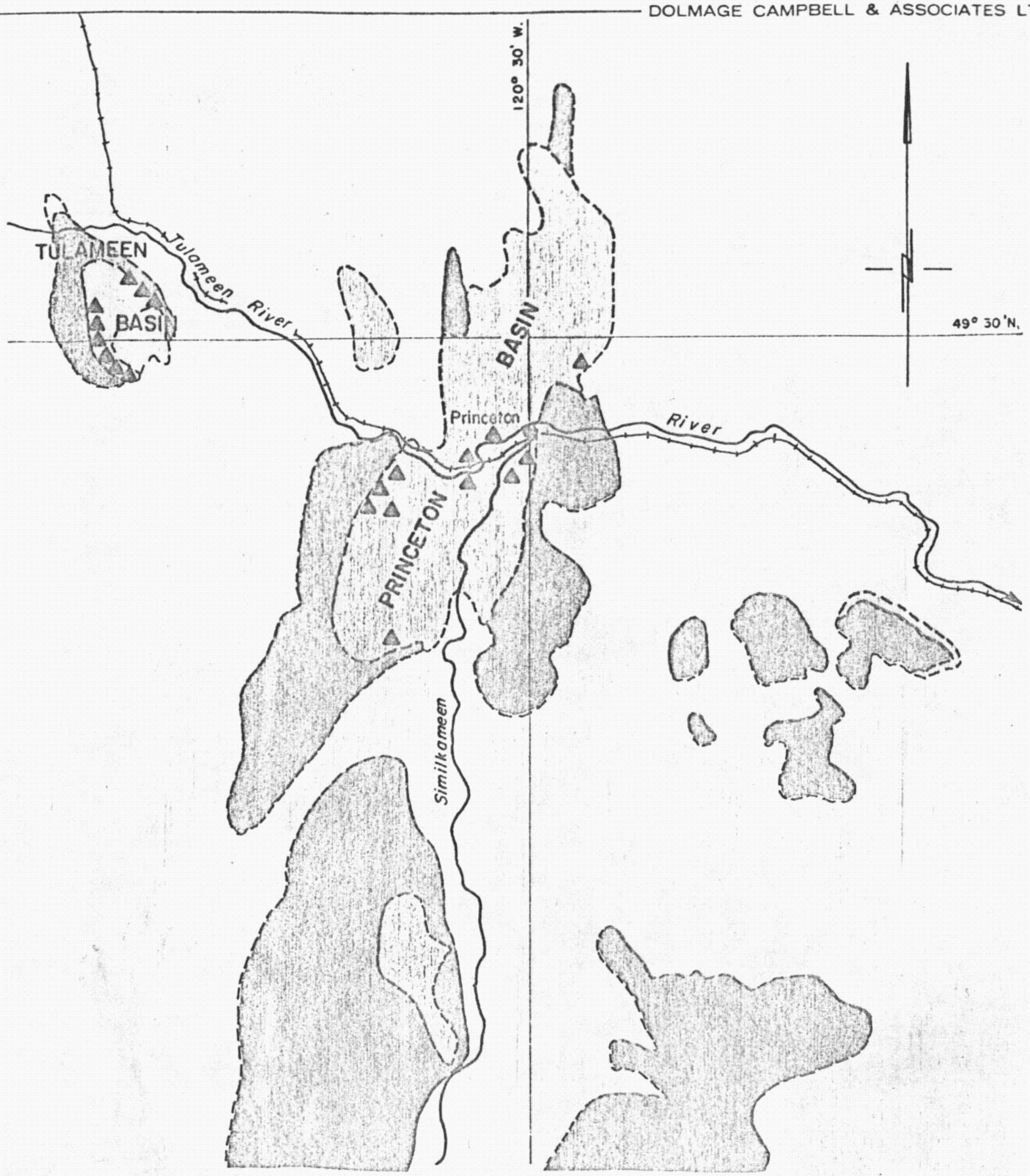

LEGEND

- MIOCENE - PLIOCENE VOLCANICS
- EOCENE SEDIMENTARY ROCKS
- EOCENE VOLCANICS
- BASEMENT ROCKS
- ▲ COAL DEPOSITS

FIGURE 6 - 2

SIMILKAMEEN COALFIELDS
TERTIARY GEOLOGY

0 4 8
MILES

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6.2 REGIONAL GEOLOGY

Coal deposits in the Similkameen fields occur exclusively in sedimentary rock which lies between two Tertiary volcanic formations. Together the three formations comprise the Princeton Group.

PRINCETON GROUP (Figure 6-2)

The basal volcanic formation in the Princeton Group contains massive and banded lavas with a few thin tuffaceous beds. The colour varies from grey-purplish to purplish-red. The estimated thickness is somewhat in excess of 4500 feet.

The sedimentary rocks, designated the Allenby Formation in the Princeton basin, consist of fluvial and lacustrine sediments with intercalated coal horizons. These rocks for the most part overlie the lower volcanic formation but also in the district frequently are found in unconformable contact with underlying Upper Triassic volcanic and Cretaceous granitic intrusive basement rocks. The Allenby Formation contains fine grained shale, arkosic sandstone, and conglomerate with predominantly granitic boulders. Coal and bentonitic clays occur at intervals throughout the sedimentary section. The estimated thickness of the formation is 3500 feet.

The upper volcanic formation, approximately 500 feet in thickness, is characterized by lengthy sections of pyroclastic rocks, (tuffs, aglomerates, etc.), interbedded with massive volcanic flows. They tend to be reddish-black in colour.

The age of the Princeton Group has been dated as Eocene, although the upper volcanic formation may extend into the Oligocene. In the Similkameen district, Princeton Group sedimentary rocks are distributed in two large basins, the Princeton basin and the Tulameen basin, and in several, much smaller basins which, because of their limited areal extent, are of little economic interest.

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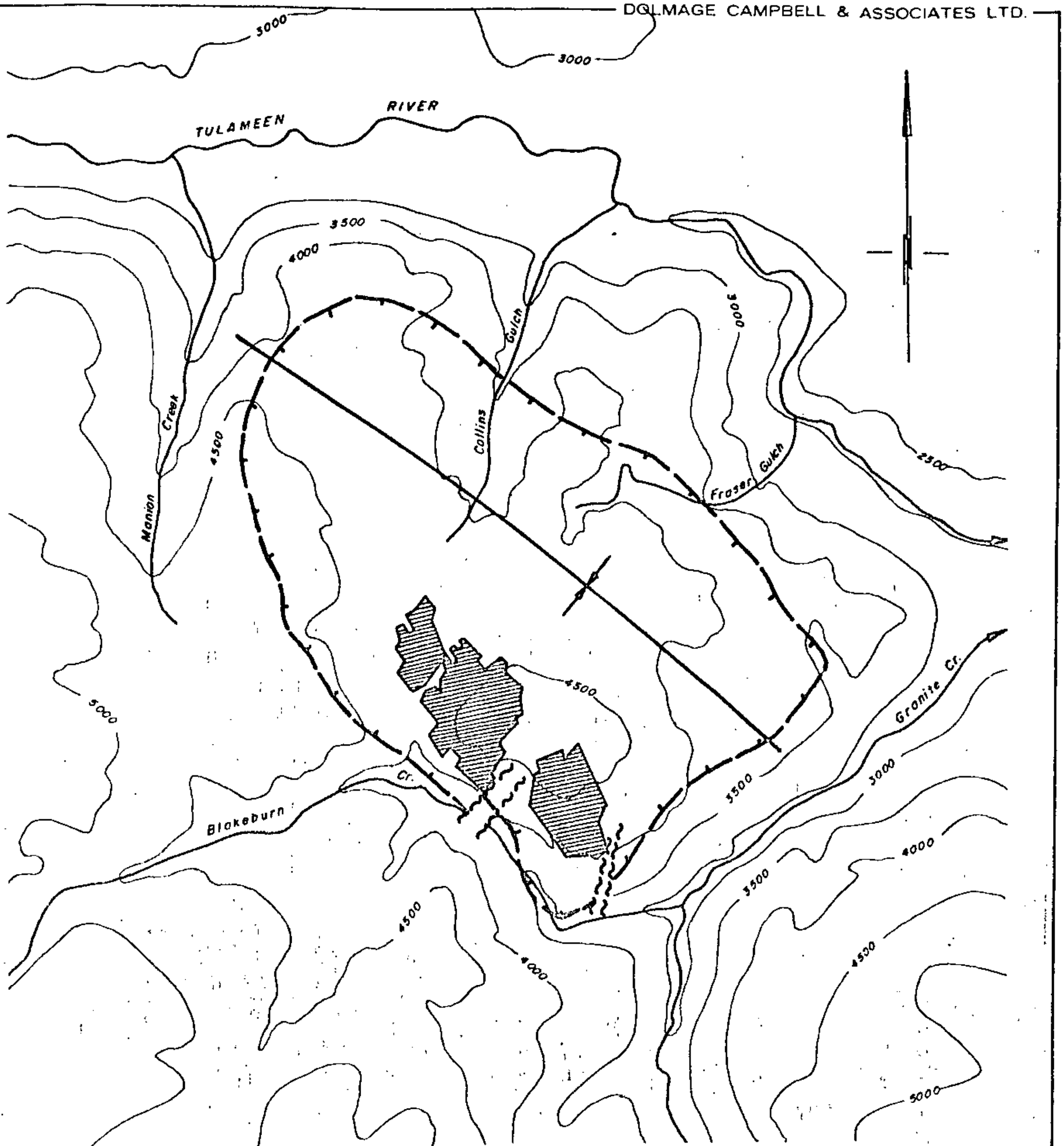

LEGEND

EDGE OF BASIN

OLD MINE WORKINGS

SYNCLINAL AXIS

FIGURE6 - 3

SIMILKAMEEN COALFIELDS
TULAMEEN COALFIELD

0 1 2
MILES

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6.3 TULAMEEN COALFIELD

INTRODUCTION

Exploration for coal in the Tulameen basin began around the turn of the century. Coal was found in outcrop in Collins Gulch and Fraser Gulch and at a locality between these gulches known as Bear's Den, (Figure 6-4). Extensive exploration and development were done; but, with very poor results, no production was achieved. Later, coal was discovered in outcrop along the southwestern rim of the basin on Blakeburn Creek. These exposures were developed successfully and production began in 1919 and extended through 1940. Mining, confined to one seam ranging in thickness from 7 to 12 feet, was carried out along strike for 7500 feet and down dip for 2500 feet. Three separate underground mines were developed, separated from one another by faults.

Beginning in 1954, Mullins Strip Mine Co. Ltd. produced 238,000 tons of coal from the No. 3 Mine pillar by open-cast mining. In addition, the company implemented further exploration along the northeastern rim of the basin by trenching the area between Collins' and Fraser Gulches around the northeastern periphery of the basin.

Subsequently, Imperial Metals and Power Ltd. carried out extensive exploration over the entire periphery of the basin with a view to defining sufficient coal reserves to support a possible intergraded iron pelletizing operation in the area. The company exposed the main coal zone on the southwest rim northwestward for an additional 7500 feet and drilled the zone to provide samples for testing purposes. In addition, further trenching along the northeastern rim extended the coal zone exposures an additional 8000 feet northwestward.

GEOLOGICAL SETTING (Figure 6-5)

The Tulameen basin consists of an elongate, northwesterly-trending sequence of sedimentary rocks, which covers an area $3\frac{1}{2}$ miles in length by $2\frac{1}{2}$ miles in width. The sedimentary formation comprising the centre of the basin conformably overlies lower volcanic rocks of the Princeton Group at the northwestern edge of the basin, but toward the southeast it overlaps these volcanic rocks and rests directly on the pre-Tertiary basement. The formation, exhibiting a thickness of 2560 feet, is not overlain by Princeton Group volcanic rocks, having been folded, eroded, and subsequently capped by younger volcanic rocks of Miocene-Pliocene age.

The strata comprising the sedimentary formation are divisible into three distinct members; an upper member (1900 feet in thickness), a middle coal-bearing member (460 feet), and a basal member (200 feet). The basal member contains sandstone, shale, and siltstone with one or two thin lava flows. The middle member contains shale, siltstone, sandy shale, and minor sandstone with interbedded coal and bentonite. The coal measure lies in the lower 260 feet of the middle member.

The upper member exhibits a marked change in lithology. The strata comprise massive beds of conglomerate and sandstone indicating rapid deposition of material. A few beds of shale and minor lenses of coaly material reflect local short-lived quiescent conditions in the basin. This relatively abrupt major change in the sedimentary environment, from coal forming swamps to an inundation of molasses-type conglomerates, is common to other explored Tertiary basins in the central interior belt of British Columbia.

Structurally, the basin has been folded in synclinal fashion along a northwest axis. Asymetrically folded, the basin exhibits gentle (20° - 25°) dips on its southwestern limb and steeper (40° - 65°) dips on its northeastern flank (Figure 6-5). Two large fault zones which partially transect the basin (Figure 6-4), have been mapped in old mine workings. The faults strike northeast and north northeast and dip steeply. Severely crushed coal beds along the northeastern rim of the basin probably reflect differential movement due to folding rather than indications of faulting.

COAL MEASURE

The coal-bearing member within the sedimentary sequence of the Tulameen basin is 460 feet in thickness. The coal measure within the member occurs in the lower 260 feet of the member. Coal seams are interbedded with shale, bentonite and minor sandstone.

The coal measure, characterized by dark grey to chocolate-coloured fissile shales, thin beds of bentonite, siltstone, and coal, can be traced with reasonable confidence throughout the entire periphery of the Tulameen basin. The rim of the basin has been explored by bulldozer-trenching for approximately three quarters of its length.

COAL DEPOSITS

Exploration carried out by Imperial Metals and Power Ltd. and Mullin Strip Mine Co. Ltd. has defined a coal-bearing section that averages 70 feet in thickness and ranges up to 120 feet in thickness. The section has

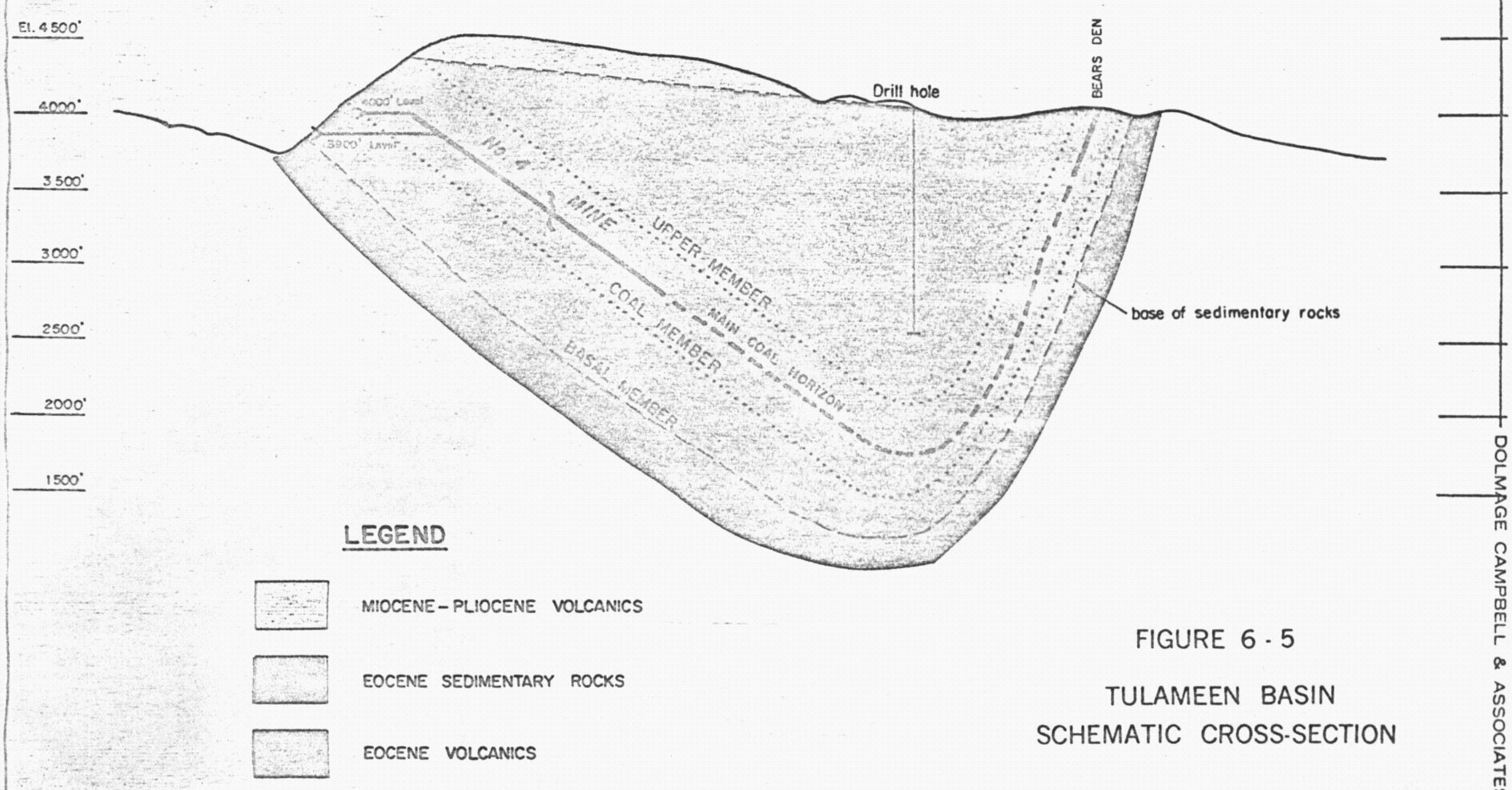

FIGURE 6 - 5

TULAMEEN BASIN
SCHEMATIC CROSS-SECTION

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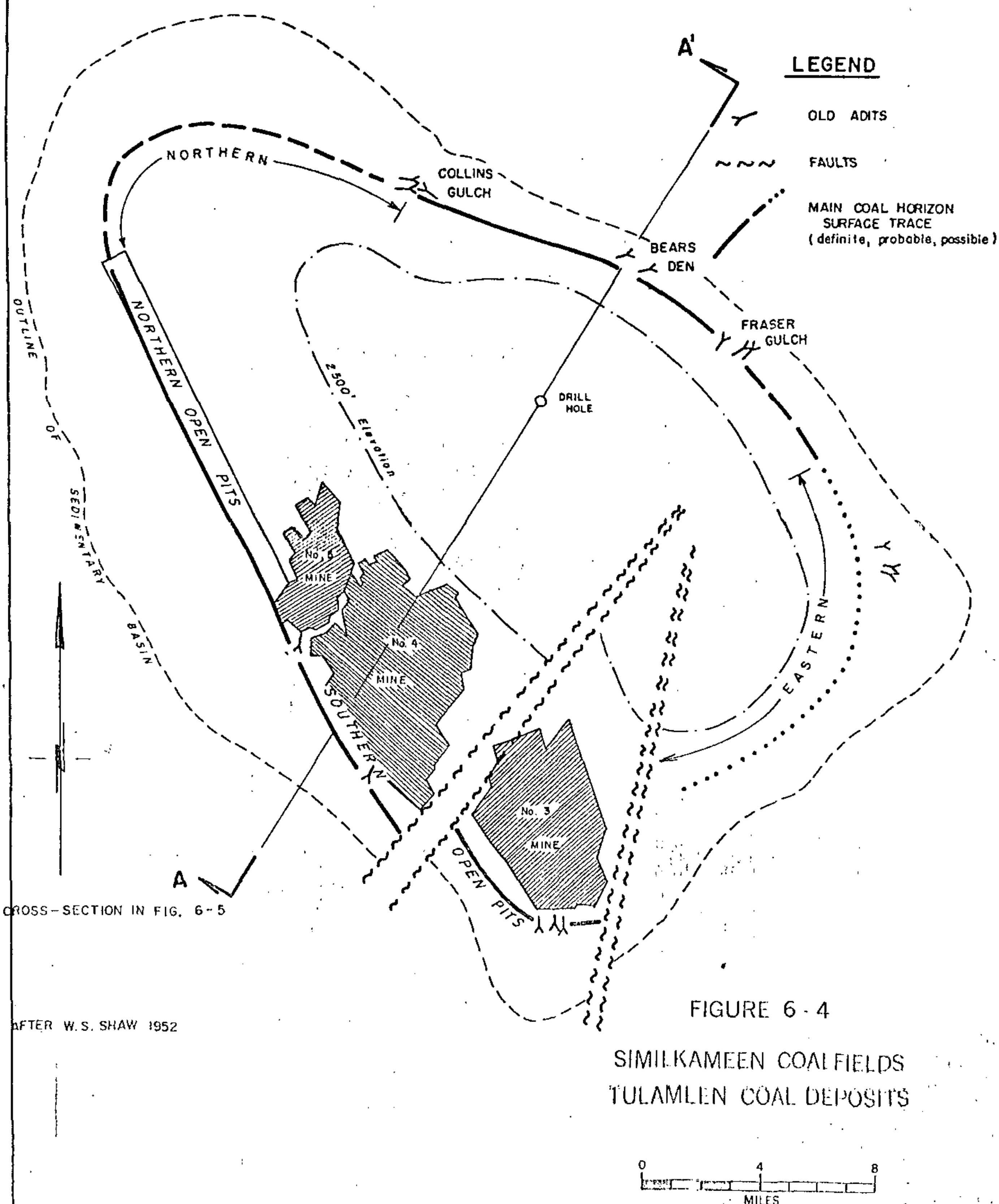

FIGURE 6-4

SIMILKAMEEN COALFIELDS
TULAMEEN COAL DEPOSITS

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been explored most intensely at two localities around the rim of the basin; on Blakeburn Creek where all production from the basin occurred, and on the northeast where intermittent exploration (surface and underground) has been undertaken over many years.

Four coal seams have been recognized in the coal section on Blakeburn Creek; the upper three, ranging in thickness from 7-12 feet, are interbedded with coaly shale and are sufficiently close together to form a single mineable coal zone. The lowest (fourth) seam, of unknown thickness, apparently lies near the base of the coal section; however, little is known about this seam. The uppermost seam in the coal section, which also occurs within the mineable coal zone, provided all of the underground production from the Tulameen basin.

The coal zone has been traced by bulldozer trenching for 7500 feet in strike length, occurring as a surface pillar above the old underground mines. Mullins Strip Mine Co. Ltd. have extracted 238,000 tons of coal from the surface pillar of the old No. 3 mine since 1954. The zone has been traced northwestward for an additional 7500 feet by bulldozer trenching and by drilling four holes.

On the northeast rim of the basin bulldozer trenching confirmed the continuity of the coal zone between the Collins and the Fraser gulches, as shown on Figure 6-4. A width of 70 feet of coal and coaly shale is indicated.

The area between Blakeburn Creek and the northeastern area on the northern rim of the basin has been explored by bulldozer trenching, although not as systematically and thoroughly as the two principal localities. However, sufficient exploration has been done to indicate that the zone is continuous.

Along the eastern rim, insufficient bulldozer trenching has been done to determine fully whether the coal zone continues around the complete periphery of the basin, although it is evident that the coal member does.

COAL ZONE RESERVES

Because of the consistency of the coal zone around the periphery of the Tulameen basin it has been possible to calculate a coal reserve. Systematic bulldozer trenching has demonstrated the zone is continuous along strike. Diamond drilling and continuous coal in underground workings has shown that the zone probably continues down dip. The reserve is based upon the assumption that the coal can be mined by open pit (or strip) methods.

Openpit (strip) mining in the Tulameen basin is contingent on the local influence of two principal conditions; namely, the general ruggedness of the terrain, and the variable dips of the sedimentary strata containing the coal zone. Because of these variabilities, the coal/waste stripping ratios will differ considerably in different sectors of the basin periphery. The influence of topography alone can be inferred from the contours around the periphery of the basin shown in Figure 6-3.

For this report the Tulameen surface coal reserves are considered to be established and are placed in proven, probable and/or possible categories, recognizing that detailed studies of stripping ratios may prohibit surface mining in some localities.

The calculated resources in the Tulameen basin for a coal zone 70 feet in width which might be mined to a vertical depth of 200 feet are:

Proven	8.1	million tons
Probable	13.7	million tons
Possible	8.8	million tons
	~~40.6~~ 30.6	million tons.

COAL CHARACTERISTICS

The coal in the Tulameen basin has been ranked as high volatile subbituminous A.

The calorific value of the coal mined in the early days by Coalmont Collieries Ltd. is reported to have averaged 11,800 Btu's per lb.; however, the earlier mined coal was extracted from a single seam hence this figure cannot be expected to apply over a wider zone of poorer quality coal mined by normal surface methods or mechanized underground methods. The coal mined by Mullin Strip Mine Ltd. averaged 9000 Btu's per lb. and apparently consisted of coaly shale material that contained these coal seams, all included within the 70 foot thick coal zone. Some sorting was apparently carried out selectively during the mining.

Imperial Metals and Power Ltd. analyzed coal from three of the four holes drilled in the area north of the old underground workings. A composite of the three samples returned the following proximate analysis:

		As Received	Air Dry	Dry
TOTAL MOISTURE	%	7.4	--	--
RESIDUAL MOISTURE	%	--	1.3	--
ASH	%	20.22	21.55	21.83
VOLATILE MATTER	%	29.86	31.82	32.24
FIXED CARBON	%	42.52	45.33	45.93
SULPHUR	%	.29	.31	.31
CALORIFIC VALUE	Btu's per lb.	10,028	10,687	10,828

The above samples were derived from the clean coal intersected in the drill holes and did not include the shale bands which must be mined with the coal and coaly shale. Sink float tests run by the company from four samples indicated that if all material in the zone is included the calorific value averages 7,091 Btu's per lb.

CONCLUSIONS

A coal zone has been defined that can be mined, at least partially by surface mining methods. In the past underground mining was limited at depth by squeezing roof conditions. With more advanced mining techniques now available, the coal down dip from the surface reserves may be extractable once defined by exploration. Deep coal at Tulameen is therefore viewed as a potential resource.

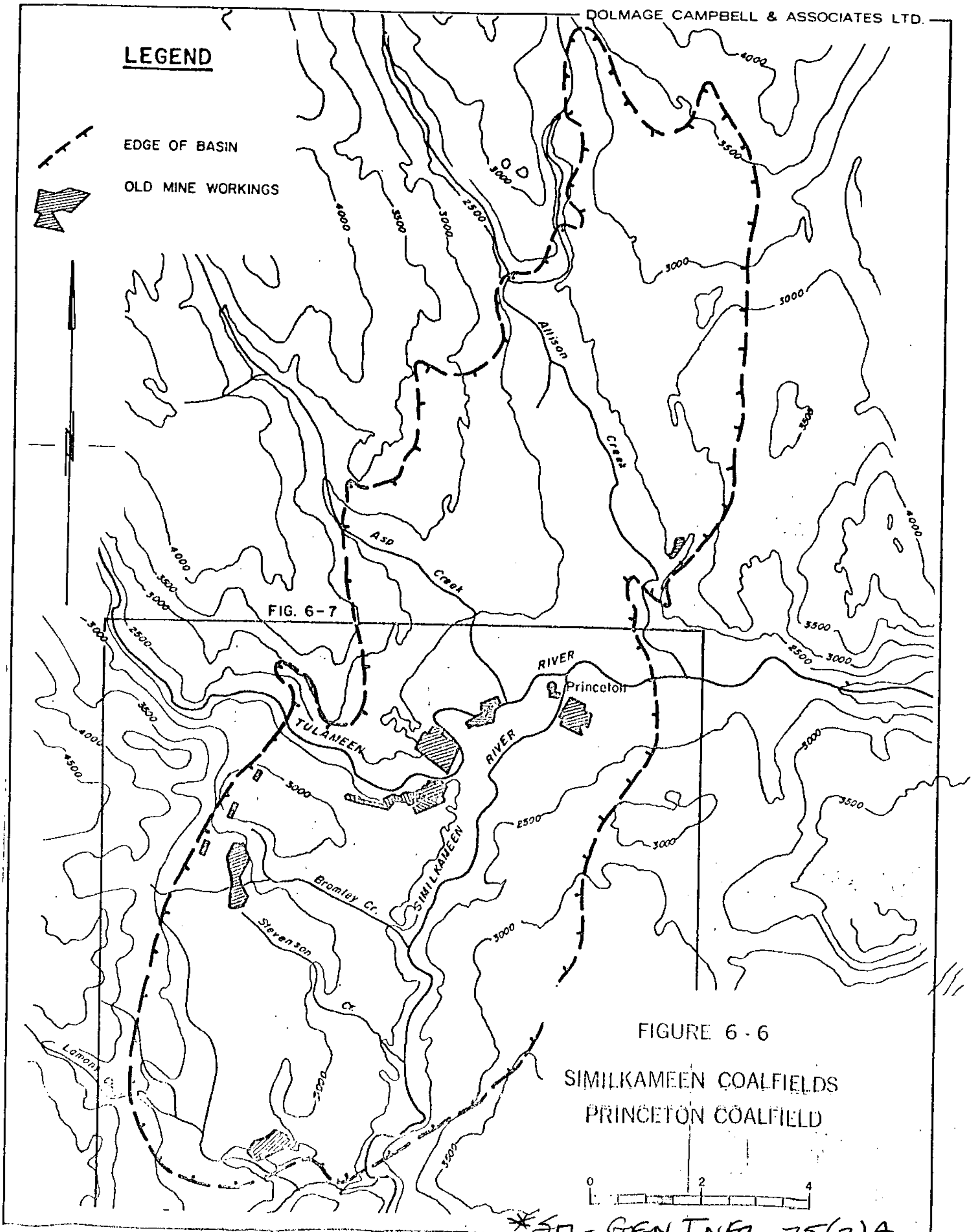

FIGURE 6-6

SIMILKAMEEN COALFIELDS
PRINCETON COALFIELD

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6.4 PRINCETON COALFIELD

INTRODUCTION

Since the early 1900's, several small-tonnage underground mining operations extracted coal from a number of seams in the southern half of the Princeton basin, principally supplying a local market. Mining in the Princeton district never on a large scale (maximum daily tonnage of 500 tons from a single mine) was usually terminated down dip by squeezing and crumbling of roof rock with increasing depth, due primarily to the presence of beds of swelling bentonite (an altered volcanic ash deposit) that lie close to the coal seams. Up to the end of 1951, a total of 2,025,460 short tons had been produced from the entire basin. From 1951 to 1961 an additional 39,530 short tons were produced from the Blue Flame mine, (M14 on Figure 7-7).

Coal was extracted from 13 underground mines and one small surface strip mine. Only three underground mines were reported to have produced on a continuous basis for any appreciable length of time, the remainder were essentially prospect adits. Granby Consolidated Mining Co. Ltd. were able to support a 17,500 KW steam generating plant located at Princeton for several years from two operations on Bromley Creek, the Granby underground mine (M13) and the Black mine (M8), which was a modest surface stripping operation.

Exploration within the basin has been carried out in sporadic fashion by various operators with a view to supplementing their operations which would be experiencing the normal mining difficulties characteristic of the district. Usually, the exploration consisted of locating bore holes along creeks or rivers where adit access to a potential seam could be developed. However, little new coal was discovered from these early bore holes. In 1971 Bethlehem Copper Corporation Ltd. acquired several leases in the district and carried out a limited diamond drill program (12 holes, 9852 feet) north of the Blue Flame mine (M 14) where coal was once produced from the central 8½ feet of a seam 31 feet in thickness. Bethlehem Copper was exploring for metallurgical coal and, since all of the coal discovered was non-coking, the company halted exploration but have retained the licenses.

In the northern half of the Princeton basin, few coal occurrences have been reported and no commercial production was attained. For the most part the area is masked by extensive, if not necessarily thick, glacial deposits. The lack of deeply-incising creeks or rivers has precluded the easy discovery and exploitation of coal seams that occurred in the southern half of the Princeton basin.

GEOLOGICAL SETTING (Figure 6-8)

The Princeton basin encompasses an area 15 miles in length by $2\frac{1}{2}$ to $4\frac{1}{2}$ miles in width. The cut-banks of two rivers, together with several, relatively wide-spread old mining operations, afford exposures from which the stratigraphy of the south half of the basin can be deduced. In contrast, extensive glacial deposits and the lack of easy access to coal seams by would-be operators have restricted exploration and development in the northern half. Consequently most of the available information pertaining to the sedimentary history of the Princeton basin has been derived only from the south half. The strata, attaining a maximum aggregate thickness of 3500 feet in the basin, overlie Eocene volcanic rocks on the west and underlie younger Eocene volcanic rocks on the east.

The Allenby Formation in the Princeton basin consists predominantly of massive conglomerate, sandstone, and shale interbedded with coal, carbonaceous siltstone and shale, and bentonite. Unlike that of the Tulameen basin, the stratigraphy of the formation cannot be subdivided into easily-recognizable periods of similar deposition. Apart from the coal horizons, few differences are displayed throughout the formation. Conglomerate in the Princeton basin occurs from top to bottom of the sedimentary sequence, whereas in the Tulameen basin conglomerate generally is confined to the upper two-thirds of the formation, and above the coal measure. Four coal zones, possibly five, are evident in the Princeton basin. They occur within a coal measure, or stratigraphic interval, of approximately 1700 feet in thickness near the middle of the Allenby Formation.

The sedimentary strata in the Princeton basin appear to be much more complexly folded than those in the Tulameen basin. The southern half of the Princeton basin comprises a broad, northerly-trending synclinal structure modified by three anticlinal folds; one anticline trends east-west, the other two trend essentially north-south. In general, on the western flank of the basin the strata dip steeply eastward, flattening toward the deeper part of the basin. In the northern half of the basin the structure is incompletely understood due to a lack of outcrop and sparse exploration activity. No major faults are in evidence or have been interpreted in the Princeton basin. A comprehensive drill exploration program, incorporating a few deep drill holes, will be required if the structure of the Princeton basin is to be clearly understood.

COAL MEASURE

The stratigraphy of the Princeton basin is not clearly understood, particularly as compared to that of the Tulameen basin. In the northern half of the basin, the lack of outcrops, coupled with the absence of old mine

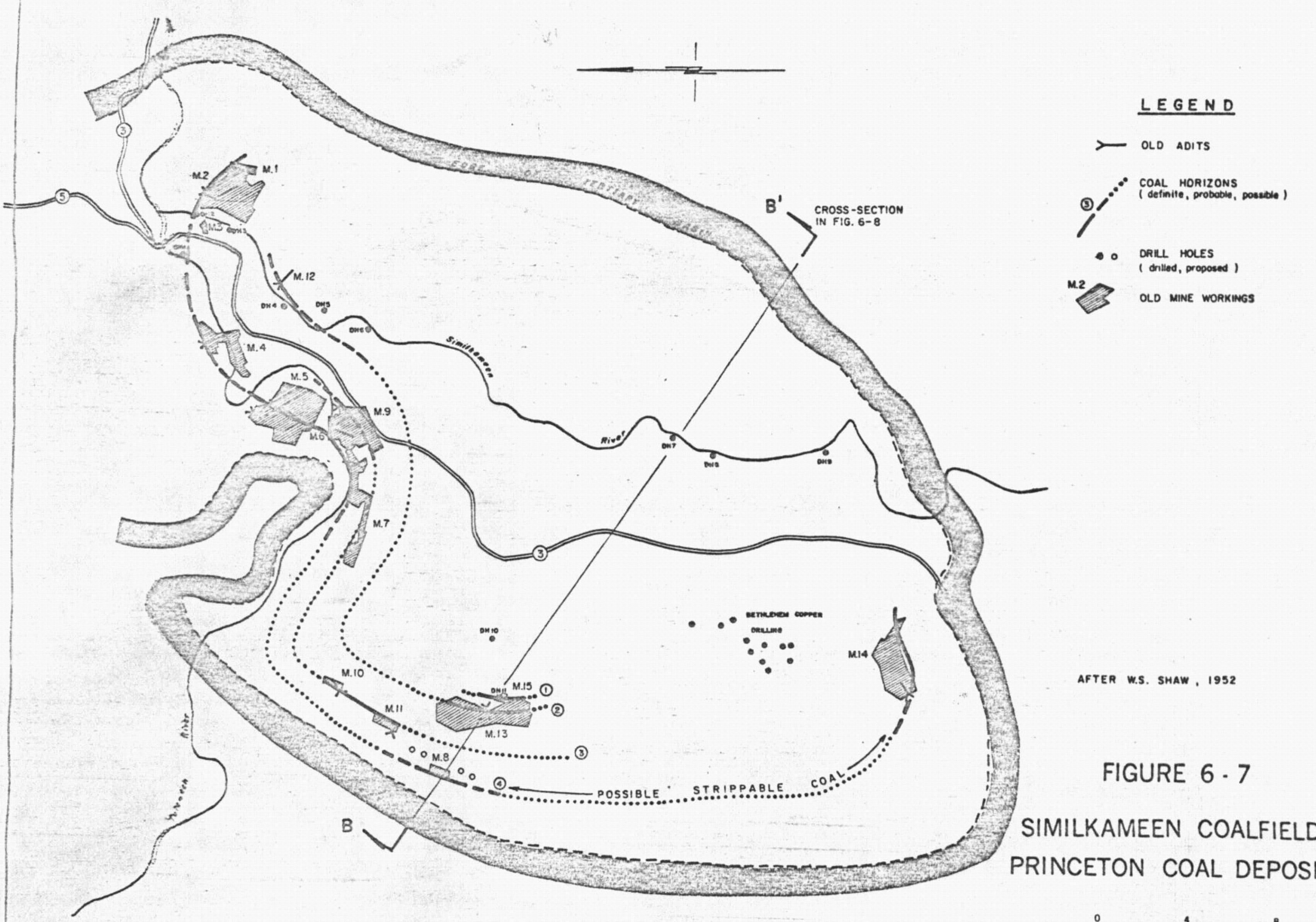

FIGURE 6-7

SIMILKAMEEN COALFIELDS
PRINCETON COAL DEPOSITS

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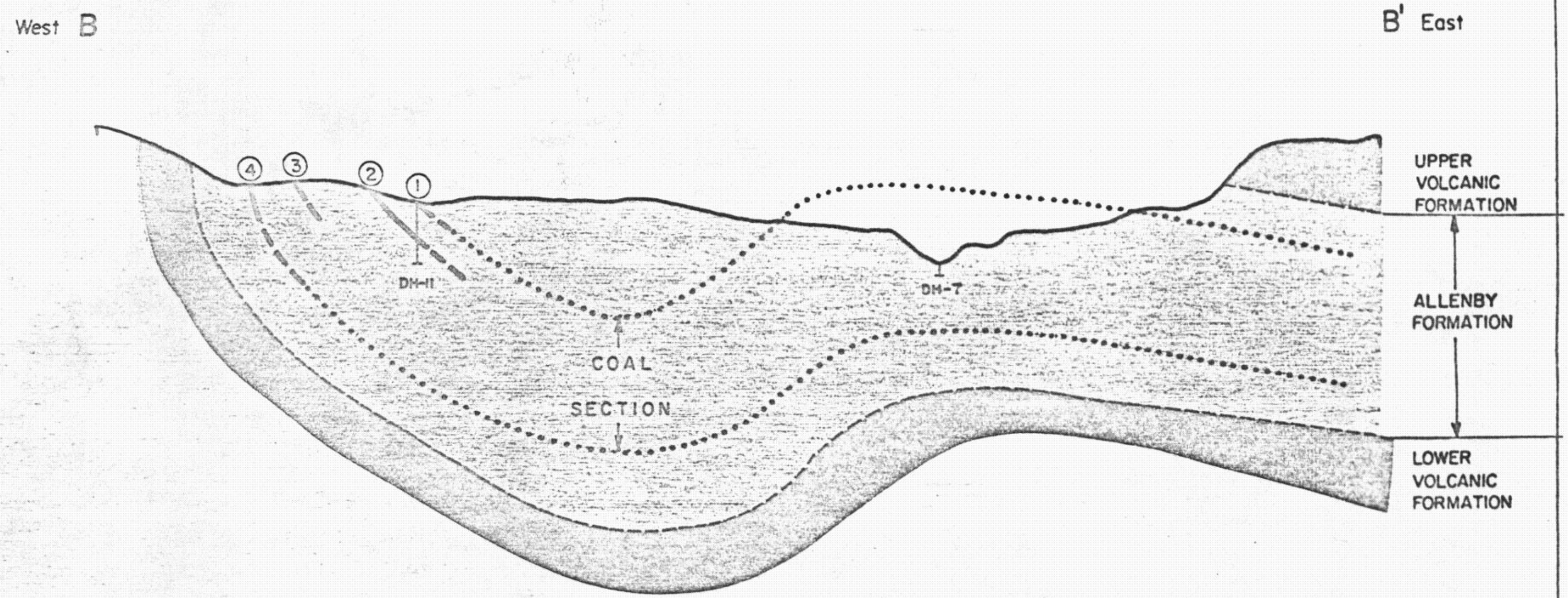

LEGEND

③ COAL HORIZONS
(definite , probable, possible)

FIGURE 6 - 8

PRINCETON BASIN
SCHEMATIC CROSS-SECTION

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workings, practically negates a comprehensive appraisal of the basin stratigraphy in that area. In the southern half, direct adit entry to coal seams was a basic requirement for the economic development of mines in the district. Consequently, most of the available information from which the basin stratigraphy can be derived is concentrated along the Similkameen and Tulameen rivers and two of the larger creeks which flow into the Similkameen. Because of the more complex depositional history of the Princeton basin, as compared to the Tulameen basin, precise correlations between drill holes (also along valleys), mine workings, and outcrop exposures must be viewed with reservation, particularly since few if any records were kept of the old mines and also since present access to the mines is essentially non-existent. The best available marker beds are the coal seams themselves and also the larger bentonite seams, even though to some extent these apparently tend to lense and pinch out locally along strike and down dip.

On the basis of the presently available information, the coal-bearing section (the coal measure) of the Allenby Formation consists of 1700 feet of sedimentary rocks situated near the centre of the 3500 foot-thick formation, (Figure 6-8). The coal measure comprises shale, sandstone, conglomerate, coal and bentonite with various mixtures of these rocks including coal, shales or shaley coal, which in close proximity with coal seams may be of economic significance.

COAL DEPOSITS (Figure 6-7)

Within the coal measure four coal zones have been recognized by previous workers in the district. Coal has been mined from individual seams within each of the zones. The presence of a fifth zone or seam is indicated; however, whether it occurs above or below the four principal zones, or indeed whether it even exists, remains conjectural. A coal zone in the Princeton basin is defined as a carbonaceous section containing one or more seams of coal in excess of five feet in thickness. The stratigraphic interval between zones contains many coal seams but normally they range in thickness from one to three feet and are not considered of economic interest at this time.

On the basis of the available evidence, the coal section (approximately 1700 feet in thickness) is estimated as follows:

Top	No. 1 Coal Zone	10	ft.
	Interval (1-2)	345	
	No. 2 Coal Zone	85	
	Interval	650	
	No. 3 Coal Zone	100	
	Interval	450	
Bottom	No. 4 Coal Zone	60	
		1700	ft.

The No. 1 zone, (Golden Glow after Shaw, 1952) has been recognized in one mine (M15) and one bore hole (DH11). It is reported to be in excess of 6 feet in the mine. In the bore hole its thickness is 9 feet.

The No. 2 Zone, (Gem-Blomley after Shaw, 1952), identified in M12, M13, DH6, and possibly DH11, contains 25 feet of coal in an overall zone thickness of 85 feet. Only 6 feet of a 16 foot seam was mined (M13).

The No. 3 zone, (Pleasant Valley-Jackson after Shaw, 1952), is reported to contain two or three workable seams in an overall zone thickness of 100 feet. Seams from the zone have been locally exploited from M9, M10, and M11. A bore hole (DH4) intersected a 5 foot seam which probably lies within the zone.

The No. 4 zone, (Princeton-Black after Shaw, 1952), has been, to a large degree, the most productive. Several small underground mines were developed on the upper seam within the zone, notably at M1, M2, M3, M4, M5, M6, and M7. Granby Consolidated carried out a small stripping operation until 1950 from M8, mining the upper 40 feet of the zone. Clean coal seams in close proximity to dirty coal, coupled with a favourable topography, offered inexpensive open pit extraction of relatively low-quality coal. Underground mines in the vicinity of the village of Princeton are reported to contain thick sections of dirty coal beneath the mineable seam; however, topographic conditions are not favourable for open pit methods in this area. On the basis of the available evidence it appears that the Blue Flame mine (M13) near the southern extremity of the basin lies within the No. 4 coal zone. The Bethlehem Copper drill holes apparently interesected the same zone about a mile north of the Blue Flame. The overall thickness of the zone ranges from 36 feet near Princeton, 31½ feet at the Blue Flame (M14), 29 feet in the Bethlehem drill holes, and up to 160 feet in Granby's Black open pit (M8), although the upper 49 feet contains most of the coal.

Coal is known to occur at isolated localities in the northern half of the Princeton basin. Insufficient exposures and a lack of previous production precludes an analysis of the stratigraphy of the northern area. However, coal zones of comparable thickness and extent to those in the southern half could occur, but exploration consisting initially of wide-spaced fairly-deep drill holes would be required to determine this.

COAL ZONE RESERVES

Because of the scattered and very poorly documented nature of the past production in the Princeton basin, no attempt was made in this report to derive established coal reserves which require exploitation by underground mining methods. Coal which could possibly be mined by surface methods is placed into established reserve categories, (proven, probable, and possible), whereas underground coal is viewed as potential resources for the same reasons as those adopted for the Tulameen basin; namely, undetermined underground mining conditions.

From a practical standpoint openpit mining will probably require the extraction of a zone of coal seams, coaly shale, and interbedded coal and shale, rather than individual coal seams. The quality may possibly be improved by some selective mining or by washing. As in the Tulameen basin, a combination of zone thickness, dip, and a favourable topographic setting determines whether a zone can be economically extracted by surface mining methods.

A coal zone potentially mineable by openpit methods is indicated to exist between the Granby (or Black) open pit (M8) and the Blue Flame Mine (M13), a distance of approximately 4 miles. The thickness of the zone ranges from 36 to 49 feet and dips 20° to 50° southeast toward the Bethlehem copper drilled area. (Figure 6-7). For calculation of reserves the zone is considered in two sectors: one 5500 feet in length containing the Granby pit, shown as a definite and probable coal horizon, (Figure 6-7); the other is projected southward for 3½ miles along a lineal topographic depression to the Blue Flame Mine (M13).

The surface coal reserves calculated to exist along this belt and including the Granby pit are:

Proven	none	
Probable	2.5	million short tons
Possible	8.6	million short tons
	11.1	million short tons.

The probable coal reserves lie beneath and adjoining the Granby pit. The possible coal reserves occur at deeper levels beneath the probable reserves (0.8 million tons) and the indicated southern extension toward the Blue Flame Mine (7.8 million tons).

COAL CHARACTERISTICS

Coal from the Princeton basin has been variously classified as having a rank ranging from lignite to sub-bituminous "A". It has been reported to slack readily upon exposure to air and to exhibit generally poor storage characteristics, with a tendency to spontaneous combustion when stockpiled in large volumes.

Coal analyses data are available from three localities in the southern half of the basin:

1) Five samples each were taken from two mines near the town of Princeton by the British Columbia Dept. of Mines in 1947; the thickness of the seam (presumably from the No. 4 zone) was not specified. The assays of the two samples averaged (probably on an as received basis):

Moisture	14.5%
Ash	13.0%
Volatile Matter	28.5%
Fixed Carbon	43.8%
Calorific Value	8745 Btu's per lb.

The calorific values ranged from 7,400 to 10,360 Btu's per lb.

2) Bethlehem Copper Corp. Ltd. intersected coal in seven of twelve holes drilled. Coal thickness ranged from 23 to 49 feet, averaging 29 feet. The central core of the zone for the seven holes averaged 12 feet and only it was assayed, presumably because it was recognized as the best coal for coking purposes. The values ranged as follows (on a dry basis):

Moisture	---
Ash	23.0 - 26.1 %
Volatile Matter	33.3 - 34.4 %
Fixed Carbon	40.5 - 42.6 %
Sulphur	0.75 - 0.83 %
Calorific Value	9941 - 10,336 Btu's per lb.

3) In 1947 Granby Consolidated sampled the Black pit (M8) in order to test the suitability of the No. 4 zone for thermal plant feed. The company sampled the zone over widths of 58 feet and 94 feet. In each case the zone material was analysed both with and without bands of waste, which were extracted by hand. The results were recorded as follows (on an as received basis).

a) Width 58 feet with waste included

Moisture	24.9 %
Ash	35.3 %
Calorific Value	4996 Btu's per lb.

b) Width 58 feet with waste (9 feet) excluded

Moisture	24.7 %
Ash	21.1 %
Calorific Value	6040 Btu's per lb.

c) Width 94 feet with waste included

Moisture	24.6 %
Ash	37.6 %
Calorific Value	4571 Btu's per lb.

d) Width 94 feet with waste (11 feet) excluded

Moisture	24.5 %
Ash	25.7 %
Calorific Value	5304 Btu's per lb.

To summarize: The upper 58 feet of the No. 4 zone (at M8) could be upgraded from 5000 to 6000 Btu's per lb. and from 35% to 21% ash with sorting at the pit.

The upper 94 feet of the No. 4 zone could be upgraded from 4500 to 5300 Btu's per lb. and from 37% to 26% ash with pit sorting.

Coal occurs interbedded with shale, sandstone, and bentonite beneath the sampled section of the zone (overall width 126 to 160 feet near M8); however, the proportion of coal apparently decreases markedly so that if the entire zone were to be mined either pit sorting and/or washing might be required to provide a suitable thermal plant feed.

CONCLUSIONS

The Princeton coal deposits occur essentially in four poorly-defined zones which extend over 1700 feet of stratigraphic section. They presently are restricted to the southern half of the Princeton basins. It is clear that because of the topographic conditions developed by glacial deposition and river incision and because of the relative thinness of three zones most of this coal will have to be extracted by underground mining methods. In this regard underground mining conditions were historically poor at Princeton due principally to the development of squeezing bentonite that exists in close proximity to coal seams.

6.5 COAL RESERVES AND RESOURCES

TULAMEEN COALFIELD

As previously discussed the in situ strippable coal reserves are estimated to be 40,600,000 tons grading 7,000 Btu per lb. With selective discarding of mined material at the pit this may be upgraded to 9000 Btu per lb.

The Tulameen coal down-dip from the surface reserves has been categorized for the purpose of this report as potential resources, rather than established reserves, because the economy of modern underground mining in the Tulameen basin has not been determined at this time. There is little doubt that if the demand for this coal is great enough methods will be found to mine it underground. Until such methods are known, the percentage of the coal that can be recovered is unknown, also, with current improvements in coal extraction technology, together with a possibility of employing in situ gasification at some time in the future, particularly in a closed basin such as the Tulameen, no depth limitation for underground mining has been set for the Tulameen coal. Any such limit would be arbitrary at this time. Therefore, the coal resources listed here for the Tulameen basin are the total in situ tons.

The indicated coal resources lie in the remainder of the basin beneath the strippable reserves yet above the lowest limit of mining that was restricted by heavy ground conditions. Three seams (total 24½ feet) were taken into consideration only, rather than the overall zone. The indicated resources are estimated to be 5 million short tons.

The inferred coal resources lie below the old mining depth limitation. They range form 40 to 240 million tons; the lower range represents the main seam, whereas the upper limit includes the 70 foot thick zone. If only the three seams were to be taken into consideration the inferred resources would be 14.5 million tons.

The grade of the potential resiyrces if the Tulameen basin, where better selectivity of coal would be achieved by underground mining, but to a much lesser extent by surface stripping, of individual seams would be approximately 10,000 Btu's per lb. The grade of the best seam was 11,800 Btu's per lb.; presumably, the two lower seams in the zone consist of poorer quality coal, hence they were not mined.

PRINCETON COALFIELD

The coal reserves of the Princeton basin as discussed are estimated to be 11.1 million tons;none are in the proven category and most are in the possible category.

In addition to the above coal reserves the potential coal resources of the Princeton basin are large; however, the great majority of it would have to either be mined by underground methods, providing the technology can be developed to cope with the squeezing ground caused by expanding bentonitic clays, or by in situ gasification. This coal must be viewed as a potential resource.

The indicated coal resources of the Princeton basin occur within the area embracing the old mine workings and the Bethlehem drilling. They are calculated to be 855 million tons and are dependent upon the four zone thickness being sustained throughout the area.

The inferred coal resources range from 1,900 million tons (the south half of the basin only) to 3,900 million tons (including the north half.)

The grade of the potential in situ resources in the Princeton basin cannot be postulated as the basis of the available data.

6.6 CONCLUSIONS

The Tulameen and Princeton coalfields host very large tonnage of coal that would be suitable for thermal power plant feed. However, only a small proportion can presently be classified as established reserves; the remainder are potential resources that must be identified.

The established reserves comprise approximately 50 million tons of coal that appear to be amenable to extraction by relatively low-cost openpin mining methods. Eighty per cent of these reserves are indicated to occur in the Tulameen basin.

The potential resources within the Similkameen coalfields occur as potential underground coal in the Tulameen basin, potential undergroung coal in the south half of the Princeton basin, and possibly both openpit and underground coal in the north half of the Princeton basin. Underground coal at Tulameen because it clearly occurs as definable seams in a consistent coal zone could condeivably, with modern mining techniques, be a future assured source of thermal coal. On the other hand, it is evident that coal in the south half of the Princeton basin occurs in seams and zones of much weaker continuiry, with more erratic grades and under more complex geological circumstances than that at Tulameen. For these reasons coal in the south half of the Princeton basin may be better suited for eventual development by in situ resources.

With respect to the north half of the Princeton basin, it really has not been explored, except possibly in a very minor sense. To fully assess the potential of the Princeton basin exploration as required, beginning with a few reconnaissance-type relatively-deep drill holes distributed over the entire basin and supported by geological mapping around known coal areas.

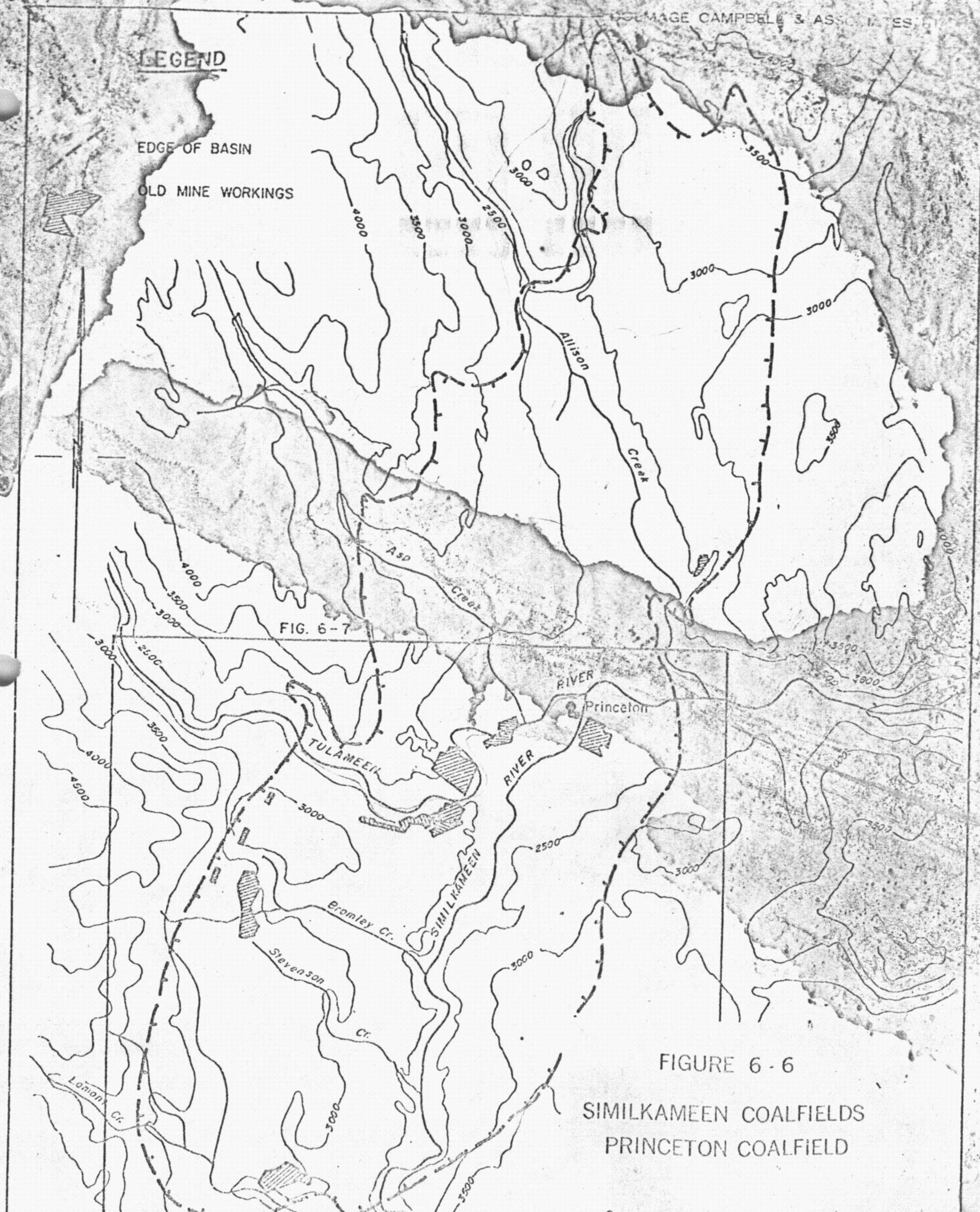

FIGURE 6 - 6

SIMILKAMEEN COALFIELDS
PRINCETON COALFIELD

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6.4 PRINCETON COALFIELD

INTRODUCTION

Since the early 1900's, several small-tonnage underground mining operations extracted coal from a number of seams in the southern half of the Princeton Basin, principally supplying a local market. Mining in the Princeton district, never on a large scale (maximum daily tonnage of 500 tons from a single mine), was usually terminated down dip by squeezing and crumbling of roof rock with increasing depth, due primarily to the presence of beds of swelling bentonite (an altered volcanic ash deposit) that lie close to the coal seams. Up to the end of 1951, a total of 2,025,460 short tons had been produced from the entire basin. From 1951 to 1961 an additional 39,530 short tons were produced from the Blue Flame Mine, (M14 on Figure 6-7).

Coal was extracted from 13 underground mines and one small surface strip mine. Only three underground mines were reported to have produced on a continuous basis for any appreciable length of time, the remainder were essentially prospect adits. Granby Consolidated Mining Co. Ltd. was able to support a 17,500 KW steam generating plant located at Princeton for several years from two operations on Bromley Creek, the Granby underground mine (M13) and the Black Mine (M8) which was a modest surface stripping operation.

Exploration within the basin has been carried out in sporadic fashion by various operators with a view to supplementing their operations which would be experiencing the normal mining difficulties characteristic of the district. Usually, the exploration consisted of locating bore holes along creeks or rivers where adit access to a potential seam could be developed. However, little new coal was discovered from these early bore holes. In 1971 Bethlehem Copper Corporation Ltd. acquired several leases in the district and carried out a limited diamond drill program (12 holes, 9852 feet) north of the Blue Flame Mine (M14) where coal was once produced from the central $8\frac{1}{2}$ feet of a seam 31 feet in thickness. Bethlehem Copper was exploring for metallurgical coal and, since all of the coal discovered was non-coking, the company halted exploration but has retained the licenses.

In the northern half of the Princeton basin, few coal occurrences have been reported and no commercial production was attained. For the most part the area is masked by extensive, if not necessarily thick, glacial deposits. The lack of deeply-incising creeks or rivers has precluded the easy discovery and exploitation of coal seams that occurred in the southern half of the Princeton Basin.

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GEOLOGICAL SETTING (Figure 6-8)

The Princeton Basin encompasses an area 15 miles in length by $2\frac{1}{2}$ to $4\frac{1}{2}$ miles in width. The cut-banks of two rivers, together with several, relatively wide-spread old mining operations, afford exposures from which the stratigraphy of the south half of the basin can be deduced. In contrast, extensive glacial deposits and the lack of easy access to coal seams by would-be operators have restricted exploration and development in the northern half. Consequently most of the available information pertaining to the sedimentary history of the Princeton Basin has been derived only from the south half. The strata, attaining a maximum aggregate thickness of 3500 feet in the basin, overlie Eocene volcanic rocks on the west and underlie younger Eocene volcanic rocks on the east.

The Allenby Formation in the Princeton Basin consists predominantly of massive conglomerate, sandstone, and shale interbedded with coal, carbonaceous siltstone and shale, and bentonite. Unlike that of the Tulameen Basin, the stratigraphy of the formation cannot be subdivided into easily-recognizable periods of similar deposition. Apart from the coal horizons, few differences are displayed throughout the formation. Conglomerate in the Princeton Basin occurs from top to bottom of the sedimentary sequence, whereas in the Tulameen Basin conglomerate generally is confined to the upper two-thirds of the formation, and above the coal measure. Four coal zones, possibly five, are evident in the Princeton Basin. They occur within a coal measure, or stratigraphic interval, of approximately 1700 feet in thickness near the middle of the Allenby Formation.

The sedimentary strata in the Princeton Basin appear to be much more complexly folded than those in the Tulameen Basin. The southern half of the Princeton Basin comprises a broad, northerly-trending synclinal structure modified by three anticlinal folds; one anticline trends east-west, the other two trend essentially north-south. In general, on the western flank of the basin the strata dip steeply eastward, flattening toward the deeper part of the basin. In the northern half of the basin the structure is incompletely understood due to a lack of outcrop and sparse exploration activity. No major faults are in evidence or have been interpreted in the Princeton Basin. A comprehensive drill exploration program, incorporating a few deep drill holes, will be required if the structure of the Princeton Basin is to be clearly understood.

COAL MEASURE

The stratigraphy of the Princeton Basin is not clearly understood, particularly as compared to that of the Tulameen Basin. In the northern half of the basin, the lack of outcrops, coupled with the absence of old mine

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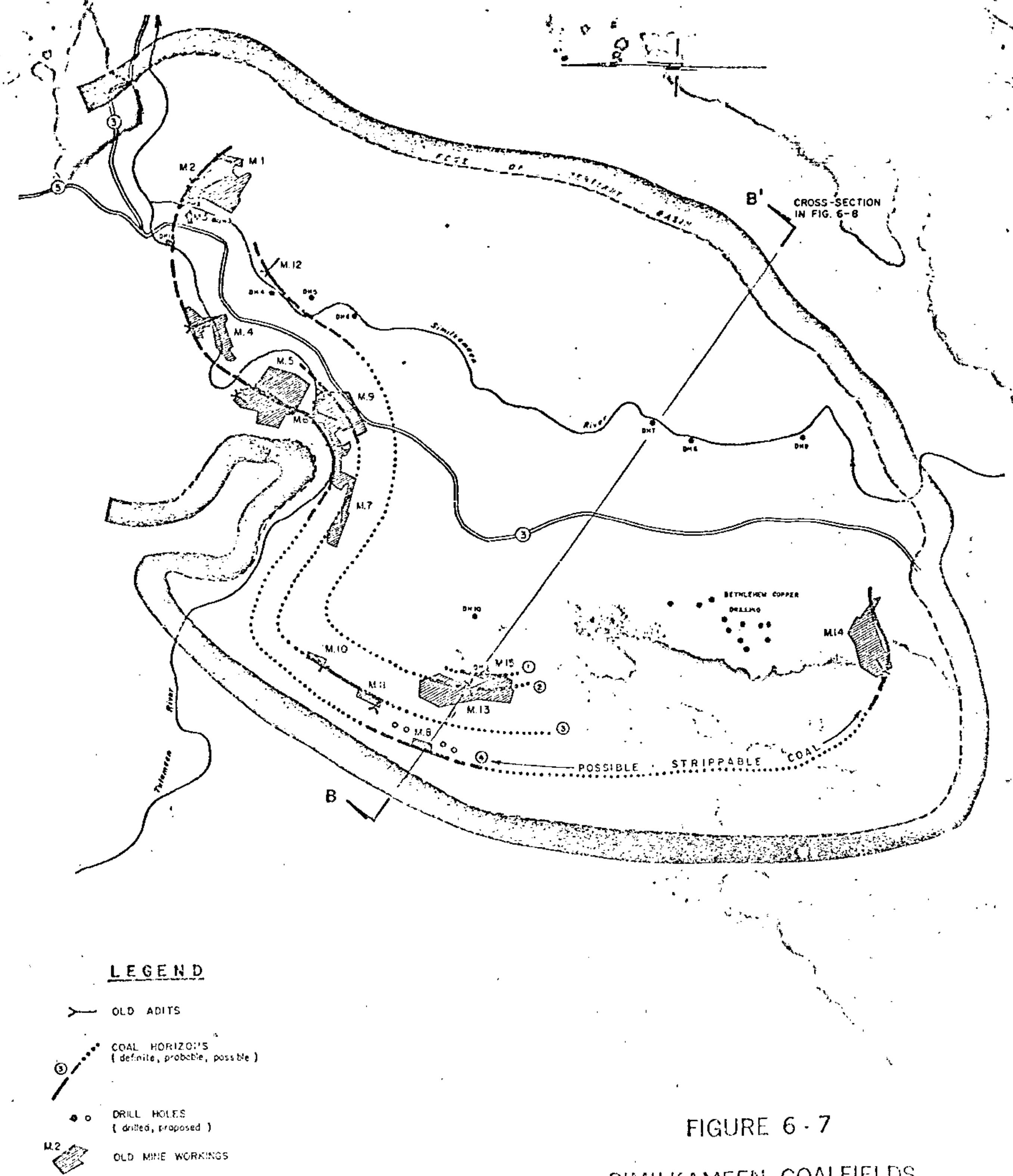

AFTER W.S. SHAW, 1952

FIGURE 6-7

SIMILKAMEEN COALFIELDS
PRINCETON COAL DEPOSITS

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MILES

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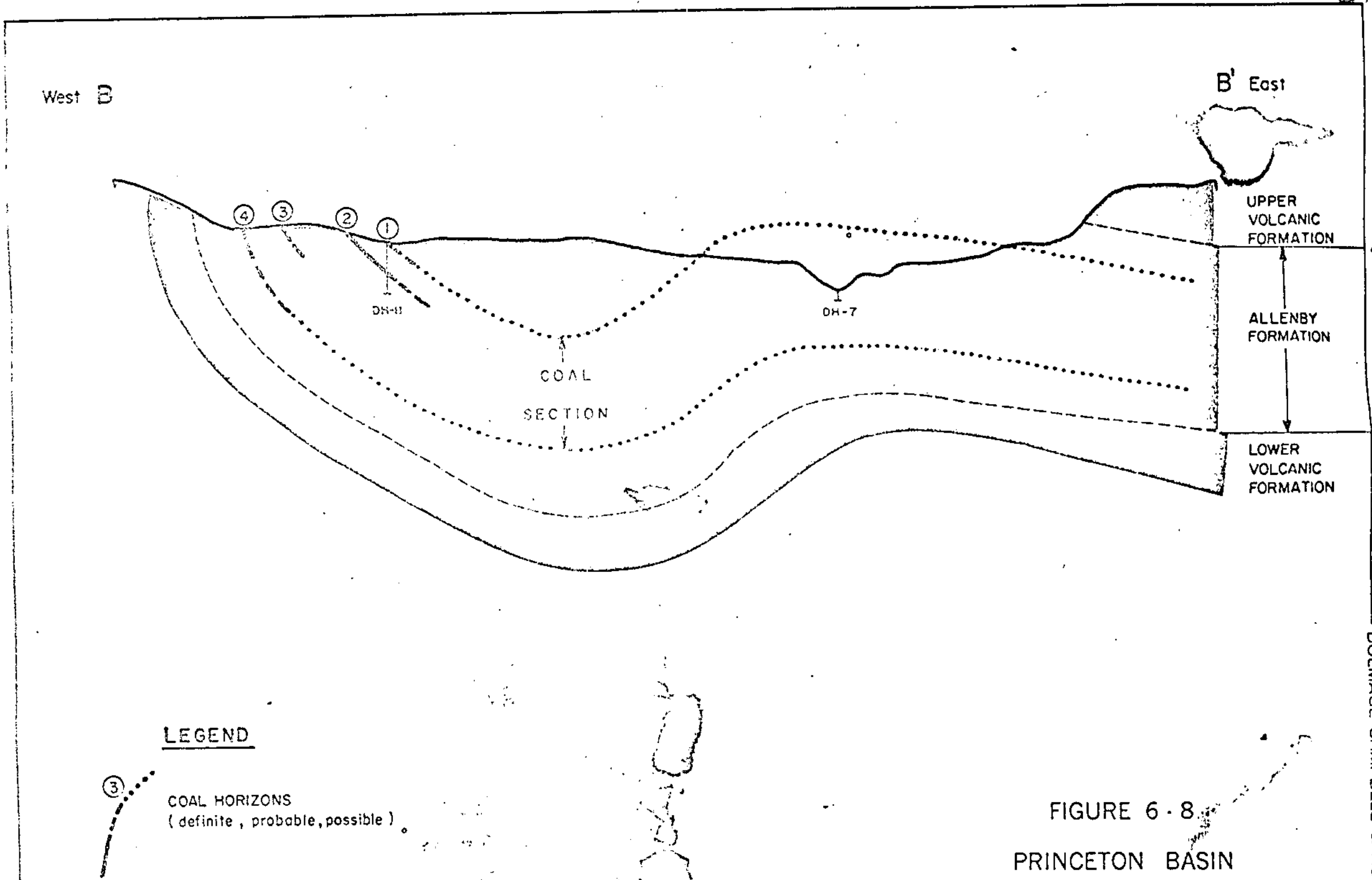

FIGURE 6 · 8
PRINCETON BASIN
SCHEMATIC CROSS-SECTION

DOLMAGE CAMPBELL & ASSOCIATES LTD.

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workings, practically negates a comprehensive appraisal of the basin stratigraphy in that area. In the southern half, direct adit entry to coal seams was a basic requirement for the economic development of mines in the district. Consequently, most of the available information from which the basin stratigraphy can be derived is concentrated along the Similkameen and Tulameen rivers and two of the larger creeks which flow into the Similkameen. Because of the more complex depositional history of the Princeton Basin, as compared to the Tulameen Basin, precise correlations between drill holes (also along valleys), mine workings, and outcrop exposures must be viewed with reservation, particularly since few if any records were kept of the old mines and also since present access to the mines is essentially non-existent. The best available marker beds are the coal seams themselves and also the larger bentonite seams, even though to some extent these apparently tend to lense and pinch out locally along strike and down dip.

On the basis of the presently available information, the coal-bearing section (the coal measure) of the Allenby Formation consists of 1700 feet of sedimentary rocks situated near the centre of the 3500 foot-thick formation, (Figure 6-8). The coal measure comprises shale, sandstone, conglomerate, coal and bentonite with various mixtures of these rocks including coal, shales or shaly coal, which in close proximity with coal seams may be of economic significance.

COAL DEPOSITS (Figure 6-7)

Within the coal measure four coal zones have been recognized by previous workers in the district. Coal has been mined from individual seams within each of the zones. The presence of a fifth zone or seam is indicated; however, whether it occurs above or below the four principal zones, or indeed whether it even exists, remains conjectural. A coal zone in the Princeton basin is defined as a carbonaceous section containing one or more seams of coal in excess of five feet in thickness. The stratigraphic interval between zones contains many coal seams but normally they range in thickness from one to three feet and are not considered of economic interest at this time.

On the basis of the available evidence, the coal section (approximately 1700 feet in thickness) is estimated as follows:

Top	No. 1 Coal Zone	10 ft.
	Interval (1-2)	345
	No. 2 Coal Zone	85
	Interval	650
	No. 3 Coal Zone	100
	Interval	450
Bottom	No. 4 Coal Zone	60
		1700 ft.

The No. 1 zone, (Golden Glow after Shaw, 1952) has been recognized in one mine (M15) and one bore hole (DH11). It is reported to be in excess of 6 feet in the mine. In the bore hole its thickness is 9 feet.

The No. 2 Zone, (Gem-Blomley after Shaw, 1952), identified in M12, M13, DH6, and possibly DH11, contains 25 feet of coal in an overall zone thickness of 85 feet. Only 6 feet of a 16 foot seam was mined (M13).

The No. 3 zone, (Pleasant Valley-Jackson after Shaw, 1952), is reported to contain two or three workable seams in an overall zone thickness of 100 feet. Seams from the zone have been locally exploited from M9, M10, and M11. A bore hole (DH4) intersected a 5 foot seam which probably lies within the zone.

The No. 4 zone, (Princeton-Black after Shaw, 1952), has been, to a large degree, the most productive. Several small underground mines were developed on the upper seam within the zone, notably at M1, M2, M3, M4, M5, M6, and M7. Granby Consolidated carried out a small stripping operation until 1950 from M8, mining the upper 40 feet of the zone. Clean coal seams in close proximity to dirty coal, coupled with a favourable topography, offered inexpensive open pit extraction of relatively low-quality coal. Underground mines in the vicinity of the village of Princeton are reported to contain thick sections of dirty coal beneath the mineable seam; however, topographic conditions are not favourable for open pit methods in this area. On the basis of the available evidence it appears that the Blue Flame mine (M14) near the southern extremity of the basin lies within the No. 4 coal zone. The Bethlehem Copper drill holes apparently interesected the same zone about a mile north of the Blue Flame. The overall thickness of the zone ranges from 36 feet near Princeton, 31½ feet at the Blue Flame (M14), 29 feet in the Bethlehem drill holes, and up to 160 feet in Granby's Black open pit (M8), although the upper 49 feet contains most of the coal.

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Coal is known to occur at isolated localities in the northern half of the Princeton Basin. Insufficient exposures and a lack of previous production precludes an analysis of the stratigraphy of the northern area. However, coal zones of comparable thickness and extent to those in the southern half could occur, but exploration consisting initially of wide-spaced fairly-deep drill holes would be required to determine this.

COAL ZONE RESERVES

Because of the scattered and very poorly documented nature of the past production in the Princeton Basin, no attempt was made in this report to derive established coal reserves which require exploitation by underground mining methods. Coal which could possibly be mined by surface methods is placed into established reserve categories, (proven, probable, and possible), whereas underground coal is viewed as potential resources for the same reasons as those adopted for the Tulameen Basin; namely, undetermined underground mining conditions.

From a practical standpoint openpit mining will probably require the extraction of a zone of coal seams, coaly shale, and interbedded coal and shale, rather than individual coal seams. The quality may possibly be improved by some selective mining or by washing. As in the Tulameen Basin, a combination of zone thickness, dip, and a favourable topographic setting determines whether a zone can be economically extracted by surface mining methods.

A coal zone potentially mineable by openpit methods is indicated to exist between the Granby (or Black) open pit (M8) and the Blue Flame Mine (M13), a distance of approximately 4 miles. The thickness of the zone ranges from 36 to 49 feet and dips 20° to 50° southeast toward the Bethlehem Copper drilled area, (Figure 6-7). For calculation of reserves the zone is considered in two sectors: one 5500 feet in length containing the Granby pit, shown as a definite and probable coal horizon, (Figure 6-7); the other is projected southward for 3½ miles along a lineal topographic depression to the Blue Flame Mine (M13).

The surface coal reserves calculated to exist along this belt and including the Granby pit are:

Proven	none
Probable	2.5 million tons
Possible	8.6 million tons
	11.1 million tons.

The probable coal reserves lie beneath and adjoining the Granby pit. The possible coal reserves occur at deeper levels beneath the probable reserves (0.8 million tons) and the indicated southern extension toward the Blue Flame Mine (7.8 million tons).

COAL CHARACTERISTICS

Coal from the Princeton Basin has been variously classified as having a rank ranging from lignite to sub-bituminous "A". It has been reported to slack readily upon exposure to air and to exhibit generally poor storage characteristics, with a tendency to spontaneous combustion when stockpiled in large volumes.

Coal analyses data are available from three localities in the southern half of the basin:

1) Five samples each were taken from two mines near the town of Princeton by the British Columbia Dept. of Mines in 1947; the thickness of the seam (presumably from the No. 4 zone) was not specified. The assays of the two samples averaged (probably on an as received basis):

Moisture	14.5%
Ash	13.0%
Volatile Matter	28.5%
Fixed Carbon	43.8%
Calorific Value	8745 Btu per lb.

The calorific values ranged from 7,400 to 10,360 Btu per lb.

2) Bethlehem Copper Corp. Ltd. intersected coal in seven of twelve holes drilled. Coal thickness ranged from 23 to 49 feet, averaging 29 feet. The central core of the zone for the seven holes averaged 12 feet and only it was assayed, presumably because it was recognized as the best coal for coking purposes. The values ranged as follows (on a dry basis):

Moisture	---
Ash	23.0 - 26.1 %
Volatile Matter	33.3 - 34.4 %
Fixed Carbon	40.5 - 42.6 %
Sulphur	0.75 - 0.83 %
Calorific Value	9941 - 10,336 Btu per lb.

3) In 1947 Granby Consolidated sampled the Black pit (M8) in order to test the suitability of the No. 4 zone for thermal plant feed. The company sampled the zone over widths of 58 feet and 94 feet. In each case the zone material was analysed both with and without bands of waste, which were extracted by hand. The results were recorded as follows (on an as received basis):

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