PROJECT AND APPLIED GEOLOGY

GEOLOGY IN THE VICINITY OF THE SULLIVAN DEPOSIT KIMBERLEY, BRITISH COLUMBIA (82F, G)

By T. Höy

INTRODUCTION

The study of the Purcell Supergroup, initiated in 1977, was intended to develop a better understanding of the stratigraphic, structural and tectonic setting, and ore controls of the Sullivan and other smaller but similar clastic-hosted lead-zinc deposits in southeastern British Columbia. Kanasewich (1968) recognized a basement structure from anomalous magnetic and gravity trends and by deep seismic reflections that cut northeasterly across the more northerly regional stratigraphic and structural trends. He concluded that the structure was a Precambrian rift and that the Sullivan deposit originated within it. The proposed rift coincides with the pronounced St. Mary-Boulder Creek and the Moyie-Dibble Creek fault systems that cut across the Purcell Mountains and the western ranges of the Rocky Mountains (Fig. 2). Lower Paleozoic (for example, Leech, 1958) and earlier Hadrynian movements, generally block-faulting and tilting (Lis and Price, 1976), had been recognized along these transverse fault systems, but earlier Purcell age movements had not been documented. A primary objective of this study was to determine if these transverse structures were active in Purcell time and could therefore have controlled the regional distribution of lead-zinc deposits.

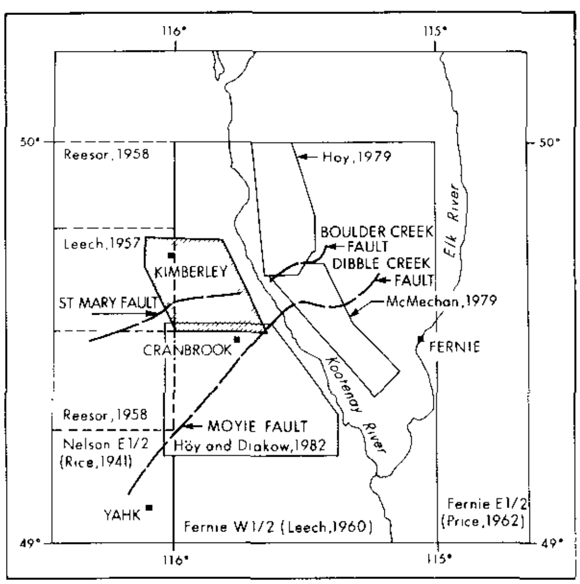

Figure 2. Location map, showing St. Mary, Boulder Creek, Moyie, and Dibble Creek faults, and published geological maps in the vicinity of the Kimberley map-area.

The study initially focused on the Kootenay Ranges east of the Rocky Mountain Trench and results were released as two preliminary maps (Höy, 1979; McMechan, 1979). Locations are given on Figure 2. Dramatic thickness increases and rapid facies changes in the Aldridge Formation (near the base of the exposed Purcell succession) occur in the vicinity of the Boulder Creek fault. The fault is interpreted to have been a growth fault which down-dropped the area to the south (Höy, 1979, 1982a). Further south, McMechan (1979, 1981) recognized that overlying Purcell platformal rocks have similar, though less dramatic, changes. These data tend to confirm the presence of a transverse Precambrian rift structure.

It was suggested (Höy, 1982b) that this transverse zone is marked in Purcell rocks to the west by the preferential distribution of intraformational conglomerate and Purcell sills. It is also characterized by anomalous concentrations of boron that are supposedly related to deep crustal fractures (Ethier and Campbell, 1977). Mapping and detailed section measurements were subsequently begun in the vicinity of the Moyie fault in the Purcell Mountains (Höy and Diakow, 1981, 1982). The work continued this past summer and was extended northward to encompass the St. Mary fault and the Sullivan mine at Kimberley. Mapping of the Kimberley map-area is being compiled and will be released as a preliminary map (1:50 000 scale) when completed. Further fieldwork on the Purcell project will be minimal and will only include fill-in traverses and section measurements; these will be completed next field season.

The Kimberley map-area is within the Fernie west-half (82G/W) sheet (Leech, 1960), and the eastern part of the St. Mary sheet (Leech, 1957). Many of the salient features of the geology were initially outlined by Rice (1937). Other maps published in the vicinity of the Kimberley sheet are shown on Figure 2.

GENERAL GEOLOGY

The Kimberley area (Fig. 3) is transected by the right lateral, reverse St. Mary fault. The fault brings Lower and Middle Aldridge rocks in its hangingwall (the St. Mary block of Benvenuto and Price, 1979) against Creston and younger Purcell rocks or, locally, Cambrian siltstone and shale of the Eager Formation. The Sullivan deposit occurs at the boundary between the Lower and Middle Aldridge within the St. Mary block. It is just south of the north-dipping, normal Kimberley fault (Hamilton, *et al.*, 1982). Sullivan is one of the largest base metal deposits in the world, having produced in excess of 100 million tonnes of ore and with remaining reserves of approximately 50 million tonnes grading 4.9 per cent lead, 6.1 per cent zinc, and 37 grams silver per tonne (Ransom, 1977; Hamilton, *et al.*, 1981, 1982). The North Star and Stemwinder deposits lie just to the south. They are small lead-zinc deposits with less than 100 000 tonnes production that are situated in the upper part of the Lower Aldridge Formation (*see* Fig. 3).

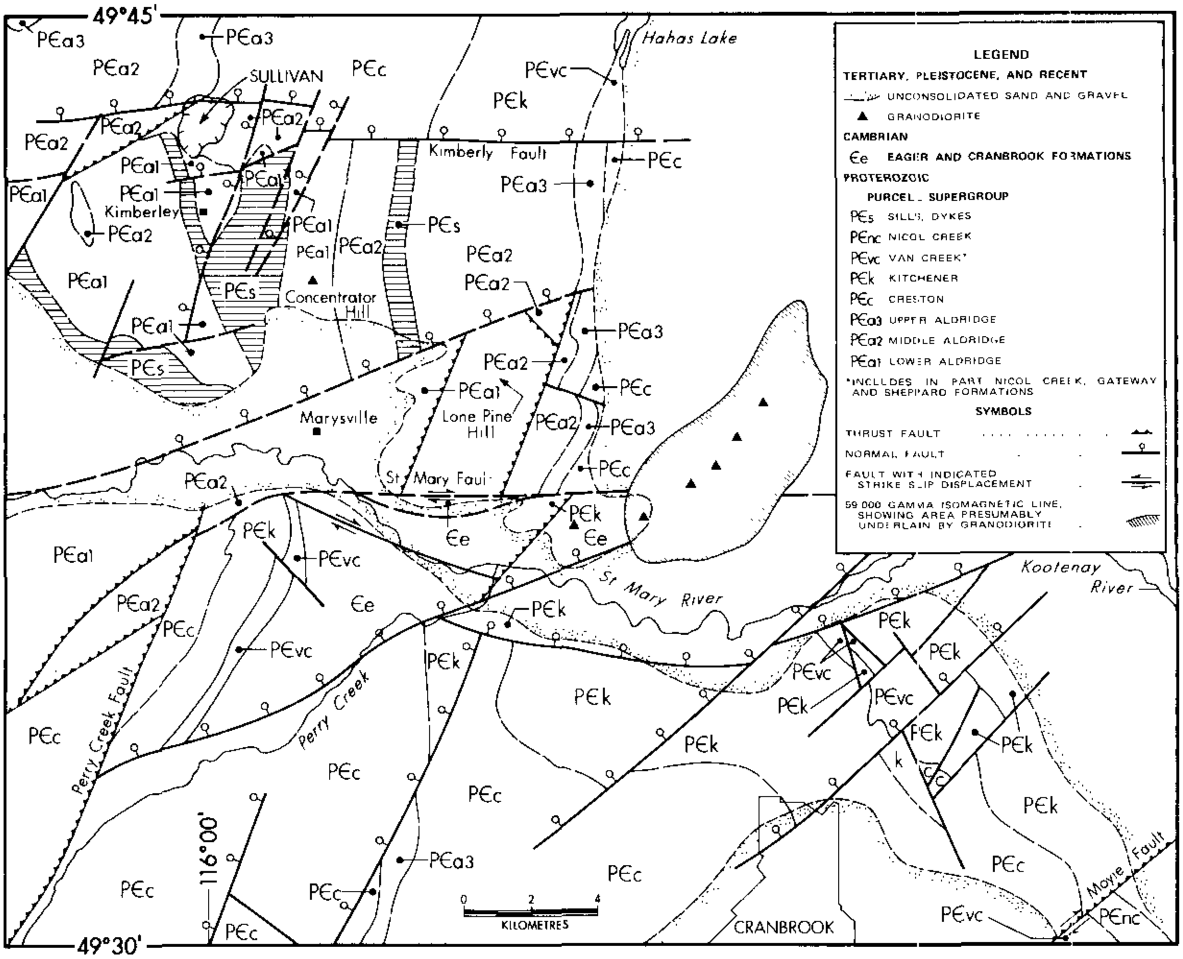

Figure 3. Geological map of the Kimberley area.

PURCELL SUPERGROUP STRATIGRAPHY

The stratigraphic succession in the Kimberley area is illustrated on Figure 4. The oldest rocks, rusty-weathering siltstone, quartz wacke and argillite of the Lower Aldridge Formation, are only exposed in the hangingwall of the St. Mary fault south of the Sullivan mine. Crossbeds and graded beds, and occasional flute casts suggest it consists largely of turbidites. A 250-metre-thick succession of grey-weathering quartzite and quartz wacke turbidite beds, which is lithologically similar to much of the Middle Aldridge succession, occurs approximately 300 metres below the Lower-Middle Aldridge boundary. It is well exposed on the western and southern slopes of North Star Hill and also a few kilometres northeast of Kimberley.

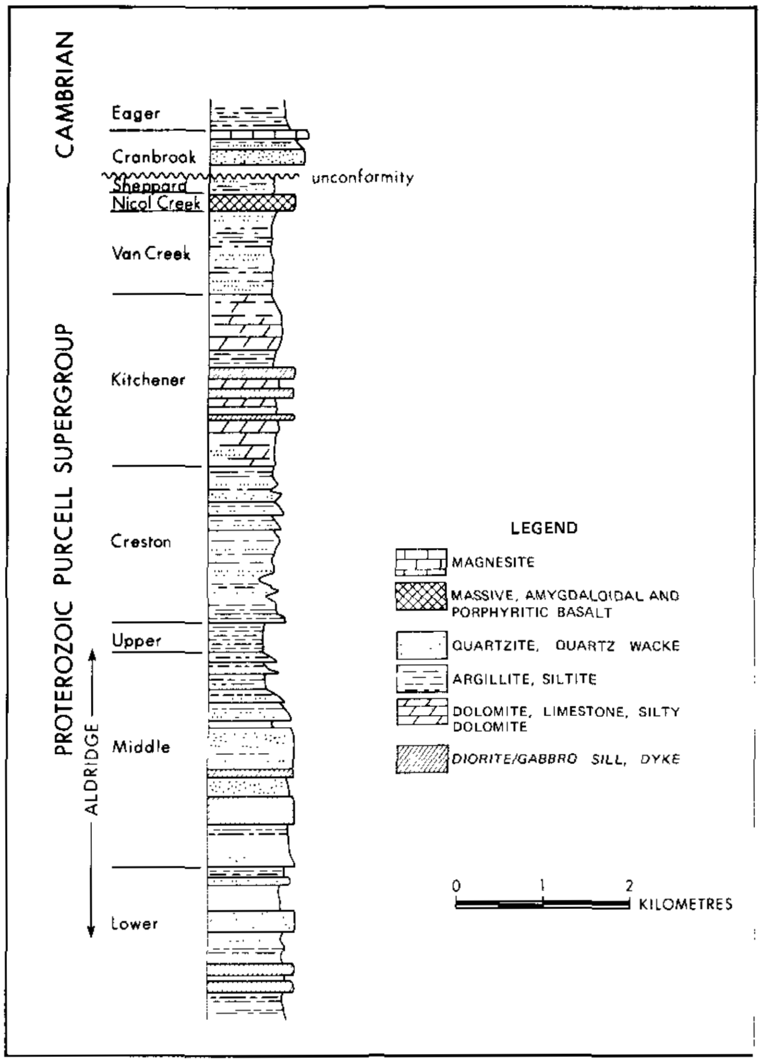

Figure 4. Stratigraphic succession in the Kimberley area.

The Lower-Middle Aldridge contact is poorly exposed. It crops out near the Sullivan deposit and subcrops on Concentrator Hill east of Kimberley. Stratigraphically, it has been placed below exposures that contain prominent, blocky, grey-weathering quartz wacke beds. Finely laminated pyrrhotite-pyrite beds in laminated argillaceous siltstone, that may be distal equivalents of the Sullivan deposit, have been described at approximately this horizon in two Cominco Ltd. diamond-drill holes that were drilled east and southeast of the Sullivan deposit (Hagen, 1978). Just west of Lone Pine Hill, the Lower Aldridge is in fault contact with the Middle Aldridge (Hagen, 1981).

The Middle Aldridge consists of grey-weathering quartz wacke and quartzite beds with local interlayered siltstone and silty argillite. It is estimated to be approximately 2 000 metres thick in the section southeast of the Sullivan mine, where individual quartzite beds are up to several metres thick. The thick quartzites may be amalgamated turbidite beds; that is, they may comprise a number of individual massive turbidite beds without either intervening silt component or recognizable graded tops. Coarse (1 to 2-millimetre) quartz grains may occur within these thicker beds. Measurements of flute casts at the base of some turbidite beds indicate a north to northwesterly current transport direction. Up section within the Middle Aldridge, the proportion of dark silty argillite increases. Locally it becomes predominant, making it difficult to distinguish isolated outcrops from Upper Aldridge exposures. The Upper Aldridge consists of approximately 300 metres of rusty to dark grey-weathering laminated argillite and silty argillite.

Rocks overlying the Aldridge Formation, the Creston, Kitchener, and Van Creek Formations (Fig. 4), are similar to those described to the south in the Cranbrook area (Höy and Diakow, 1981, 1982). Quartzites and siltstones of the Creston Formation are typically green or grey with lesser amounts of mauve-coloured siltstone. Numerous sedimentary structures indicate shallow marine subtidal to supratidal depositional environments. However, exposures of well-bedded, grey-weathering AE turbidites just northwest and northeast of Cranbrook indicate local deeper water environments. The Kitchener Formation is dominantly buff to grey-weathering dolomite, dolomitic siltstone and limestone. The Van Creek Formation is olive green, to locally mauve and tan shale and siltstone.

The Nicol Creek Formation includes tuffs; massive, porphyritic, and amygdaloidal basic lava flows; and intercalated green siltstone and quartzite. It thins northwestward from approximately 180 metres, north of Cranbrook to 36 metres south of Marysville. Only the basal few hundred metres of the overlying Sheppard Formation are exposed in the Kimberley map-area. They consist of light green, tan, and lesser purple, finely laminated siltstone and argillite.

Purcell basic igneous sills and dykes are prominent in the Lower Aldridge and lower part of the Middle Aldridge, but uncommon or absent in much of the Creston Formation. Similar rocks appear again, probably as a separate intrusive event in the Kitchener and Van Creek Formations. In contrast with Middle Aldridge sills in the Moyie Lake area that can commonly be traced tens of kilometres and are therefore valuable markers, Purcell intrusive rocks in the Kimberley area are commonly crosscutting dykes that change appreciably in attitude and thickness as they are traced in outcrops. They are locally very coarse grained and plagioclase phenocrysts can be several centimetres across.

CAMBRIAN STRATIGRAPHY

The Sheppard Formation is unconformably overlain by quartzite and carbonate of the Cranbrook Formation and shale and siltstone of the Eager Formation of Cambrian age. The contact, where exposed north of Cranbrook and near Antwerp Creek south of Marysville, is discordant. The Cranbrook Formation at Antwerp Creek consists of an interlayered sequence of pure to feldspathic quartzite and green siltstone. It is overlain by approximately 80 metres of white to light grey orthoquartzite which has a few impure siltstone layers near the top. Intercalated carbonate layers occur at the top of the unit. The carbonate is dominantly magnesite (McCammon, 1964) and one relatively pure section is approximately 7 metres thick. The Cranbrook grades up into green siltstone and shale of the Eager Formation. Dark to light grey silty argillite comprises the bulk of the Eager Formation. It is generally well cleaved and locally contains prominent cubes of pyrite.

GRANITIC ROCKS

A number of outcrops of granitic rocks, initially located by Rice (1937), crop out in the vicinity of Cranbrook airport north of the St. Mary River. Their textures range from aphanitic to coarse grained and porphyritic, with altered biotite and hornblende phenocrysts. As Rice suggested, these occurrences are probably part of a larger, unexposed granitic body. A pronounced, oval-shaped magnetic anomaly trends north-northeast over these occurrences (*see* B.C. Ministry of Energy, Mines and Petroleum Resources/Geological Survey of Canada Map 8469G and Fig. 3). The intrusive rocks straddle the St. Mary fault and therefore will provide a minimum age for movement on the fault. A megascopically similar stock in the Moyie Lake sheet (Leech, 1960; Höy and Diakow, 1982) has been dated at 122 Ma (unpublished date).

STRUCTURE

The Kimberley area is dominated by a complex array of faults. The largest of these trend easterly to northeasterly and are essentially parallel to the prominent St. Mary and Moyie faults. However, net movement on these is generally normal with north side down, in contrast to the reverse, right lateral movement on the St. Mary and Moyie faults. Apparent net normal movement on the Kimberley fault has resulted in approximately 12 kilometres strike separation of the Upper Aldridge across it, whereas right lateral reverse movement on the St. Mary fault has produced 12 kilometres of right lateral strike separation (Fig. 3).

Late north and northeasterly trending normal faults cut open to moderately tight folds with pronounced axial plane cleavage in Creston and Upper Aldridge rocks west of Cranbrook (Fig. 3). Similar late faults cut structures and displace the Kimberley fault east of the Sullivan deposit. Northwest-trending faults are conspicuous in the Moyie Lake map sheet to the south (Höy and Diakow, 1982), but in the Kimberley area, they are only prominent in the complexly faulted terrane just north of Cranbrook.

Broad open folds with pronounced axial plane cleavage occur in both Purcell and Cambrian age rocks. In the vicinity of some faults, they become tight, overturned structures.

SUMMARY

The geology of the Kimberley area will be released as a 1:50 000 preliminary map sheet, which will be the last of a series of sheets that outline the geology of the Purcell Supergroup in the vicinity of the Sullivan deposit in southeastern British Columbia. Future fieldwork, planned for 1983, will consist only of fill-in traverses in the Moyie Lake and Kimberley areas, section measuring, and sampling. Newly acquired data and previously released maps (Höy, 1979; McMechan, 1979; Höy and Diakow, 1982) will be combined and eventually published in bulletin form.

The objectives of the Purcell study have been largely realized:

(1) To provide detailed (1:50 000) geological maps of the Purcell Supergroup in the vicinity of the Sullivan and other important lead-zinc deposits.
(2) To present models, based on section and paleocurrent measurements, of the depositional environment of Purcell Supergroup rocks.
(3) To place constraints on and postulate models for regional stratigraphic, structural, and tectonic controls of mineralization in the Sullivan camp.

It is concluded that synsedimentary faulting, perhaps near the northern edge of a transverse rift structure, locally controlled and modified the distribution of Purcell rocks in Lower and Middle Aldridge time. Clastic-hosted lead-zinc deposits such as Sullivan, North Star, Stemwinder, and Kootenay King are also located near the northern edge of this transverse structure, suggesting a genetic link between mineralization and synsedimentary faulting (Höy, 1982a, 1982b).

ACKNOWLEDGMENTS

Discussions with Cominco Ltd. geologists (J. Hamilton, P. Ransom, G. Delaney, and A. Hagen) at the Sullivan mine helped clarify a number of problems, and the geology in the vicinity of the Sullivan mine (Fig. 3) is from their published work (Hamilton, *et al.*, in press). Discussions with K. McClay (Goldsmiths College, London, England), B. Lovell (University of Edinburgh, Scotland), and L. Diakow (University of Western Ontario, London, Ontario) are gratefully acknowledged. Access to unpublished maps (the Dean and All Over claims) of the North Star Hill area by Asarco Exploration Company of Canada, Limited is appreciated. Mike Fournier and Ian Webster provided cheerful and able field assistance.

REFERENCES

Benvenuto, G. and Price, R. A. (1979): Structural Evolution of the Hosmer Thrust Sheet, Southeastern British Columbia, *Cdn. Pet. Geol.*, Bull., Vol. 27, No. 3, pp. 360-394.

B.C. Ministry of Energy, Mines & Pet. Res. and *Geological Survey of Canada,* Geophysical Series (Aeromagnetic), Cranbrook, British Columbia, 1970, Map 8469G.

Ethier, V. G. and Campbell, F. A. (1977): Tourmaline Concentrations in Proterozoic Sediments of the Southern Cordillera of Canada and Their Economic Significance, *Cdn. Jour. Earth Sci.,* Vol. 14, pp. 2348-2363.

Hagen, A. S. (1978): Drilling Report, DDCH 6423, Chance No. 5 Group, *B.C. Ministry of Energy, Mines & Pet. Res.,* Assessment Rept. 6786.

.... (1981): Drilling Report, Golf 2, Fal 10, Fal 12, DDCH 6444-6446, *B.C. Ministry of Energy, Mines & Pet. Res.,* Assessment Rept. 9711.

Hamilton, J. M., Bishop, D. T., Morris, H. C., and Owens, O. E. (1982): Geology of the Sullivan Orebody, Kimberley, British Columbia, *in* Precambrian Sulphide Deposits, H. S. Robinson Memorial Vol., R. W. Hutchinson, C. D. Spence, and J. M. Franklin, editors, *Geol. Assoc. Can.,* Special Paper 25.

Hamilton, J. M., Delaney, G. D., Hauser, R. L., and Ransom, P. W. (in press): Geology of the Sullivan Deposit, Kimberley, British Columbia, Canada, *in* Sediment-Hosted Lead-Zinc Deposits, D.F. Sangster, editor, *Min. Assoc. Can.,* Short Course Notes, Chapter 2.

Hamilton, J. M., Hauser, R. L., and Ransom, P. W. (1981): The Sullivan Orebody, *in* Field Guide to Geology and Mineral Deposits, *Geol. Geol. Assoc. Can.,* pp. 44-79.

Höy, T. (1979): Geology of the Estella-Kootenay King Area, Hughes Range, Southeastern British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.,* Prelim. Map 36.

.... (1982a): Stratigraphic and Structural Setting of Stratabound Lead-Zinc Deposits in Southeastern British Columbia, *C.I.M.,* Bull., Vol. 75, No. 840, pp. 114-134.

.... (1982b): The Purcell Supergroup in Southeastern British Columbia; Sedimentation, Tectonics, and Stratiform Lead-Zinc Deposits, *in* Precambrian Sulphide Deposits, H. S. Robinson Memorial Vol., R. A. Hutchinson, C. D. Spence, and J. M. Franklin, editors, *Geol. Assoc. Can.,* Special Paper 25.

Höy, T. and Diakow, L. (1981): Geology of the Moyie Lake Area, Purcell Mountains, Southeastern British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.,* Geological Fieldwork, 1980, Paper 1981-1, pp. 9-14.

Höy, T. and Diakow, L. (1982): Geology of the Moyie Lake Area, *B.C. Ministry of Energy, Mines & Pet. Res.,* Prelim. Map 49.

Kanasewich, E. R. (1968): Precambrian Rift: Genesis of Stratabound Ore Deposits, *Science,* Vol. 161, pp. 1002-1005.

Kanasewich, E. R., Clowes, R. M., and McCloughan, C. H. (1969): A Buried Precambrian Rift in Western Canada, *Tectonophysics,* Vol. 8, pp. 513-527.

Leech, G. B. (1957): St. Mary Lake, Kootenay District, British Columbia (82F/9), *Geol. Surv., Canada,* Map 15-1957.

Leech, G. B. (1958): Fernie Map-Area, West Half, British Columbia, *Geol. Surv., Canada,* Paper 58-10.

.... (1960): Geology, Fernie (West Half), Kootenay District, British Columbia, *Geol. Surv., Canada,* Map 11-1960.

Lis, M. G. and Price, R. A. (1976): Large-Scale Block Faulting During Deposition of the Windermere Supergroup (Hadrynian) in Southeastern British Columbia, *Geol. Surv., Canada,* Paper 76-1A, pp. 135-136.

McCammon, J. W. (1964): The Marysville Magnesite Belt, *B.C. Ministry of Energy, Mines & Pet. Res.,* Ann. Rept., 1964, pp. 187-193.

McMechan, M. E. (1979): Geology of the Mount Fisher-Sand Creek Area, *B.C. Ministry of Energy, Mines & Pet. Res.,* Prelim. Map 34.

.... (1981): The Middle Proterozoic Purcell Supergroup in the Southwestern Purcell Mountains, British Columbia and the Initiation of the Cordilleran Miogeocline, Southern Canada and Adjacent United States, *Cdn. Pet. Geol.,* Bull., Vol. 29, No. 4, pp. 583-621.

Price, R. A. (1962): Fernie Map-Area, East Half, Alberta and British Columbia, *Geol. Surv., Canada,* Paper 61-24.

Ransom, P. W. (1977): Geology of the Sullivan Orebody, *in* Lead-Zinc Deposits of Southestern British Columbia, T. Höy, editor, *Geol. Assoc. Can.,* Fieldtrip Guidebook 1, pp. 7-21.

Reesor, J. E. (1958): Dewar Creek Map-Area, with Special Emphasis on the White Creek Batholith, British Columbia, *Geol. Surv., Canada,* Mem. 292, 78 pp.

.... (1981): *Grassy Mountain, Kootenay Land District,* British Columbia, *Geol. Surv., Canada,* Open File 820.

Rice, H.M.A. (1937): Cranbrook Map-Area, British Columbia, *Geol. Surv., Canada,* Mem. 207, 67 pp.

.... (1941): Nelson Map-Area, East Half, *Geol. Surv., Canada,* Mem. 228, 86 pp.