EXAMINATION OF MINERAL OCCURRENCES

SOUTHERN ROCKY MOUNTAINS,

ALBERTA AND BRITISH COLUMBIA

November 7, 1974

K. D. Hannigan
K. D. Hannigan, P. Geol.

INTRODUCTION

The examination of mineral occurrences in the southern Rocky Mountains was somewhat late in getting started due to unusually heavy winter accumulation of snow which lasted well through the summer at the higher elevations.

A total of 17 days was spent in the field and 3 days were used in completing the present report.

Considerable delay was experienced in completing the proposed field work as three trips were made to examine the lead-zinc occurrence at the headwaters of the Oldman River, each time without success. The first attempt in late August was halted by impassable mud-holes on the access road; the second try in September switching to a 4-wheel drive vehicle was stopped by heavy snowfall; the third attempt in early October which was to utilize a helicopter which was operating from a seismic camp about 10 miles from the prospect was stopped by rain and snow.

During the other examinations no time was lost due to weather; however one day was lost on an abortive climb to Copper Mountain early in July only to find the winter snows still covering most of the exposures.

Prospecting began in the Rocky mountains in the late 1800's and a few finds were made. Results were however disappointing and at the same time, many spectacular finds of gold and silver were being reported from the British Columbia interior. Accordingly the prospectors left never to return.

In some ways, the results of the field work were disappointing. It is perhaps too simplistic to expect that one can readily find showings that are almost 100 years old or that the exposures will be so good that geological picture is readily apparent or that, even with good exposures, there is necessarily some spectacularly geological environment that readily explains the occurrence. Often showings for all the above reasons are enigmatic.

On the other hand, certain basic points of lithology emerged which seem to point towards a valid exploration potential.

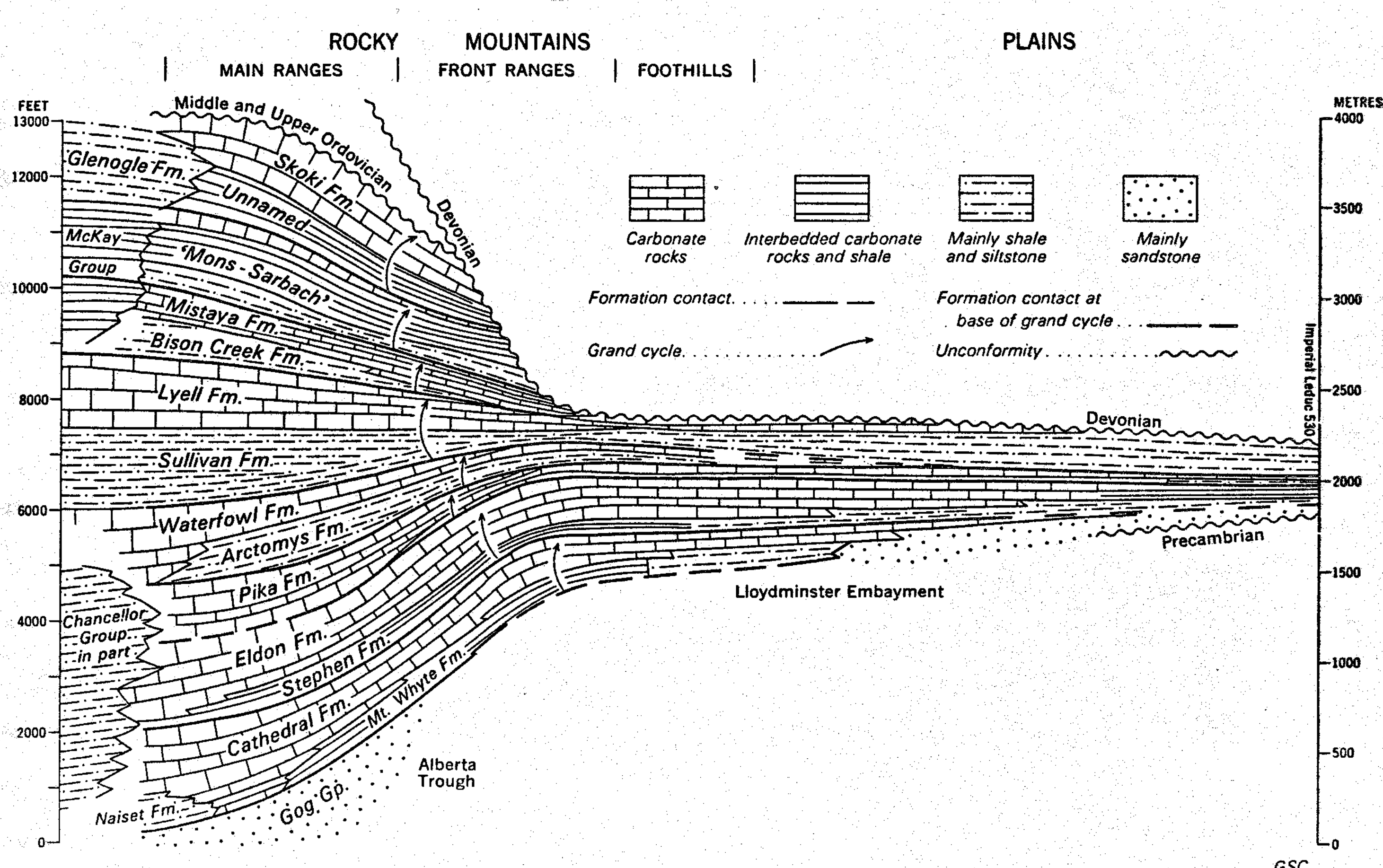

FIGURE VIII-7. Schematic restored stratigraphic section of Cambrian and Ordovician rocks, southern Rocky Mountains and Interior Plains of Alberta and British Columbia (Aitken, 1966).

LOCATION MAP
MINERAL EXAMINATION, 1974
SCALE 1:250,000
1 INCH = 4 MILES

1 MOUNT STEPHEN
2 MOUNT FIELD
3 OTTERTAIL RIVER
4 MOUNT BOSWORTH
5 CASTLE MOUNTAIN
6 HAWK CREEK
7 COPPER MOUNTAIN

MOUNT STEPHEN - MOUNT FIELD

References: Aitken, J. D. 1971: Control of lower Paleozoic sedimentary Facies by the Kicking Horse rim, southern Rocky mountains, Canada; Bul Can Pet Geol, Vol 19, No 3.

Allan, J. A., 1914: Geology of Field map-area B.C. and Alberta; Geol. Surv. Can. Mem.55, pp 222-225

Cook, Donald G., 1970: A Cambrian facies change and its effect on structure, Mount Stephen - Mount Dennis area; in GAC Special Paper No. 6

Ney, C. S., 1954: Monarch and Kicking Horse mines, Field, British Columbia; Alta Soc Pet Geol Guidebook, 4th Ann Field Conference

Lead - zinc mineralization was discovered in the talus at the foot of Mount Stephen in 1885 during construction of the Canadian Pacific Railway. Exploration by means of adits began shortly thereafter and continued intermittently until 1912 when the concentrator was completed and production commenced.

The mineralization occurs at and near the base of the Middle Cambrian Cathedral dolomite which has a thickness in excess of 300 metres.

Stratigraphically the sequence at Mount Stephen - Mount Field begins at the lower elevations with the Lower Cambrian Gog formation, a sequence of fine to medium grained, white to light grey, maroon to brown weathering quartzites. (Sample 29)

This is overlain by a thin unit, estimated at 50 metres, of

1. Mount Stephen - north face. Monarch mine occurs at base of brown weathering unit at about its juncture with talus at left (east) side of photo, approximately at top of foreground spruce tree. This brown dolomite tongue is in excess of 200 metres thick at this section.

2. Mount Stephen - north face further west from photo 1. The thin dark unit below the brown weathering dolomite can be used for correlation between the two photos. The brown weathering dolomite is fingering westward into dark Chancellor shales. This facies front involves a vertical interval of at least 300 metres and includes the Cathedral formation (brown weathering unit) and the lower Eldon formation.

3. Mount Field - south face. Brown weathering dolomite tongue (same as across valley on Mount Stephen) displaying its lower contact cutting up-section westward (to the left of photo). The unit is quickly thinning westward as well.

4. Mount Field - south face further east from photo 3. Brown weathering dolomite tongue has very irregular upper contact "stoping" into the well bedded dolomite.


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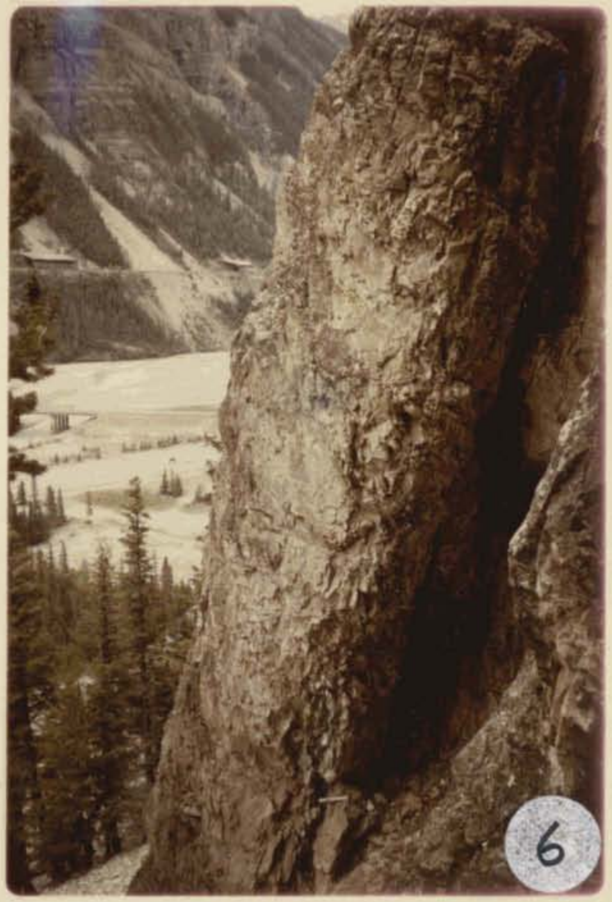
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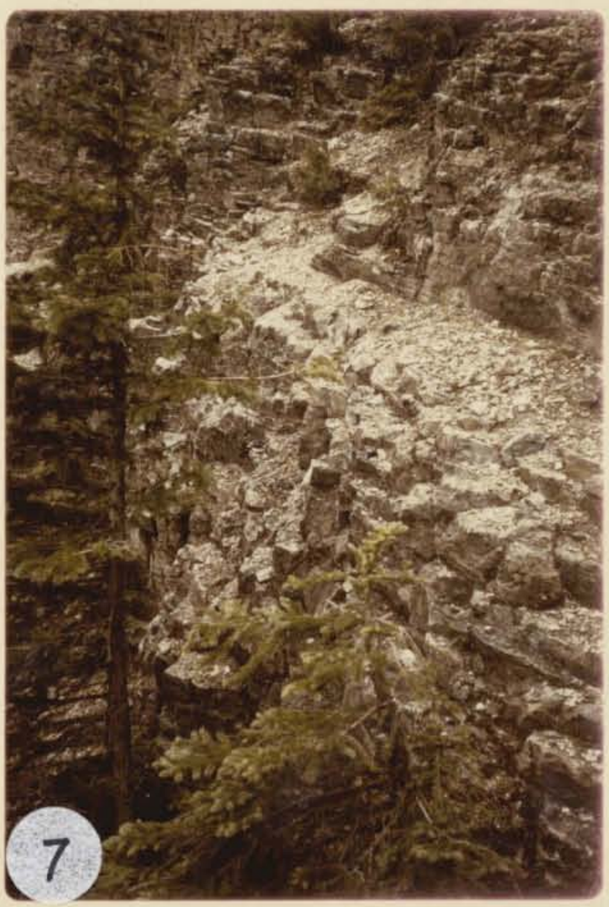
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5. Pink dolomite tongue, Mount Field, showing prominent jointing, massiveness of the unit and obscure horizontal bedding.

6. Pink dolomite tongue, Mount Field. See hammer lower centre for scale. Massive and unbedded.

7. Thin-bedded, medium grey, silty dolomite, Mount Field, lying immediately below the pink dolomite tongue.

8. Same thin-bedded dolomite as in photo 7 with the pink dolomite occupying the upper right corner of the photo.

thin bedded, alternately light and dark banded, medium grey, fine-grained dolomite and limestone known as the Mount Whyte formation. (Samples 4 - 7) (Photos 7&8). The Mount Whyte has been assigned a Middle Cambrian age by Aitken and Cook.

Overlying the Mount Whyte is a thick brown weathering dolomite tongue the Cathedral formation, also assigned to the Middle Cambrian. This dolomite, in excess of 300 metres thick, is white to cream to light grey, medium to coarsely crystalline, brown to pink weathering, and universally mineralized with a dusting of fine pyrite. (Samples 1 - 3) (Photos 1 - 6, 13 & 14).

Some of the very fine sulphide crystals are so black that it was suspected that they might be sphalerite. Large samples are provided for assay if desired.

This distinctive brown-weathering white dolomite appears to be of post-diagenetic origin, both its upper and lower contacts appear to have nonconformable relations with the enclosing strata (Photos 3, 4, 13, 14) although it might be argued that the irregular upper contact might have originated as bio-hermal type of surface. Similarly the lower contact could have non conformable relations if one wished to assume a tectonically active Kicking Horse rim (see Aitken) which produced, even locally, an unconformable surface which, with shallow submergence, initiated growth of a reef-like structure.

HAWK CREEK

References: Hedley, M. S., 1954: Mineral deposits in the southern Rocky mountains of Canada; in A.S.P.G. 4th Ann Field Conf. Guide Book

Henderson, G. G. L., 1954; in Minister of Mines Ann. Report, British Columbia, 1953 p A155-6

The Hawk Creek prospect is easily reached from the Ball Pass trail; an excellent trail connecting the Hawk Creek valley to the Redearth Creek valley of Banff National Park. The showing lies about 2 miles northeast of and about 1400 feet higher than the Banff - Radium highway. Henderson reports that the deposit was discovered in 1929. Four open cuts, downhill from the deposit, lie along the Ball Pass trail and at one of them a high-grade float boulder still remains. It seems likely that the float was discovered during the trail construction and eventually traced uphill to its source. The hillside is well timbered with only occasional small outcrops.

All rocks in the immediate area of the deposit are affected by a pervasive near vertical cleavage. This is more prominent in the fine-grained clastics than in the more massive carbonates. Bedding has been essentially destroyed by the cleavage and it is only that the superposition of litholgies over a broad area shows that the bedding is almost horizontal. Cleavage strikes northwest and dips southwest from 50° to near vertical. The ore horizon consists of a fine-grained, medium grey dolomitic limestone (Sample 8) probably about 10 m thick. It is overlain and underlain by buff limey argillites. (Sample 9).

9. Hawk Ridge zinc prospect showing old trenching on heavily wooded hillside.

10. Hawk Ridge showing pervasive vertical cleavage in calcareous "Chancellor type" shales. Bedding is actually near horizontal.

11. Well mineralized dolomite float boulder, Hawk Creek. This boulder brought down north flowing tributary by spring 1974 avalanche. Pyrite, as individual crystals and masses, in white to cream sugary dolomite.

12. As above.


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13. Mount Field - abrupt contact within Cathedral interval at facies front between white dolomite and buff-weathering grey limestone. Contact is at angle with bedding but roughly parallels fracture at hammer head.

14. Mount Field - at western termination of main Cathedral dolomite tongue. Note mound shape of small dolomite mass and abrupt cutting relationships with enclosing thin bedded limestone.

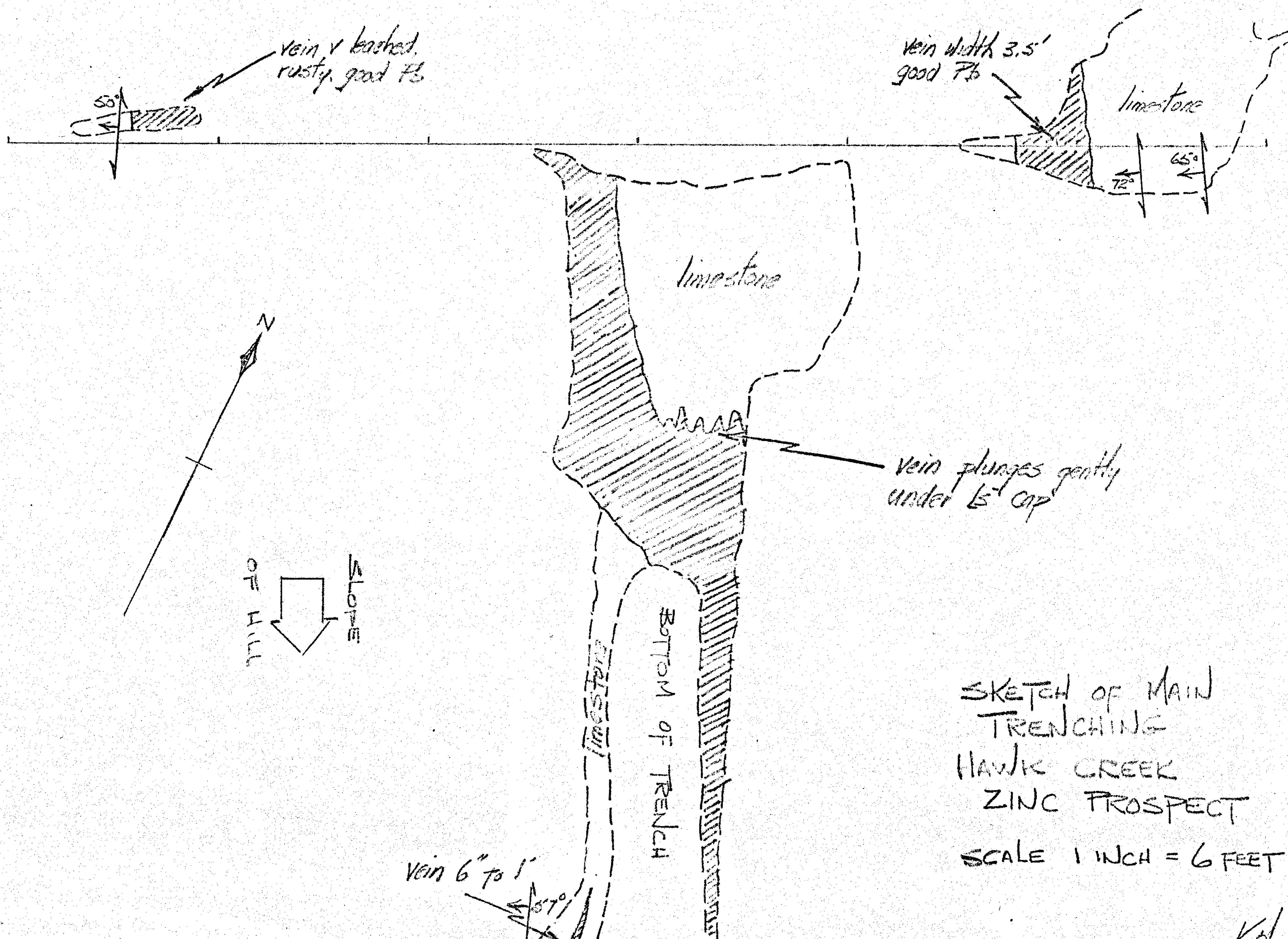
The higher grade sphalerite together with all the galena and chalcopyrite forms vein-like tabular bodies paralleling the cleavage.

The ore limestone does not outcrop laterally beyond the trenched area so that one cannot assess its potential. According to Henderson the 1942 drilling explored the mineralized zone for 250 feet northwestward into the hillside following the cleavage or fracturing. Since the mineralization control appears to be the combination of "ore limestone" and fracturing and/or cleavage and since the cleavage is likely a regional phenomenon, the actual extent of the mineralized horizon might be great. This is, of course, academic since the area is in the middle of Kootenay National Park.

One half mile eastward across a south flowing tributary of Hawk Creek, a large cliff shows lense-shaped masses of very coarse-grained brown-weathering dolomite (Sample 18)

One quarter mile easterward and below the Ball Pass trail occur large blocks (3 m to 5 m dia) of very coarse grained dolomite. These blocks are believed to be essentially in place. Pyrite, as rounded tarnished black pyritohedrons, is common in the dolomite.

One quarter mile east at creek level, large float boulders of white medium to coarsely crystalline dolomite (Photos 11 and 12) (Sample 19), well pyritized with rounded crystals and masses up



SKETCH OF MAIN TRENCHING
HAWK CREEK
ZINC PROSPECT

SCALE 1 INCH = 6 FEET

to 2 inches in diameter, has been carried down the north flowing tributary by an avalanche in the spring of 1974. Similar float occurs all the way up this tributary.

The Hawk Creek deposit occurs essentially right at the facies front; if it could be drawn as a single line I would draw it following north and south tributaries of Hawk Creek.

Two stream sediment geochem samples were taken on the north flowing pyrite bearing tributary, one at its mouth and the other $\frac{1}{4}$ mile upstream.

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OTTERTAIL RIVER

References: Allan, John A., 1914: Geology of Field map-area, B.C. and Alberta; Geol. Surv. Can. Mem.55, pp 222-225
Balkwill, H. R., 1971: In Guide to geology of eastern cordillera; A.S.P.G. Cdn. Expl. Symposium p.71
Cook, Donald G., 1970: A Cambrian facies change and its effect on structure, Mount Stephen-Mount Dennis area; in GAC Special Paper No. 6

Although a number of prospects were reported by Allan to occur within the drainage of the Ottertail River, these were worked in the period from 1890 to 1910 with disappointing results. Even by the time of Allan's work (1910-1911), the workings were beginning to be covered and inaccessible.

One of the old prospects was found on Haskin's Creek about 4 miles above (upstream) the Trans-Canada Highway. An old trail follows the northeast flank of Mount Hurd maintaining a constant elevation of about 400 feet above the Ottertail River.

Few outcrops exist at this elevation but numerous drainages are crossed which give an excellent sampling of the mountainside. It consis consists entirely of phyllite of the Chancellor formation, Sample 26, (called Upper Chancellor slate by Balkwill). Cook reports the unit (p 34) to be at least 4500 feet thick on Mount Hurd. The phyllite is typically buff weathering, light green to buff, platey and at an outcrop strikes 335° and dips 37° south. Judging from the float, a continuous cliff about 1000 feet uphill from the trail must be all Chancellor phyllite. An amazing proportion of the float, particularly in the final (upper) 2 miles of the trail, consists of barren vein quartz. Obviously the phyllites are laced with quartz veins.

A series of 7 stream sediment geochem samples was taken in the minor drainages along this 4 mile length to give some geochemical background data for this geological environment of basinal shales cut by apparently unmineralized quartz.

The Haskin's Creek prospect occurs at an elevation of about 4500 feet. It is unclear whether this is the same showing reported by Allan as his map locates the showing at over 5500 feet. Nonetheless some considerable work was done as a moderate dump exists together with the remains of several cabins. The adit portal could not be found. Some mineralization was found on the dump (Sample 27) but was probably only a narrow (3") "ore streak".

The vein is exposed in the vertical bank of Haskin's Creek following a set of fractures normal to the platey phyllite bedding. The fractures are spaced 1 foot to 5 feet apart. The vein, of white quartz, varies from 6" to 2' in width over a length of about 30 feet. Due to slumping, it is not clear the vein follows persistently one particular fracture or whether it pinches, swells, disappears, and reappears. No mineralization was seen in the outcrop.

The vein style is so typical of incompetent platey and thin bedded rocks which are so often cut by swarms of barren quartz veins. Small pockets of mineralization which do occur have no economic significance.

Since the Chancellor formation is regarded as having a thickness of some 10,000 feet of incompetent strata, it obviously must occupy areally a large part of the country. Unless some sizeable competent units can be determined within the formation, then its economic potential for structurally controlled mineralization must be seriously downgraded.

20.4 (25.3) Mt. Hurd ahead, capped by Upper Cambrian Ottertail limestone. The lower slopes are Upper Chancellor slate and slaty limestone.

20.6 (25.1) Park Warden's cabin.

20.8 (24.9) Bridge over Ottertail River. Outcrops of Chancellor Formation slate for next 1.5 miles. Prominent ridge to the northeast (Fig. 16), between Amiskwi and Otterhead Rivers, is formed from resistant limestones of the Ottertail Formation, outlining northwesterly plunging Split Creek synclinorium. To the northwest, Upper Cambrian - Lower Ordovician McKay (Goodsir) Group slate and limestone form the core of the synclinorium; to the southeast, the youngest beds in the core of the structure are the upper part of the Chancellor Formation (Upper Cambrian).

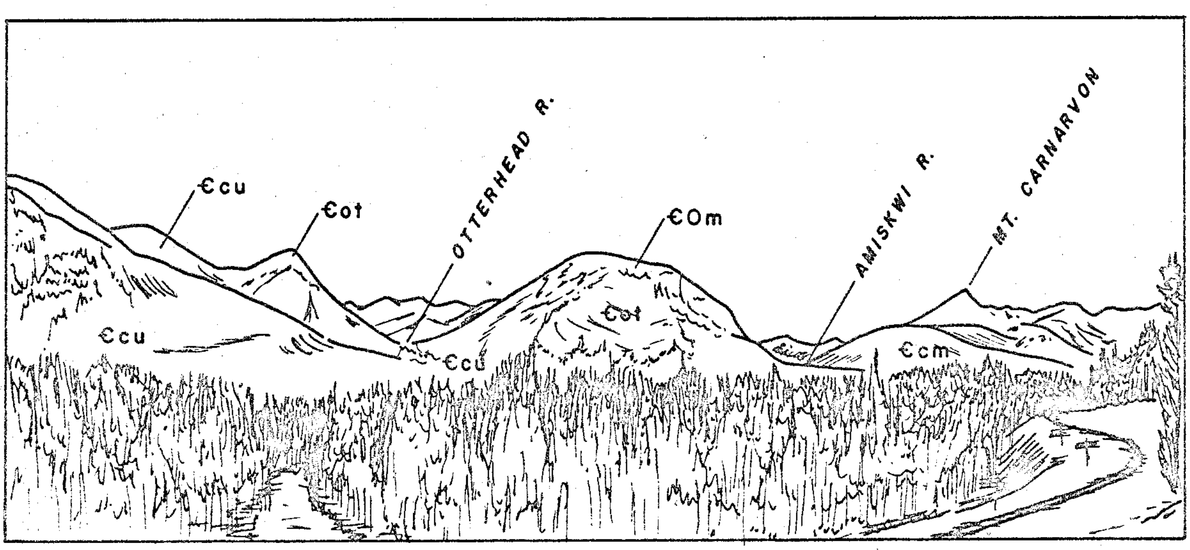

Figure 16 Northeastward view from Highway 1 at Ottertail River. Sketch by H. R. Balkwill.

15. Haskin's Creek - Buff weathering Chancellor phyllites cut by irregular quartz vein which was explored by adit.

16. Mount Field - west gulch - Recessive Mount Whyte interval with massive Cathedral dolomite (upper left) and Gog quartzites (lower right).

17. Mount Field - west gulch - Contact between Cathedral dolomite (above) and Mount Whyte formation.

18. Castle Mountain - lowermost adit - Medium grey, fine grained brecciated dolomite with fractures filled with white dolomite. Barren.


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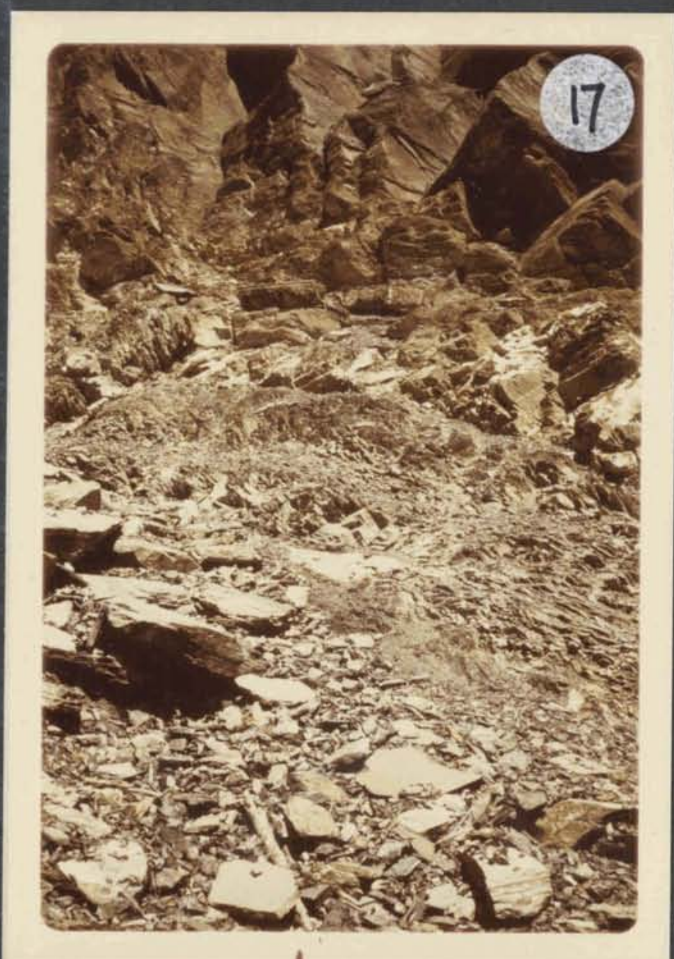
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19. Castle Mountain - Brown weathering dolomite breccia (angling across photo from upper left to lower right) with light buff-grey weathering unbrecciated dolomite beyond (in upper right)

20. Castle Mountain - Close-up of pink to brown-weathering dolomite breccia of Photo 19. These fragments are set in a fine-grained dolomite matrix and are possibly slump breccia from a nearby bank edge.

21. Castle Mountain - pink to buff weathering dolomite breccia (to right and foreground) with stratigraphically equivalent buff dolomitic shale and some maroon and green shale (left side of photo)

22. Castle Mountain - Upper part of Cathedral formation with massive cliffs of Eldon formation above.

CASTLE MOUNTAIN

References: Mount Eisenhower Sheet; Geol. Surv. Canada, Map 1297A
Price, R. A., 1971: in Guide to geology of eastern cordillera; ASPG Expl Symposium p 65

In the late 1800's a settlement known as Silver City was established near the foot of the mountain which was later known as Castle Mountain and has been recently renamed Mount Eisenhower. This settlement was to serve the new "mines" being established on Castle Mountain and across the valley on Copper Mountain. Even to-day brick piles attest to the optimism as these were brought by wagon to construct a crude smelter. After driving several short adits, work was discontinued.

At the north end of Castle Mountain above Baker Creek at an elevation of about 8200 feet occur three short adits. These lie in the upper part of the Cathedral dolomite which displays a wide range of brecciation and dolomitization. Some of the breccia displays coarse angular dolomite fragments in a finer-grained dolomite matrix (Photos 19 and 20) and are likely slump breccias of material from a nearby carbonate bank. Other breccia could best be called "crackle" breccia (Photo 18) in which the fragments are simply spread apart without rotation or transport and the interfragment areas filled with coarse white dolomite. The brecciation is extensive within the Upper Cathedral but has no obvious pattern.

Structurally the area is simple, lying close to the axis of the gently dipping Mount Eisenhower syncline. Dips are on the order of five degrees. The syncline is underlain by the gently westward dipping (approx 8 degrees) Castle Mountain thrust; however this thrust should lie at a depth of almost 1000 metres below the Upper Cathedral level and so would have no relation to the brecciation. The brecciation is thus ascribed to differential compaction of complex local facies variations (Photo 21) under a thick Paleozoic and Mesozoic section, and to volume changes involved in dolomitization processes.

Bunches of galena occur within brecciated finely crystalline dolomite, (Sample 33) at the northernmost adit. The galena occurs mostly in the white dolomite infilling the breccia and also within fragments of the original dolomite. The mineralization is local, erratic and very low-grade. No particular control for the mineralization can be suggested. The other two adits were driven short distances in brecciated dolomite but no mineralization was noted. The "ore pocket" was probably all "mined out" with the driving of the adit.

Copper, as chalcopyrite but more often as malachite or azurite, occurs sparingly in the talus on Castle Mountain. Where seen in place it was either part of a glassy quartz veinlet cutting the brecciated dolomite or as a copper carbonate film coating fractures near a veinlet. These fractures were always normal to the bedding and postdated the healing of the breccia by white dolomite.

It would seem likely that the source of both the copper and the

23. Mount Field - panormic view

24. Hawk Creek - caved open-cut along Ball Pass trail.

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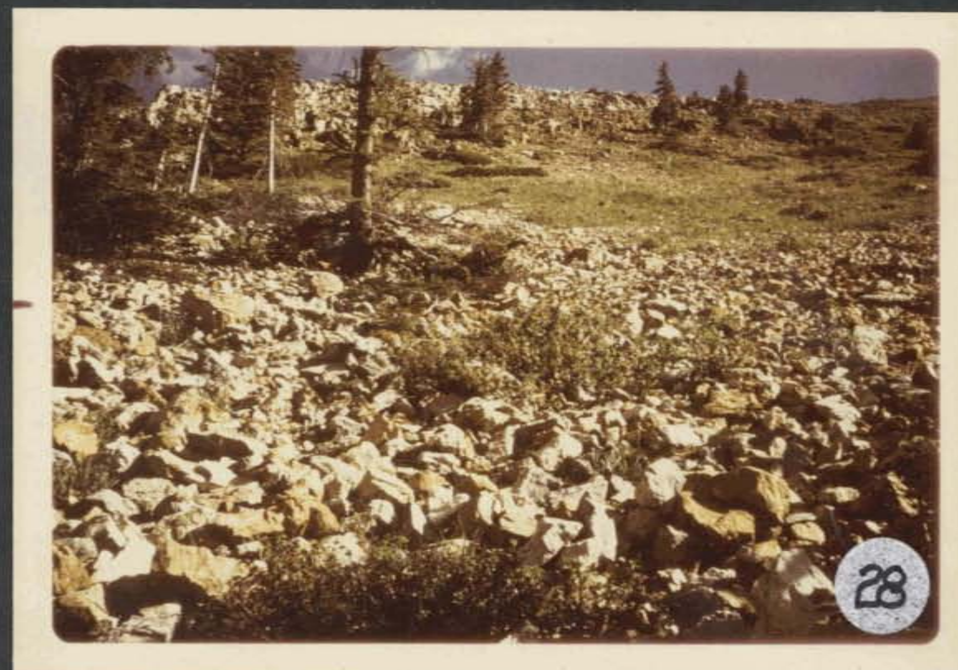
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25. Castle Mountain - showing buff weathering dolomite development

26. Mt Field - thin bedded, light and dark banded limestone and dolomite unit (Samples 6 and 7)

27. Copper Mountain - near vertically dipping Upper Cambrian Lyell formation

28. Copper Mountain - talus of orange weathering blocks of white dolomite developed in the Lyell formation.

quartz would be Precambrian or Lower Cambrian quartzose clastics which underlie the area and which are copper-bearing at Waterton, in northeast British Columbia, and even into the Northwest Territories and Yukon.

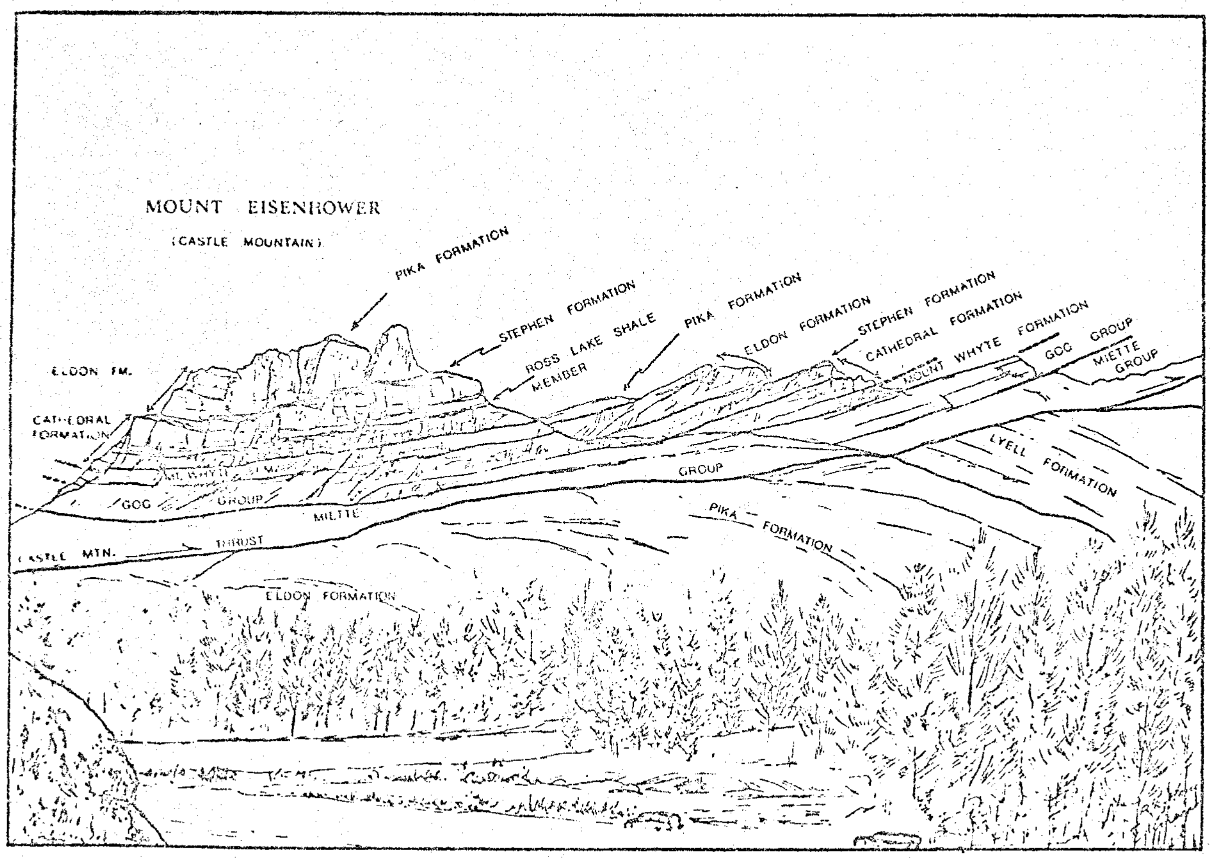

Figure 14 Northward view of Mount Eisenhower. Sketch by R. A. Price.

Stratigraphy: At Mt. Eisenhower, section is Precambrian Lower Miette slates, sandstones, and pebbly grits (1,000' min. in thrust plate); Lower Cambrian Gog Group (quartzites, minor shales, 1,050'), Middle Cambrian Mount Whyte Fm. (recessive, interbedded shale and limestone, 308'); Cathedral Fm. (resistant limestones, 959', with thin recessive ledge with *Albertella* (Ross Lake Shale, 1/3 up from base); Stephen Fm. (recessive, flaggy limestones and shales with *Glossopleura*, 231'); Eldon Fm. (massive, resistant limestone and dolomite, 893'); Pika Fm. (flaggy limestone and dolomite, shales near base, 522' on Helena Ridge, incomplete on Mt. Eisenhower).

The Miette forming the base of the Mt. Eisenhower section overlies a thin plate of Lower, Middle and Upper Cambrian along the Castle Mountain thrust which crosses the timbered slopes. This latter plate is in turn faulted over steeply dipping Precambrian to Devonian beds which extend across the Bow Valley from this quarry. They are cut by several transverse faults on the north slope of the valley, and overlie the Upper Paleozoic and Triassic of Johnston Canyon along the Johnston Creek fault.
The quarry itself is in east-facing Eldon dolomites belonging to the lower, folded plate. The westernmost, flaggy beds here are characteristic of the basal Eldon, and the Stephen occupies the covered interval to the west.

MOUNT BOSWORTH

References: Aitken, J. D., 1971: Control of lower Paleozoic sedimentary facies by the Kicking Horse rim, southern Rocky mountains, Canada; Bul Can Pet Geol, Vol 19, No 3.

Mount Bosworth lies 7 miles northeast of the facies front at Mount Stephen. A traverse was made up Mount Bosworth to determine what lithologic changes had occurred 7 miles shelfward from the front.

Two dolomite bands or tongues occur separated by a 100 foot section of thin-bedded limestone. The dolomites are light to medium grey, fine to medium grained, frequently mottled with buff to white more coarsely crystalline dolomite. Pyrite is sparingly present as fine discrete crystals. The most notable difference from areas immediately adjacent to the facies front is the absence of the white sugary medium grained to coarse grained dolomite which is so typical of the facies front lithology. The pyrite content is also markedly less.

The section traversed at Mount Bosworth is as follows:

Base of section - Middle Cambrian Gog formation, orange-brown weathering, fine-grained greyish white quartzite (Photo 29)

Mount Whyte formation, medium grey weathering, thin bedded, very finely crystalline, medium grey, silty limestone, approximately 25 metres thick (Photo 32)

Cathedral formation, first dolomite tongue, light to medium grey, fine to medium grained, mottled with buff medium to

29. Mount Bosworth - orange-brown weathering, fine-grained Gog quartzite Elevation 5340'.

30. Mount Bosworth - second dolomite tongue of Cathedral formation Elevation 5890'. (Sample 22)

31. Mount Bosworth - top of second dolomite tongue of Cathedral formation overlain by 20 metres of thin-bedded limestone which, in turn, is overlain by buff weathering green shale (Sample 23). Elevation 7200'.


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32. Mount Bosworth - Cathedral formation (background) lying on thin-bedded Mount Whyte formation (foreground) Elevation 5660'.

33. Mount Bosworth - upper limestones of Stephens formation (foreground) capped by light grey Eldon formation.

34. Mount Bosworth - westward vertical facies change in upper part of Cathedral formation from dark grey limestone (foreground) (Sample 24) to light grey dolomite (Sample 25).

coarse grained dolomite. Thickness approximately 140 feet.

Limestone, thin bedded, medium grey, medium grained mottled with buff to orange-brown dolomite with some pyrite. Unit approximately 30 metres thick.

Second dolomite tongue, approximately 400 metres thick. (Sample 22) (Photo 30)

Stephen formation, 20 metres of thin bedded, fine grained, medium grey silty limestone, then 70 metres of green calcareous buff weathering shale, then 60 metres of thin bedded dark grey limestone.(Photo 31 and 33)

Eldon formation, not traversed

-16

COPPER MOUNTAIN

References: Banff (West Half) Sheet; Geol. Surv. Canada, Map 1295A

The near vertically dipping succession at Copper Mountain exposes Middle Cambrian Cathedral through Upper Cambrian Lyell.

Dolomite representing the early and middle diagenetic stages is common in most of the thicker bedded more massive units. A minor amount of late stage dolomite was seen only in talus from the Lyell formation. (Photo 28)

Very minor chalcopyrite and bornite (Sample 41) was found in white dolomite and quartz, filling vugs and fracture in medium grey Lyell dolomite.

Very minor nests of sulphide were also found in dolomite talus from Waterfowl or Arctomys formations (Sample 42)

A dump from old workings at an elevation of 7000 feet was found to be still mostly snow covered at the end of July. A few fragments of grey dolomite with iron oxide patches from the disintegration of pyrite were found on the dump. The adit was driven in thin bedded buff weathering calcareous dolomite belonging to either basal Pika formation or upper Eldon.

Little information could be gained from Copper Mountain. The mineralization is very sparse although there must have been something considerably better originally to have warranted whatever underground work was done. Neither the type of late stage dolomite nor plentiful pyrite is present at Copper Mountain and this is regarded as negative aspects.

CONCLUSIONS AND RECOMMENDATIONS

The mineral occurrences examined in the program stratigraphically fall in a narrow range involving essentially the Middle Cambrian Cathedral formation.

The Hawk Creek deposit lies within the thick basinal Chancellor sequence and is therefore almost impossible to equate chronologically; however, from the regional mapping of the G.S.C. (Map 1279A), it appears that the sequence at the Hawk Creek deposit would not be too far off the Cathedral level.

The dolomitization process falls into three overlapping stages.

1. An early diagenetic stage which produces micro to finely crystalline, light to medium grey, well bedded dolomite which is often calcareous and is intimately mixed with similar appearing limestone.
2. A middle diagenetic stage which evolves a medium crystalline, light to medium grey dolomite often mottled with buff to white more coarsely crystalline dolomite. A very fine dusting of very fine pyrite is common at this stage.
3. A late diagenetic stage which produces medium to very coarsely crystalline, white to cream to buff dolomite universally mineralized with pyritohedrons from a powder up to one cm in diameter. At this stage, one sees the sharp white dolomitization boundaries cutting abruptly up and down section across the bedding. This may have been a function of hydrostatic pressure fronts during the late stage process.

From Hawk Creek to Mount Stephen to Mount Bosworth to Castle Mountain provided a rough cross-section through the facies front and about 13 miles in a shelfward direction. From these sections the following observations can be made.

1. the late stage dolomitization is a function of the facies front, decreasing eastward in volume and grain size, but still a factor 13 miles from the front
2. the occurrence of important amounts of pyrite is also a function of the facies front, decreasing eastward as well.
3. the two "economic size" deposits, Hawk Creek and the Monarch mine at Mount Stephen occur within a mile or so of the facies front.

It would not be surprising if trace amounts of copper and zinc were present with the pyrite of the facies front and analysis of Hawk Creek and Mount Stephen or Mount Field is recommended.

Observations in this field program confirm that the Middle Cambrian facies front is a valid exploration target. The general facies change should be traced northward and southward to beyond the National Park boundaries. This can best be accomplished by air photo interpretation.

Since the areas outside of the parks present access problems, the air photo study can assess the most economic exploration method. All probable helicopter landing sites could be plotted to determine if helicopter use can provide adequate geochemical coverage.


▲ 1-3 G.S.C. MAP 1295A
M. CAMBRIAN ELDON
CARBONATE FACIES
CHANGE TO CHANCELLOR
SHALES
▲ 4 COOK, 1970
M. CAMBRIAN CATHEDRAL
TO PIKA CARBONATE
FACIES CHANGE TO
CHANCELLOR SHALES
▲ 5 COOK, 1970, AS ABOVE
M. CAMBRIAN CATHEDRAL ?
FACIES FRONT OBSERVED
THIS REPORT
MINERAL LOCALITIES EXAMINED
THIS REPORT
GENERAL ZONE OF FACIES
CHANGE FROM AIR PHOTOS
A PORTION OF
YOHO & KOOTENAY
NATIONAL PARKS
SCALE 2 MILES = 1 INCH
NATIONAL PARKS
BOUNDARY
MT. WAPTA
MT. OGDEN
MT. FIELD
MT. BURGESS
WAPUTIK PK.
MT. BOSWORTH
CATHEDRAL CRAGS
MT. STEPHEN
MT. DENNIS
VANGUARD PK.
CATHEDRAL MTN.
NARAO PK.
MT. NIBLOCK
POPES PK.
MT. WHYTE
MT. DUCHESNAY
MT. ODARAY
MT. HUBER
MT. VICTORIA
FAIRVIEW MTN.
HADDO PK.
MT. ABERDEEN
THE MITRE
MT. OWEN
PARK MTN.
MT. SCHAFFER
MT. BIDDLE
MT. HUNGABEE
RINGROSE PK.
PINNACLE MTN.
MT. TEMPLE
CURTIS PK.
FULMEN MTN.
DELTAFORM MT.
MT. BABEL
QUADRA MTN.
CHIMNEY PK.
MT. SHARP
BOOM MTN.
MT. WHYMPER
STORM MTN.
MT. DRYSDALE
VERMILION PK.
STANLEY PK.
MT. HAFFNER
MT. BALL
COPPER MTN.
ISABELLE PK.
HAIDUK PK.
PHARAOH PEAKS
NUMA MTN.
THE MONARCH
QUARTZ HILL
CITADEL PK.
SPAR MTN.
NESTOR PK.
INDIAN PK.
MT. LACHINE
OCTOPUS MTN.
MT. SELKIRK
MT. WATSON
MT. HARKIN
KOOTENAY

BULLETIN OF CANADIAN PETROLEUM GEOLOGY
VOL. 19, NO. 3, (SEPT., 1971) P. 557-569

CONTROL OF LOWER PALEOZOIC SEDIMENTARY FACIES BY THE KICKING HORSE RIM, SOUTHERN ROCKY MOUNTAINS, CANADA[1]

J. D. AITKEN[2]

ABSTRACT

The Kicking Horse Belt is here recognized as a strip of country not over ten miles wide, at present recognized over a length of eighty miles, and occupying a single thrust-sheet in the Rocky Mountains Main Ranges, within which are localized many of the significant changes in Lower Paleozoic strata of southwestern Canada. These localized occurrences are as follows: 1) The only pronounced physical evidence for unconformity at the Lower Cambrian - Middle Cambrian boundary. 2) Westward pinch-out of the Mount Whyte Formation and of shale tongues in the Cathedral and Pika formations, all of Middle Cambrian age. 3) Westward facies change of the Middle Cambrian Stephen and lower Cathedral formations to deep-water facies. 4) Abrupt westward termination of the upper Cathedral Formation in a submarine depositional scarp. 5) Appearance of supratidal facies in abundance in the Middle Cambrian Cathedral and Eldon formations. 6) Westward appearance of slumped, slope facies in the Eldon Formation. 7) Eastward pinch-out of a tongue of outer-detrital facies within the Eldon Formation of the middle-carbonate facies. 8) Passage of the entire sequence of shelf carbonates of Middle Cambrian age into mudstones and argillaceous limestones of the lower and middle Chancellor Formation, to which a deep-water origin is ascribed. 9) Westward facies change of the clastic rocks of the Middle Cambrian Arctomys Formation to carbonates of the Waterfowl Formation.

Additional changes that may take place within the Kicking Horse Belt, but cannot be demonstrated to do so because of post-Laramide erosion, are the westward disappearance of the carbonates of the Upper Cambrian Mistaya and Middle Ordovician Owen Creek formations, and the westward change of the carbonates of the Lower and Middle Ordovician Outram and Skoki formations to graptolitic Glenogle Shale.

The Kicking Horse Belt encompasses the limits of temporal shifting of a slightly elevated paleotopographic feature, the Kicking Horse Rim. Throughout most of the time considered, the Rim prevented craton-derived fine clastic sediments (inner detrital facies) from reaching the deep-water basin. The Rim probably was localized initially in latest Early Cambrian time by a narrow tectonic welt. Once carbonate sedimentation was preferentially established on this linear "high," depositional processes and differential compaction may have sufficed to perpetuate the Rim, although tectonic renewal of relief cannot be ruled out.

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[1]Manuscript received April 1971.

[2]Department of Geology, University of Calgary.

Field work providing the observational basis for this paper was done by the writer while employed by the Geological Survey of Canada, whose permission to publish is gratefully acknowledged. Costs of manuscript preparation were met by Research Grant No. A7469 of the National Research Council.

The paper was critically read in manuscript by D. G. Cook, W. H. Fritz, B. S. Norford and F. G. Young of the Geological Survey of Canada, and by J. W. Harrington and S. J. Nelson of the Department of Geology, University of Calgary. They offered helpful comment, pointed out numerous errors and omissions, and gave needed encouragement to carry the work to completion.

Introduction

A writer giving account of stratigraphic relationships in strata of Middle Cambrian to Middle Ordovician age, in the southern Rocky Mountains of Canada, finds himself repeatedly describing a narrow geographic zone or belt less than ten miles wide, within which occur numerous abrupt changes in thickness and facies. Formal recognition and naming of this geographic zone will simplify the discussion of lower Paleozoic stratigraphy in the region, and will draw attention to the probability that some fundamental feature has caused the localization of so many stratigraphic "events." It is here proposed to identify the geographic zone encompassing all these localized stratigraphic changes as the Kicking Horse Belt.

In this paper, where observations are not otherwise attributed, they are those of the writer.

Geographic Location

At the southern end of its presently recognized extent (Fig. 1), the Kicking Horse Belt passes through Mount White Man, thence northwesterly through the Mount Assiniboine massif, to Vermilion Pass, Mount Odaray, Mount Stephen and Emerald Lake. At the northern end of its studied extent, it crosses Blaeberry River just east of Mount Laussedat.

Definition of Terms

Stratigraphic nomenclature employed for Cambrian units will follow that of Aitken (1966, p. 406-409) and Cook (1970, p. 29), and for Ordovician units that of Aitken and Norford (1967) and Norford (1969). The stratigraphic column is summarized in Figure 2.

Stratigraphic Features of the Kicking Horse Belt

Many of the relationships described below can be understood best in terms of the "facies belt" concept of Palmer (1960). This concept has been successfully applied to the Middle Cambrian of the eastern Great Basin (U.S.A.) by Robison (1960), to the Upper Cambrian of Nevada by Palmer (1960), and to the Middle and Upper Cambrian and Lower and Middle Ordovician of the southern Rocky Mountains (Canada) by Aitken (1966) and Aitken and Norford (1967). The essence of this idea, in different terms and with slightly different emphasis, is seen in the "facies realms" of Lochman-Balk and Wilson (1958) and in the environments of deposition in the Upper Cambrian mapped by Lochman-Balk (1970).

Briefly, according to Palmer's concept, the Lower Paleozoic facies belts, arranged concentrically about the craton, are: the *inner detrital belt,* dominated by clastic rocks of mud to sand grade, commonly glauconitic; the *middle carbonate belt,* dominated by fairly pure, partly thick-bedded, shallow-water limestone and dolomite; the *outer detrital belt,*

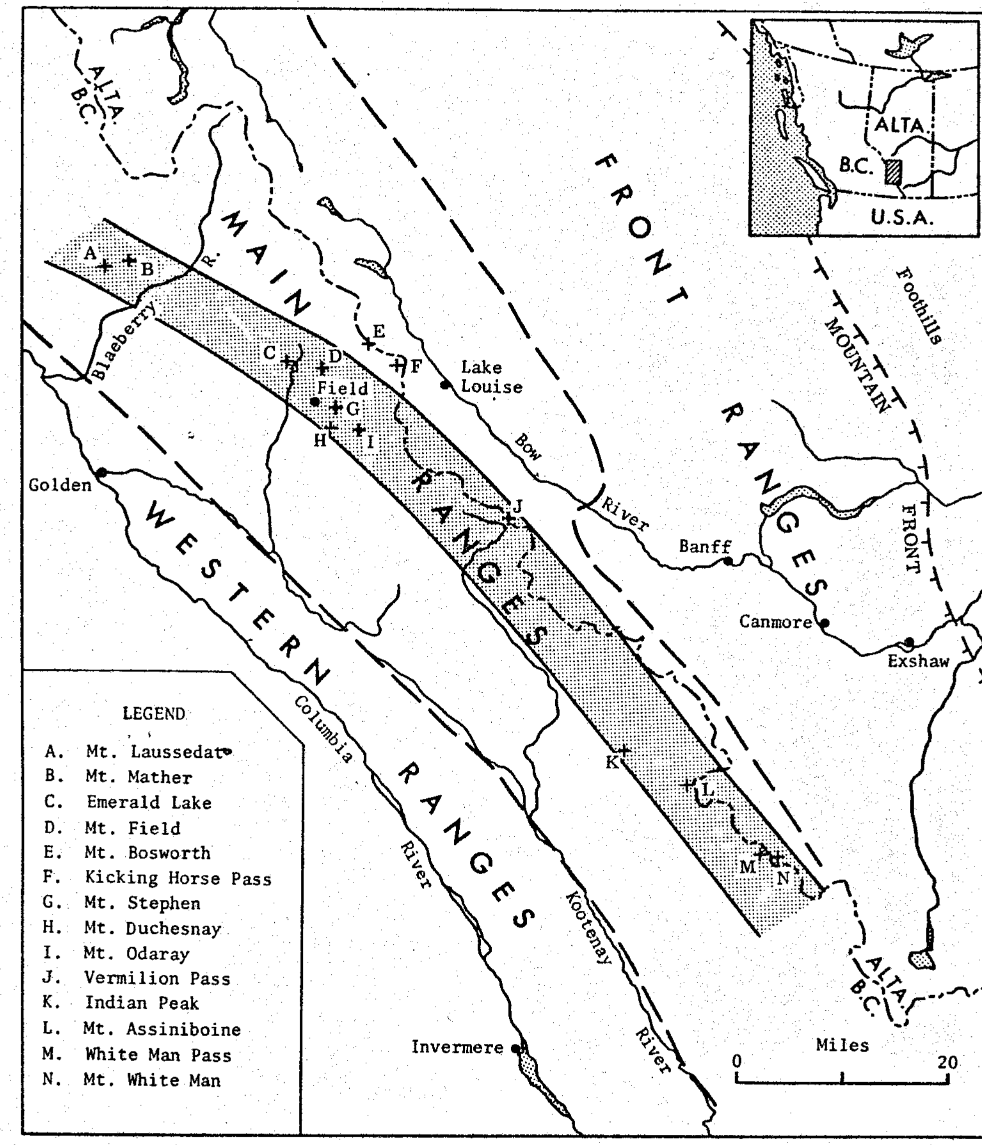

Fig. 1. The Kicking Horse belt (stippled).

dominated by mudstones and thin-bedded, argillaceous limestones. The outer detrital facies contains trilobite faunas distinct from those of the middle and inner facies. The facies belts were not fixed, but migrated back and forth according to the interplay between rate of subsidence and clastic supply.

The following features and relationships of lower Paleozoic strata are confined to the Kicking Horse Belt.

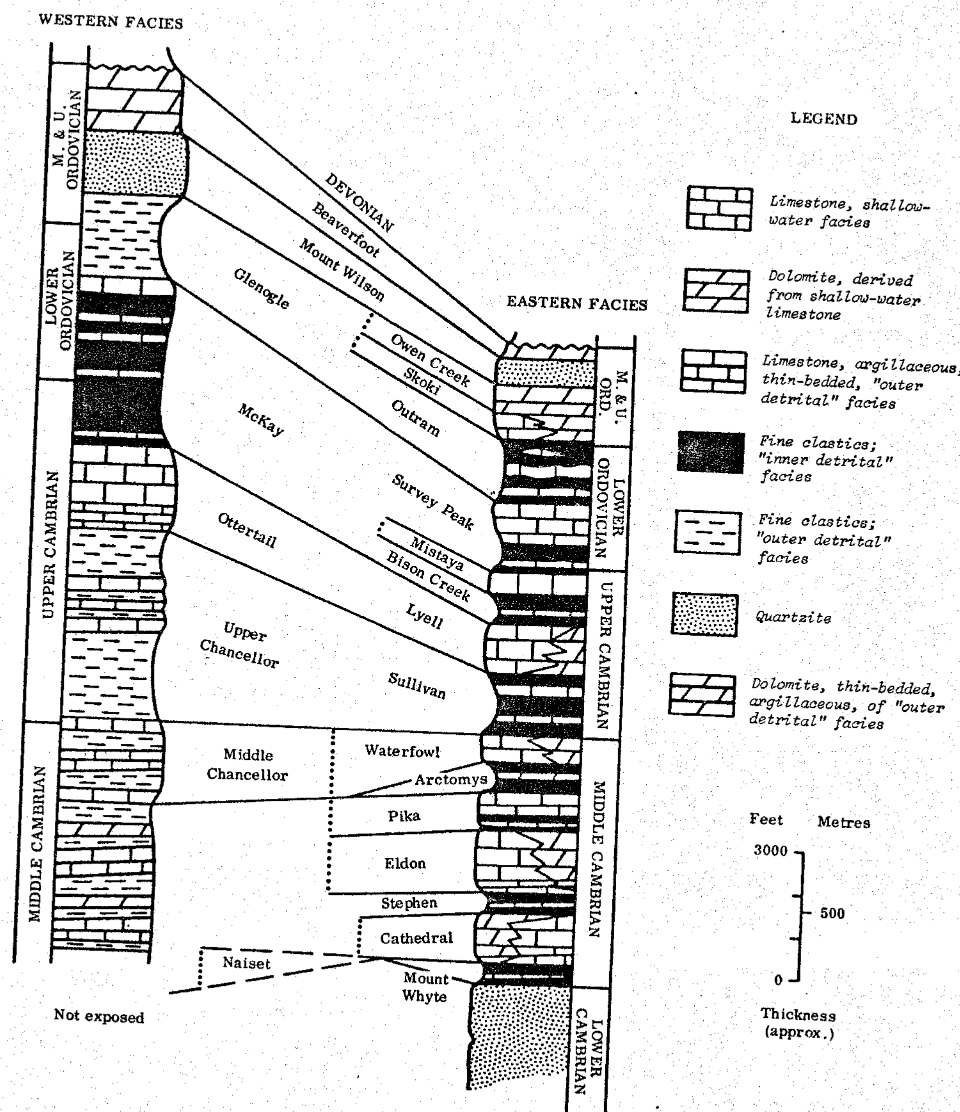

Fig. 2. Summary of stratigraphy east and west of the Kicking Horse belt (adapted in part from Cook, 1970, fig. 3-2).

1. *Localized Physical Evidence of Unconformity at Base of Middle Cambrian*

Rasetti (1951) and W. H. Fritz (pers. comm., 1971) have pointed out the paleontological evidence for a stratigraphic break between the Lower Cambrian Gog Group and the Middle Cambrian Mount Whyte Formation. In most of the region, however, this contact appears conformable; the basal glauconitic sandstone of the Mount Whyte generally lies with abrupt but concordant contact upon the Peyto Limestone Member of the Gog.

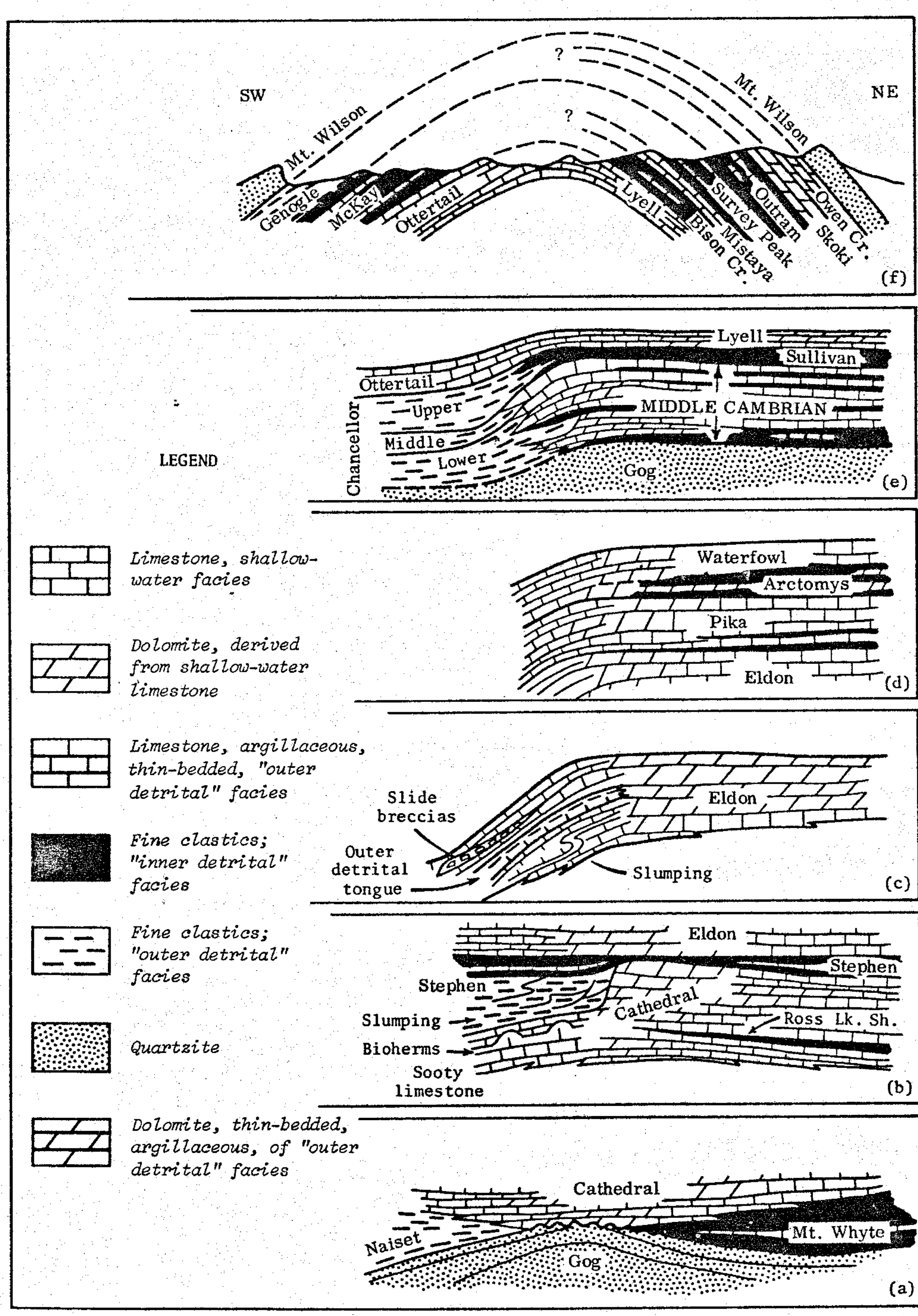

Fig. 3. Diagrammatic cross-sections illustrating relationships at the Kicking Horse Rim.

Where the Peyto is missing, it appears to be by facies change to calcareous sandstone rather than by erosion.

Only at Mount Assiniboine and Indian Peak, within the Kicking Horse Belt, has direct physical evidence of unconformity been observed, in the form of obvious erosional relief, a regolith, and a coarse basal breccia of the underlying quartzite and slate. At these localities, the Lower Cambrian Gog is overlain by the outer detrital Naiset Formation rather than by the inner detrital Mount Whyte (see below).

The above observations are taken to record the existence of a localized, emergent, paleotopographic "high" (Fig. 3a). A similar indication is seen in the regional minimum thickness observed in basal Middle Cambrian shales (Mount Whyte, Naiset) within the Kicking Horse Belt, and in the absence of these shales at Vermilion Pass, where carbonates of the Cathedral Formation rest upon Gog quartzites.

K. W. Bell has drawn the writer's attention to the results of diamond drilling at the Monarch Mine (Mt. Stephen) and the Kicking Horse Mine (Mt. Field), as reported by Ney (1954, p. 124 and fig. 5). The drill-intersections can be interpreted as demonstrating Cathedral carbonates in depositional contact with Gog quartzites on a surface of appreciable relief. Ney (1954) remarks on the difficulty of explaining the drilling results by a fault interpretation.

2. *Facies Change in Basal Middle Cambrian*

Basal Middle Cambrian strata east of the Kicking Horse Belt are assigned to the Mount Whyte Formation, a unit of shales with interbeds of limestone, commonly oölite and biocalcarenite. The Mount Whyte, in its lithology and stratigraphic relationships, is clearly of inner-detrital origin. Within the Kicking Horse Belt, the Mount Whyte thins to a regional minimum and locally at least pinches out (Fig. 3a). Strata of equivalent age in the western part of the Belt belong to the Naiset Formation, characterized by monotonous mudstones with graded lamination, slumped intervals, and complete trilobite skeletons, all characteristic of outer-detrital-belt deposition.

3. *Pinch-out of the Ross Lake Shale*

On the transect of the Trans-Canada Highway, the Ross Lake Shale Member is the sole break in the otherwise uninterrupted limestones and dolomites of the Cathedral Formation, and has been demonstrated to be an extremely attenuated tongue of inner detrital facies, traceable westward from the Mountain Front to Kicking Horse Pass, a distance of 45 mi, uncorrected for palinspasis (Aitken, 1966). It pinches out rapidly from a thickness of 20 ft at Mount Bosworth, and is missing six miles to the west, at Mount Stephen and Mount Field (Fig. 3b). The Ross Lake Shale is similarly missing at Mount Assiniboine, but there the rate of pinch-out cannot be assessed.

4. *Facies Change in Lower Cathedral Formation*

Between the Mountain Front and the Kicking Horse Belt, the Cathedral Formation is a monotonous, westward-thickening, variably dolomitized unit of dolomite-mottled, burrowed lime-mudstone with minor pellet calcarenite. In the more westerly sections, intervals of intertidal to supratidal cryptalgalaminate limestone-dolomite and fenestral ("birdseye") limestone appear. Within the Kicking Horse Belt, in Mount Stephen and Mount Field, tongues of sooty, black, argillaceous lime-mudstone, thickening westward, appear in the lower part of the Cathedral (Fig. 3b). Within these tongues, a number of small (less than 20 ft high or wide) algal bioherms, definitely neither stromatolites nor thrombolites and consisting mainly of *Girvanella* and *Epiphyton*, appear. Such bioherms are unknown elsewhere in the Cathedral Formation or, indeed, in the Cambrian of the region. Concurrently with the appearance of this new facies, carbonates of algal-flat origin disappear, and the interpretation of the sooty limestones with bioherms as a deeper-water facies appears justified. Before its westward dip carries it from view, the Cathedral has changed to an entirely argillaceous interval (i.e., to the lower Chancellor Formation).

5. *"Facies Scarp" in the Upper Cathedral*

In the opposed faces of Mount Stephen and Mount Field, the uppermost 580 ft of the Cathedral Formation terminate abruptly in a nearly vertical face, against which lie anomalously thick shales of the Stephen Formation (Fig. 3b), as first recognized by Ney (1954). The configuration of this steep contact strongly suggests a fault, but lower strata pass unfaulted beneath the contact. Fritz (1971) has shown in detail that the steep dolomite face is a buried submarine scarp, the outer edge of the regional carbonate bank represented by the upper Cathedral Formation or, in other words, the western limit of the middle carbonate belt of that time.

6. *Regional Minimum in the Stephen Formation*

The Stephen Formation thickens regionally westward, from 70 ft at the Mountain Front to 200 to 500 ft in the Main Ranges. It is 340 ft thick in Kicking Horse Pass, but three miles to the west, in the eastern part of Mount Field, has thinned to 180 ft (Fig. 3b). Even more pronounced thinning is seen at Mount Assiniboine, where the Stephen is only 50 to 60 ft thick. Within Mounts Field and Stephen, the Stephen thickens abruptly to 1,030 ft on crossing the upper Cathedral bank-edge (*see* above, Fig. 3b).

7. *Facies Change in the Stephen Formation*

East of the Kicking Horse Belt, the Stephen Formation is of shallow-water character throughout, as witnessed by such features as oölite beds, beds of limestone-pebble conglomerate, and a few stromatolites. In the abruptly thickened sections of Mount Field and Mount Stephen (Fig. 3b), the upper third of the formation retains much of this shallow-water character. The lower two-thirds, however, lacks shallow-water indicators, contains gravity-slumped intervals, and contains also the celebrated Burgess Shale, whose many complete specimens of soft-bodied animals testify to a quiet, presumably deep-water environment.

Fritz (1971) has demonstrated that the contact between the *Glossopleura* and *Bathyuriscus-Elrathina* zones is at least 680 ft lower, in the "thick" Stephen west of the scarp in the upper Cathedral, than it is in the "thin" Stephen on top of the scarp. Structural explanations for this fact having been ruled out *(see above)*, the shales at the zonal boundary west of the upper Cathedral submarine scarp must have accumulated in water on the order of 680 ft deeper than did the time-equivalent shales on top of the carbonate bank.

8. *Facies Change in the Eldon Formation*

The Eldon Formation represents a regional, Middle Cambrian carbonate bank very similar to the Cathedral Formation. Like the Cathedral, the Eldon Formation contains, within the Kicking Horse Belt, abundant carbonates of intertidal to supratidal origin; such carbonates are generally missing or, at most, weakly represented east of the Belt. The Eldon disappears in the western part of the Kicking Horse Belt. Where last seen, as at Mount Duchesnay near Field and at Mount Mather on Blaeberry River, the Eldon lacks all evidence of shallow-water deposition and contains instead contorted, slumped intervals and limestone breccias that are clearly submarine slides (Fig. 3c). These observations indicate that a regional flat-topped bank graded into a sloping bank-edge that plunged into deep water. On the Trans-Canada Highway transect, the facies change in the Eldon takes place about a mile west (basinward) of the change in the Cathedral Formation.

9. *Outer Detrital Tongue in the Eldon Formation*

The Eldon Formation is a deposit of the middle-carbonate facies belt. At three localities within the Kicking Horse Belt (Mount Field, Mount Stephen, Vermilion Pass), a tongue of sooty, platy-flaggy limestone locally capped by a thin argillite bed intrudes easterly to interrupt the pale, "normal" carbonates, and can be seen to terminate abruptly eastward (Fig. 3c). This tongue is of outer-detrital lithology, and carries an outer-detrital fauna characterized by agnostid trilobites (W. H. Fritz, *pers. comm.*, 1971).

10. *Pinch-out of Shale Tongues in the Pika Formation*

The Pika Formation consists mainly of shallow-water carbonates of the middle carbonate facies belt. It is delineated from the underlying Eldon Formation by the presence, in the base of the Pika, of several thin intervals of shale that can be demonstrated (Aitken, 1966) to be attenuated tongues of the inner detrital facies. The number of tongues decreases westward, but the lowest and most persistent is five feet thick at Mount Bosworth. In a relationship exactly comparable to that displayed by the Ross Lake Shale, it pinches out within the Kicking Horse Belt, and is not seen, for instance, at Mount Assiniboine, Mount Stephen or Mount Mather. As a result, the Eldon and Pika are not distinguishable within the western part of the Belt (Fig. 3d).

11. *Disappearance of the Arctomys Formation by Facies Change*

The Arctomys Formation is an easily recognized unit of inner-detrital origin, characterized by red shales and ripple-marked and mud-cracked siltstone with salt-crystal casts, interbedded with laminated dolomites. From its depositional limit or truncated edge between the Foothills and the westernmost wells of the Plains, the Arctomys thickens westward to a maximum of 770 ft. As the Kicking Horse Belt is reached, however, it thins rapidly westward by facies change to the carbonates of the overlying Waterfowl Formation and disappears, being last seen as an interval of pink-weathering dolomite (Fig. 3d). This change takes place over a distance of about eight miles at White Man Pass and Vermilion Pass. With the disappearance of the Arctomys, the Waterfowl dolomites rest upon Pika-Eldon dolomites, so that four formations traceable over an extensive region east of the Kicking Horse Belt (Eldon, Pika, Arctomys, Waterfowl) merge into a single, thick carbonate unit, subdivisible with difficulty, if at all, within the western part of the Belt.

12. *Eastward Limit of the Chancellor Formation*

The entire seven formations of the Middle Cambrian succession pass abruptly westward, as partly described above, into the lower and middle Chancellor Formation, mainly by transition of the shelf carbonates to shales and argillaceous limestones (Cook, 1970). The Upper Cambrian Sullivan Formation passes westward into the upper Chancellor Formation near Field with near-total loss of the interbeds of shallow-water limestone (oölitic, biocalcarenitic, thrombolitic) that characterize the Sullivan (Fig. 3e). On the other hand, along Blaeberry River it retains for some miles its lithologic character as it passes westward into the upper Chancellor, although it undergoes a twofold increase in thickness (Cook, 1970). These changes take place in the western part of the Kicking Horse Belt and are the youngest effects of a definite nature to be associated positively with the Kicking Horse Belt. The Lyell Formation overlying the Sullivan passes across the Kicking Horse Belt and beyond to the west (as the Ottertail Formation), with increased thickness but no significant change in facies.

13. *Features Possibly Related to the Kicking Horse Belt*

Three pronounced changes in strata younger than the Lyell Formation take place in the vicinity of the Kicking Horse Belt as here defined but, because of the vagaries of structure and exposure, cannot be demonstrated to occur within the narrow belt outlined in Figure 2. These changes, as shown in Figure 3f, are:

a. Westward disappearance of the carbonates of the Mistaya Formation (Aitken and Norford, 1967).

b. Westward change of the mainly carbonate Outram and Skoki formations to black, graptolitic Glenogle Shale (Aitken and Norford, 1967; Norford, 1969).

c. Westward disappearance of the carbonates of the Owen Creek Formation (Norford, 1969).

14. *Summary*

Most of the changes seen within the Kicking Horse Belt can be summarized in terms of two simple concepts:

Firstly, the Belt contains the western limit of four great carbonate formations, and may contain the limit of four more. The Belt can hence be regarded as the long-term locus of the outer edge of the middle-carbonate facies belt. The relative fixity of the outer edge thus contrasts markedly with the widely ranging position of the inner edge (Aitken, 1968).

Secondly, as the "line" across which the Lower Paleozoic stratigraphy of the Front and Eastern Main ranges changes to the almost completely different Lower Paleozoic stratigraphy of the Western Main and Western ranges, the Kicking Horse Belt contains all those changes formerly (but no longer) attributed to the Stephen-Dennis Fault, and marks the boundary between two distinct, stratigraphy-dependent structural provinces (Cook, 1970).

History of the Kicking Horse Belt

Relationships observed within the Kicking Horse Belt can be understood as the record of the effect on sedimentation of a persistent, linear, slightly positive paleotopographic feature, here named the Kicking Horse Rim,[1] that was in existence almost continuously at least from early Medial Cambrian to early Late Cambrian time, and may have persisted until Medial Ordovician time.

Initiation of the Kicking Horse Rim

The earliest observed effects attributed to the Kicking Horse Rim are a regional, elongate "thin" in basal Middle Cambrian clastics, and strong evidence of erosion at the base of the Middle Cambrian, apparently localized along the same trend. The possibility of earlier existence of the Rim will be considered later, in the context of its inferred history.

The above-mentioned relationships of basal Middle Cambrian strata are taken to record the existence of a linear and probably narrow paleotopographic "high," aligned about parallel to the present, northwesterly tectonic strike. Such a feature can only have been of tectonic origin.

[1]The concept of the Kicking Horse Rim is distinct from Walcott's (1928) now-untenable concept of several distinct "troughs" of pre-Devonian sedimentation in the southern Rocky Mountains; nevertheless, Walcott's boundary between the "Bow Trough" and the "Goodsir Trough" corresponds more or less to the Kicking Horse Belt of this paper.

The first consequence of the appearance of this tectonic "high" was the ponding of inner-detrital clastic sediments to the east and the prevention of their passing westward to the outer-detrital realm. The second was weathering and erosion along the emergent crest of the ridge. The third was the localization of the earliest Middle Cambrian carbonates along the ridge, as it was again covered by the sea.

Persistence of the Rim

Once carbonate sedimentation was established along the crest of the original tectonic ridge, with fine clastic sediments being deposited immediately to the west and at a variable distance (up to hundreds of miles) to the east, further tectonic activity may not have been required to maintain the Kicking Horse Rim as a subtly positive feature. Rapid carbonate sedimentation alone may have maintained it as a site of shallow-water to supratidal deposition. During the Middle Cambrian, the carbonate bank to the east appears to have been almost continuously submerged, albeit to shallow depth. During the Upper Cambrian, except for times of basinward shift of the inner-detrital facies belt, a shallow-shelf sea appears to have been dotted with intermittently emergent carbonate shoals (Aitken, 1966). Except at times of maximum clastic influx from the emergent craton (as during deposition of the Stephen, Sullivan, and basal Survey Peak formations), the subtly elevated Kicking Horse Rim remained out of reach of the terrigenous muds, and carbonate sedimentation proceeded uninterruptedly. During the three episodes of maximum terrigenous influx, however, muddy sediments flooded completely across the Rim, establishing physical continuity between inner- and outer-detrital deposits. Even following these events during which, presumably, some kind of clastic-depositional "profile of equilibrium" was established across the Kicking Horse Belt, differential compaction alone may have sufficed to renew topographic relief and re-initiate carbonate deposition preferentially along the Rim, independently of any renewed tectonic movement.

The existence of slope-deposited and apparently deep-water facies immediately west of the Kicking Horse Rim might suggest that the Rim continued to function as a tectonic hinge between more rapid subsidence on the west and less rapid on the east. On the other hand, in the absence of good data on thicknesses in the highly deformed and sparsely fossiliferous outer-detrital facies (mainly Chanceller Formation), this cannot be verified, and it seems equally likely that slow deposition combined with regional subsidence was responsible for maintaining deep water.

An attempt to fit the "reciprocal sedimentation" model of Wilson (1967) to the observed relationships has also been made. Weathered and eroded surfaces in the shelf or bank sequence that would be developed during the drastic, cyclic lowering of sea level called upon by Wilson to account for Pennsylvanian depositional cycles in New Mexico have not been observed, and Wilson's hypothesis appears unattractive in this instance.

Recognition of the Kicking Horse Rim brings to light another problem: if the Rim dammed all westward-moving inner-detrital sediment, except for three episodes of exceptional clastic supply, how did terrigenous muds reach the deep-water basin to the west? It would appear that, except during deposition of the Stephen, Sullivan, and Survey Peak formations, clastic supply from a source or sources other than the emergent craton must be called upon.

Several communicants, including certain of the readers of an earlier draft, have suggested that craton-derived clastics could have passed through the carbonate tract via channels, without affecting the general carbonate sedimentation. Observation does not support this concept. During the two field seasons of Operation Bow-Athabasca (Price and Mountjoy, 1970), hundreds of miles of the traces of the Cathedral, Eldon, and Pika formations were observed at ideal range from helicopters. No channels indented into the upper contacts of these carbonate formations were seen, and the postulate of mud-conducting channels therefore appears untenable.

To return now to the question of the possible pre - Middle Cambrian existence of a Kicking Horse Rim, there is suggestive evidence to the contrary, although the Lower Cambrian Gog Group dips westward out of sight all along the Kicking Horse Belt. Where Lower Cambrian strata next appear, some 25 mi to the southwest, they are still present mainly as an arenaceous sequence similar in most respects to the Gog (Hamill Formation, Cranbrook Formation). As emphasized to the writer by W. H. Fritz (*pers. comm.,* 1971), however, the upper part of the Gog undergoes a facies change to a shaly sequence, as evidenced by thick Lower Cambrian shales above the Hamill quartzites in the Dogtooth Range (Evans, 1933, p. 122) and above the Cranbrook quartzites and conglomerates in the Canal Flats area (Leech, 1954, p. 8). Furthermore, the occurrence of the trilobite *Callavia* about 100 ft below the top of the Cranbrook near Canal Flats (Leech, 1954, p. 7) shows the containing beds to be older than the top of the Gog, which yields a *Bonnia-Olenellus* fauna.

These relationships might suggest changes in Lower Cambrian sedimentation related to the Kicking Horse Belt, although the changes could as well occur anywhere in the region within which the Gog and equivalents are not exposed. On the other hand, the general trend all along the Kicking Horse Belt was for the axis or crest of the Rim to shift progressively westward with time, as sketched in Figure 3. Thus, the facies changes in the Cathedral Formation lie west of the Mount Whyte - to - Naiset facies change, and the Eldon-Pika-Waterfowl carbonates persist farther west than those of the Cathedral. Minor reversals in this trend, such as the outer detrital tongue in the Eldon Formation, must be acknowledged. Where physical evidence of unconformity has been observed at the Lower Cambrian - Middle Cambrian contact, it is outer-detrital Naiset Formation, rather than inner-detrital Mount Whyte, that overlies the Gog. These localities, therefore, are west of the axis of the Kicking Horse Rim of that time, but the Gog Group is of regionally normal facies to its top. Thus, unless there was significant migration of the axis of the Kicking Horse Rim *eastward* at the beginning of the Middle Cambrian, it can be stated that the Gog crosses the Kicking Horse Belt without change, and that pre - Middle Cambrian existence of the Kicking Horse Rim is unlikely.

Extinction of the Kicking Horse Rim

Passage of the thick carbonates of the Lyell (Ottertail) Formation across the Kicking Horse Belt without change of facies demonstrates that the Rim was not developed during deposition of the Lyell, and suggests that its history may have ended. On the other hand, if the changes involving the Mistaya, Outram, Skoki and Owen Creek formations are indeed located within the Kicking Horse Belt, then rejuvenation of the Rim is implied. At any rate, the Middle or Upper Ordovician Mount Wilson quartzite and the overlying Upper Ordovician and Devonian formations pass across the Belt without known change, and demonstrate extinction of the Kicking Horse Rim by early Late Ordovician time at the latest.

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electric scraper hoist has been installed on No. 7 level to handle the ore coming from these stopes.

Development: Drifting and crosscutting, 1,219 feet; raising, 879 feet; shaft sinking, 253 feet; and diamond drilling 1,460 feet.

During the year the tonnage milled averaged slightly over 500 tons per operating day. Maximum capacity on low-grade mill-feed was 650 tons per day. Early in the year the zinc circuit was discontinued in order to handle increased lead grades; however, the reinstallation of a larger zinc circuit, to handle the higher-grade ore to come from No. 7 level, was completed by the end of the year.

A pilot plant was installed for the recovery of barite from the mill tailings. This circuit has a production of from 5 to 10 tons per day of 4.3 specific gravity material, assaying 96 per cent barium sulphate. Preliminary tests indicate that the pilot-table concentrate is of exceptionally good quality, and in view of the quantity of material available for treatment an extensive study of markets for this product is to be made.

There were no major additions to the power plant or surface installations during the year. The average number of men employed was 100. Production: 176,289 tons.

HAWK CREEK*

Silver-Lead-Zinc

Hawk Creek (51° 116° S.E.) The Hawk Creek zinc deposit is in Kootenay National Park on the north side of Hawk Creek, about 2 miles east of the main Banff–Windermere Highway at a point 4½ miles north of Vermilion Crossing. A fair jeep-road leaves the highway about 100 feet north of the Hawk Creek road bridge and provides access to within 200 feet of the main showings. The first half-mile of this road may be travelled by automobile. The showings are on a gently sloping timbered hillside that forms the southern flank of Isabelle Peak. They are at an elevation of 5,700 feet, which is about 1,300 feet higher than the Hawk Creek road bridge.

The mineral deposit was discovered in November, 1929, by Fred W. Jowett, who, in partnership with J. E. Barbour, located six mineral claims known as the Albion group. In 1932 the National Parks Board refused Jowett and Barbour permission to do further assessment work on the grounds that the claims lay within the boundaries of a National park.

In 1942, Base Metals Mining Corporation Limited, under the direction of the Mines and Geology Branch, Department of Mines and Resources, carried out some exploratory trenching and diamond drilling on the showing. Since 1942 no work has been done.

The area in the vicinity of the showings is underlain by a series of interbedded grey limestones and brownish-grey argillites of probable Upper Cambrian or Ordovician age. At the showings the beds are gently dipping or horizonal and are cut by a pronounced northwest-trending shear zone that dips 45 to 70 degrees to the southwest. The shear zone extends well beyond the known limits of the mineralization and is believed to be of regional extent.

The ore zone consists mostly of massive sphalerite replacing limestone, and is localized at the intersection of the shear zone and an apparently favourable limestone bed. The ore is banded parallel to the shear planes, but lithology, rather than shearing, appears to have been the principal factor that controlled deposition of the ore. This control is demonstrated by the fact that the ore zone remains within the same stratigraphic horizon along its explored length of more than 250 feet. The ore in the surface showings is seen to be concentrated within a finely crystalline dolomitic limestone and tends to die out almost entirely in adjacent finer-grained and denser limestone, in spite of the fact that shearing is equally well developed in both rock types.

* By G. G. L. Henderson.

The ore zone as exposed at the surface consists of an irregularly shaped body about 55 feet wide and a maximum of 18 feet high. The diamond drilling done in 1942 explored this zone at variable intervals along a length of about 250 feet northwestward into the hillside. In general, the drilling indicated a pencil-like body with a low rake to the northwest and an irregular and variable cross-sectional shape. It suggested that the size of the zone decreases toward the northwest, although several of the cross-sections drilled contained too few holes to delimit the full lateral extent. The northwestern limit of the ore zone was not determined.

The mineralization consists principally of sphalerite, of which two varieties were noted. The commonest type is honey coloured and fine grained, and occurs as massive or disseminated bodies replacing limestone. The second type is darkish brown in colour and was seen only as disseminated crystals within veins and stringers of white crystalline calcite. At most places minor quantities of fine-grained pyrite is associated with the sphalerite. Galena occurs as small pods sparsely distributed throughout the ore zone, but not in large enough quantity to be an important constituent of the ore. Silver is reported but in negligible amounts. At a few of the surface exposures a thin enriched zone, composed dominantly of zinc carbonates, overlies the ore zone.

The distribution of zinc throughout the ore zone is not uniform. Bands assaying more than 25 per cent zinc across widths of 3 to 12 feet are not uncommon* and generally alternate with thin barren zones or with zones containing less than 25 per cent zinc.

An interpretation by the writer of the data obtained by the Mines and Geology Branch in 1942 indicates a total of 29,500 tons averaging 12.5 per cent zinc.

REVELSTOKE†

Silver-Lead-Zinc-Tungsten

Regal Silver, Snowflake (Columbia Lead & Zinc Mines Limited)

(51° 117° S.W.) British Columbia office, 800 Hall Building, 789 West Pender Street, Vancouver; mine office, Albert Canyon. T. R. Harrison, Toronto, president; W. Tattrie, mine manager; J. Hutchison, mill superintendent. Capital: 5,000,000 shares, 50 cents par value. Columinda Metals Corporation has operating control of this company. The Regal Silver and Snowflake mines are on Clabon Creek, 7½ miles by road from Silver Creek siding on the Canadian Pacific Railway, 19 miles east of Revelstoke. Activity in recent years has been restricted to the Regal Silver. Three quartz sulphide veins, known as Four, Five, and Six, have been developed by six adits, Nos. 5 to 10, with nearly all the work done on Five vein. Four vein, which is exposed in the old adit crosscut on No. 10 level, was developed in 1953 by 225 feet of drifting. Scheelite is visible in minor quantities in this vein. Box-holes were driven for mining purposes, but no further work was done. The best tungsten showing is in Five vein on No. 9 level, west of the old mill rise. The scheelite there is relatively massive and is as much as 2 feet wide. A stope was started here, and a raise 168 feet long was driven to No. 8 level. An ore-pass, 158 feet long, was driven from No. 10 to No. 9 level to aid in the handling of this ore. Lead-zinc ore was mined from Five vein on No. 10 level and from the same vein on No. 5 level. Most of the lead-zinc ore was produced from No. 5 level and had to be handled several times to lower it to the main haulage, No. 10 level.

The small mill operated first on tungsten ore and then on lead-zinc ore. Considerable difficulty was encountered in obtaining marketable tungsten concentrate. Gravity separation, using screen separators, spiral separators, and tables, was used together with some flotation, but too much pyrite still remained. About 2,800 tons of tungsten ore was milled, producing about 10 tons of concentrate, which was still unsold at the end of

* *Minister of Mines, B.C.*, Ann. Rept., 1930, p. 239.
† By J. W. Peck.

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* By R. B. King.