DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Preliminary Geologic Map of the Leonia Area Idaho and Montana

By Russell F. Burmester[1]

Open-File 86-554

This report map is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

[1] U.S. Geological Survey
Western Washington University
Bellingham, WA 98225

1986

Introduction

The Leonia map is one of a series of 1:48,000 scale preliminary geologic maps covering the Sandpoint 2^{o} quadrangle. This series is a byproduct of the Sandpoint 2^{o} project, conducted under the auspices of the regional framework studies program and the Branch of Western Regional Geology. The topographic base was a photographically mosaiced 15' sheet compiled from existing 7.5' topographic quadrangles. Nomenclature applied to the upper part of the Belt Supergroup is currently under revision and some of the names used in the report probably will not survive. Moreover, correlations of formations in the Missoula group presented here are tentative, pending revised correlations currently underway by workers throughout the Belt basin.

Description of Map Units

Qa — ALLUVIUM (QUATERNARY)--Includes alluvial material in modern drainages, on active floodplains and on alluvial fans

Qt — TALUS (QUATERNARY)

Qg — GLACIAL DEPOSITS (QUATERNARY)--Includes drift from both alpine and continental glaciations as well as older alluvium. Most drift consists of locally derived material deposited during last alpine glaciation. Older alluvium, which is topographically higher and generally coarser-grained than alluvium in modern drainages, may represent distal glacial outwash

Ql — LACUSTRINE DEPOSITS (QUATERNARY)--Tan-weathering silt, sand and gravel deposited in glacial and post-glacial lakes that occupied the Kootenai River Valley and Purcell Trench

Kg — GRANITOID ROCKS (CRETACEOUS)--Coarse-grained, variably porphyritic biotite granodiorite containing microcline phenocrysts 3 to 10 cm in length. Color index 10. Accessory magnetite (2 percent), sphene (1 percent), and epidote (greater than 1 percent). Biotite partly chloritized; plagioclase partly sericitized. Non-porphyritic granitoid rocks northeast of Bald Eagle Mountain in southwest corner of map area foliated; the foliation is enhanced by rare mafic inclusions. Undated within map area, but lithologically similar to and probably continuous with granitoid rocks west of map area that have yielded biotite and hornblende K-Ar apparent ages between 80 and 98 m.y. (Miller and Engles, 1975)

BELT SUPERGROUP (MIDDLE PROTEROZOIC)

MISSOULA GROUP

MOUNT SHIELDS FORMATION

Yms_2 — Unit 2--Green siltite and green to red argillite, typically unevenly bedded depositional couplets several millimeters to several centimeters thick of dark-green siltite grading upward to locally carbonatic, light-green argillite. Red argillite at tops of some beds contains mudcracks and mudchip breccia. Salt casts in red and green argillite occur throughout. Bed thickness and carbonate content increase upward within Unit. Unit exposed only in a band immediately east of and bounded by Moyie-Leonia fault; top of Unit is faulted. Maximum exposed thickness 400 m

Yms_1 — Unit 1--Green, carbonate-bearing siltite, maroon and green argillite, red and green quartzite and siltite, and tan limestone. Upper part consists of beds 30 to 60 cm thick of variably carbonatic, pale-green quartzite having ripple-marked tops. Middle part consists of between 10 and 20 silty, stromatolitic carbonate horizons, interbedded with maroon argillite. Lower part consists of maroon argillite with dessication cracks and of pale-maroon, micaceous quartzite and siltite. Tops of quartzite and siltite beds commonly contain breccia. Top of Unit placed above highest thick quartzite bed. Thickness approximately 200 m

SHEPARD FORMATION

Ysh_2 Unit 2--Black to gray argillite, green argillite, green siltite, and green micaceous quartzite. Argillite and siltite occur in fining-upward, wavy to plane-parallel-laminated couplets 1 to 5 mm thick. Wavy bedding is typically due to differential compaction around beds or lenses of green siltite and quartzite 1 to 40 cm thick. Small stromatolites and carbonatic siltite horizons are characteristic but minor component. Top of Unit placed at base of lowest maroon argillite in the overlying Unit. Thickness approximately 120 m

Ysh_1 Unit 1--Green, partly carbonatic siltite and argillite, white quartzite, and reddish brown weathering dolomite. Carbonate-free siltite commonly grades upward to dolomitic argillite in wavy, laminated couplets a few millimeters to 1 cm thick. Siltite cross-laminated; dolomitic argillite at tops of couplets is broken by dessication and water-escape structures and weathers yellowish orange to yellowish brown. Cross-laminated dolomite- and pyrite-bearing white quartzite occurs throughout as starved ripples, lenses, channels and beds as much as 30 cm thick. Reddish brown weathering dolomite containing vertical calcite ribbons that weather out to form "molar-tooth" structures is concentrated in middle of Unit. Top of Unit placed below lowest occurrence of black argillite in overlying Unit. Thickness 400 to 500 m

Ysn SNOWSLIP FORMATION--Laminated to very thin-bedded, black to green argillite, green to white siltite, black slate, and pyritiferous white quartzite. Rare pale purple argillite near base. Some quartzite and siltite interbeds show small scours and cross-lamination structures. Dessication and water-escape cracks and ripple marks present on parting surfaces of green argillite. Green and purple argillite laminae slightly wavy and commonly discontinuous. Black beds in middle of Unit are plane-parallel-laminated and locally alternate with gray siltite beds as much as 50 cm thick. Thickness estimated at 900 m, although the most complete section in the map area is faulted. Top placed at base of lowest "molar-tooth" weathering dolomite, stromatolite, or quartzite channel in overlying Unit

Yi_3 INTRUSIVE ROCKS, Unit 3--Fine- to medium-grained diabase and gabbro. Occurs as thin and irregularly shaped sills in upper part of Wallace Formation

WALLACE FORMATION

Yw_2 Unit 2--White dolomitic quartzite and siltite, dark-bluish-gray dolomite and limestone, black argillite, and greenish-gray siltite and argillite. Most dolomite and dolomitic beds weather reddish brown. Siltite and quartzite beds 1-10 cm thick pinch and swell irregularly, are commonly cross-laminated, and grade upward to carbonate free black argillite. Bedding-plane partings typically show water-escape and dessication structures. Pyrite cubes occur throughout. Dark-bluish-gray to black dolomite beds are parallel-laminated, typically silty and calcareous toward top and commonly contains abundant calcite ribbons which weather-out to form "molar-tooth" structure. Thinly-laminated, wavy beds of pale greenish-gray siltite and argillite form graded couplets having carbonatic tops. Middle part of unit characterized by presence of white quartzite and absence of black argillite. Top of unit placed at top of highest black argillite. Thickness estimate of 1400 m uncertain because unit is commonly deformed and faulted

WALLACE FORMATION

Yw_1 Unit 1--Medium-green siltite and light-green argillite, both locally carbonatic. Siltite forms wavy, nonparallel and lenticular beds containing ripple- and starved-ripple-lamination. Ripple-marked parting surfaces abundant in siltites, dolomite more common than calcite. Most carbonate-bearing beds weather dark yellowish orange, but some bleach white. Carbonate pods and beds in lower part of unit weather out to produce elongate or irregular-shaped holes. Purple argillite having dessication cracks and mud chip breccias common near base of unit along with rare channels of white quartzite. Top of unit placed at lowest occurrence of black argillite in overlying unit. Thickness approximately 600 m

RAVALLI GROUP

Ysr SAINT REGIS FORMATION--Interbedded maroon to green argillite and maroon siltite. Thin- to very-thin-bedded maroon argillite commonly contains mudcracks and mudchip breccias on platy partings; pale-reddish-purple siltite laminae and rare white quartzite beds as much as 10 cm thick are interbedded near base. Top of unit placed below dominantly green siltite and argillite and below lowest carbonate pods or bed of overlying unit. Base of unit faulted; maximum exposed thickness 250 m. Thickness

400 to 600 m in Eastport area to the north (Burmester, 1985)

Yr — REVETT FORMATION--Medium- to thick-bedded, white quartzite, maroon argillite, and green siltite. Some thicker beds are cross-bedded; others show apparent trough cross lamination enhanced by purple hematite concentrations similar to those in underlying unit. Top of unit faulted; maximum exposed thickness of 725 m is approximately equal to the complete thickness of the unit in Eastport area to north (Burmester, 1985)

BURKE FORMATION

Yb_2 — Unit 2--Purple quartzite, purple and green argillite, and green siltite. Quartzite very fine-grained, slabby to platy, thin- to medium-bedded with rare planar cross-laminae enhanced by purple hematite concentrations. Poorly exposed interbeds of purple argillite similar to argillite in Saint Regis Formation present in upper part of unit. Minor green to gray siltite occurs throughout. Macroscopic magnetite octahedra common. Top of unit placed at base of lowest thick-bedded gray to white quartzite in overlying unit. Thickness 400 to 500 m

Yb_1 — Unit 1--Green to grayish-green siltite. Medium- to thin-bedded, typically with slabby parting. Magnetite octahedra up to 1 mm across locally abundant. Minor carbonate rock occurs near base as very thin beds and scattered nodules less than 1 cm long. Top of unit placed at base of lowest purple siltite bed in overlying unit. Thickness 400 to 500 m

Yp — PRICHARD FORMATION--Any of Prichard lithologies described below but most likely lower and middle units

UPPER MEMBER

Tpu_3 — Unit 3--Gray siltite, black argillite, and white quartzite. Grades downward from Burke Formation through decreasing bed thickness, increasing abundance and thickness of black argillite interbeds, and change from magnetite to pyrite which causes rusty weathering throughout. Argillite and siltite have flaggy to slabby parting with dessication cracks and molds of a platy crystal, possibly gypsum or chloritoid on bedding surfaces. Siltite beds in lower part of unit irregular in thickness due to pinch and swell of ripple cross-laminae and cut-and-fill structures. Lower part of unit includes medium to thick beds of fine-grained white quartzite and thin beds and pods of manganiferous carbonate. Top of unit placed above the highest black argillite. Thickness about 700 m

Ypu_2 Unit 2--Dark- to medium-gray argillite, and white siltite and quartzite. Argillite and siltite characteristically plane parallel laminated; siltite lamellae 1-5 mm thick appears as white lines on rocks. Parting platy to flaggy. Medium to thick quartzite beds occur throughout unit as minor components. Top of unit placed at lowest occurrence of thick white siltite beds and wavy bedding in overlying unit. Thickness approximately 400 m

Ypu_1 Unit 1--Interbedded pyritiferous quartzite, siltite and argillite. Quartzite generally medium-bedded, some beds grade from bases of very fine sand to tops of argillite; others have cross-laminated siltite or arenite tops. Some 1 to 2 m thick quartzite beds have oblate concretions 20 cm in diameter and lamellae of dark brown-weathering manganiferous calcite. Sole marks rare; flute casts indicate general northward transport. Some bed surfaces are ripple-marked. Interbeds of laminated argillite and siltite are similar to overlying and underlying units. Unit grades upward into overlying argillite unit with decreasing abundance of quartzite. Incompletely exposed in map area, but 600 to 700 m thick in Eastport area to north (Burmester, 1985)

INTRUSIVE ROCKS

Yi_2 Unit 2--Massive, fine-grained biotite granodiorite to quartz-rich granitoids occurring as differentiation products or as sediment-contaminated zones in upper part of some mafic intrusions. Where contacts exposed, grades upward to more mafic but still quartz-rich lithologies, and downward to medium-grained metagabbro typical of Unit 1. Original mineralogy obscured by biotite-grade metamorphism and replacement of most microcline by muscovite. Acicular form of some biotite, especially at upper contacts, probably after hornblende. Age younger than mafic rock in same sill, but not necessarily younger than other sills of unit Yi_1

Yi_1 Unit 1--Mostly diabase and gabbro, but includes hornblendite, fine-grained diorite, and granophyre differentiates where these are not broken out as Yi_2. Generally occurs as concordant sills with constant thickness, but some bodies change thickness, crosscut strata, and form complex intrusions. Observed contacts have chilled margins, and some sills show internal chilled contacts indicating multiple intrusion of magma. Intruded rock commonly complexly deformed and hornfelsed. Zircons from samples of thick sill exposed south of Moyie Springs (Crossport C sill of Bishop, 1973) have concordant uranium-lead ages of 1433±10 m.y. (Zartman and others, 1982).

MIDDLE MEMBER

Ypm_2 Unit 2--Black argillite, and light- to dark-gray, carbonaceous siltite. Both characterized by slabby to platy parting. Carbonaceous laminae weather to a rusty color due to the presence of pyrrhotite. Some subphyllitic argillite contains visible biotite and sericite on pale lavender parting. Soft-sediment deformation common. Includes interturbidite layer reported to extend over 100 km along strike (Huebschman, 1973). Unit grades upward into overlying unit with increase in abundance of quartzite. Unit is 200-250 m thick east of Moyie-Leonia fault and approximately 400 m west of fault

Ypm_1 Unit 1--Interbedded pyritiferous quartzite, argillite, and laminated siltite as in unit Ypu_1. Fine-grained layers weather deep reddish-brown with bluish and greenish highlights. Thickness approximately 600 m. Unit grades upward into overlying unit with decrease in abundance of quartzite

Ypl LOWER MEMBER--Thin- to thick-bedded quartzite and siltite and laminated siltite and argillite. Generally less rusty-weathering than middle and upper members. Upper part of unit consists of medium- to thick-bedded, fine-grained, white-to light gray-weathering quartzite that commonly contains internal cross-lamination and scour structures. Well-rounded, medium-grained quartz is present in the bottoms of some beds and troughs. Similar quartzite occurs in at least two horizons lower in the unit; these horizons contain abundant wavy bedding and lamination, lenticular bedding, cross-lamination, scour structures, and load structures that have internal convolute- and cross-lamination. Rusty-weathering, plane-parallel-laminated siltite and argillite occur throughout the unit in horizons 1-25 m thick. One location exposes conglomeratic quartzite containing rounded clasts of laminated siltite and quartzite lithologies. Some quartzite beds contain tabular clasts 2-20 cm long of laminated siltite and quartzite. Angular and contorted clasts of laminated siltite occur in some disrupted argillite horizons. Cross-lamination indicates generally northward paleocurrents. Upper-contact placed above highest occurrenc of gray-weathering cross-laminated siltite and below lowest rusty-weathering plane-parallel laminated siltite and argillite and medium-bedded quartzite. Minimum thickness, uncertain because of internal faulting, about 2000 m

EMPLACEMENT OF PROTEROZOIC INTRUSIONS

Subdivision of mafic intrusive bodies into two age groups, and assignment of ages of intrusions relative to sedimentary strata of the Belt is based on an interpretation that at least some of the major sills intruded soft, wet sediment shortly after deposition. Hamilton (1984) suggested that the sulfide mineralization at the Sullivan Mine, Kimberly, B.C., formed in sediment that accumulated during convective cooling of an unlying sill. The Crossport "C" sill of Bishop (1973) occupies a similar stratigraphic position near the top of the lower Prichard. The most impressive conglomerate in the area is located near the center of the map, a few hundred meters above this sill in the east half of section 13. This conglomerate possibly resulted from slumping induced by intrusion of the subjacent sill. Other, less spectacular sedimentary breccias at different stratigraphic horizons may record slumping from intrusion at other times.

Some contacts between Proterozoic intrusions and invaded sediments also may be interpreted as products of intrusion into unconsolidated sediment. The northern contact of the sill on Boulder Mountain near the southwest corner of the map is locally irregular with the adjacent sediments highly contorted yet free of cleavage that is associated with more simply and probably tectonically deformed strata to the north and east. Other good examples off the map to the north and west show irregular lower contacts and mottled appearance reminiscent of lava pillows loading and partially incorporating subjacent wet sediment.

The unit Yi_2 is itself interpreted as the product of extensive mixing of a differentiated magma and wet sediments. This is based on uniformity of composition, lack of bedding, sieve texture of quartz in plagioclase, acicular habit of biotite, and muscovite habit as rosettes. Point counts on four widely separated samples indicate the mode does not vary significantly from 44% quartz, 25% plagioclase, 17% muscovite, 12% biotite and 1% potassium feldspar. The working hypothesis is that the high quartz content and quartz in plagioclase resulted from incomplete assimilation of silt, the acicular form of biotite mimics an original amphibole, and the muscovite owes its atypical form to nearly complete replacement of potassium feldspar. An alternative hypothesis is that the unit represents sediment completely mixed during slumping or convection driven by the subjacent mafic sill, then altered by residual heat of the intrusion.

If, as seems likely, more than one sill in the lower Prichard was intruded soon after the invaded sediments were deposited, more than one event is required. The position for Yi_1 and Yi_2 in both the correlation and description of map units is a minimum age for the majority of mafic intrusions. Those in the lowest part of the Prichard may be nearly as old as the enclosing sediments.

If sills in the Prichard Formation formed during its depostion, then the sills in the upper part of the Wallace Formation must be substantially younger. There is no evidence for their age with respect to overlying sediments except that they must be younger than the adjacent material. However, it seems simplest to attribute the sills to the magmatic event that produced the Purcell Lavas found near the top of the Snowslip Formation as close as 50 km to the southeast. If so, the sills are 1075±/-(6%) Ma, the K-

Ar apparent age of hornfels produced by Purcell Lava east-northeast of the area (Hunt, 1962).

Igneous activity in the Proterozoic, at least the first period of magmatism, may have had a direct effect on sedimentation. The lower Prichard exhibits sedimentary structures indicative of reworking by traction currents which are easiest to explain in shallow water. Addition of the sills would have helped maintain or restore shallow water during deposition of the lower Prichard sediments. The paucity of similar indicators of traction currents in most of the overlying Prichard is explained most simply by deepening of the water. Without increase in sediment supply, reduction of cessation of intrusion would have led to decreased accumulation of the section. Cooling and densification of these sills would have contributed to increase in the rate of subsidence. Both would have contributed to deepening of the basin.

METAMORPHISM

Metamorphism in the area is generally low grade. Rocks of the Burke Formation through the Mount Shields Formation in the map area are metamorphosed to the chlorite zone of the greenschist facies; the Prichard Formation is metamorphosed to the biotite zone. All of these rocks generally retain their original grain size and sedimentary structures, and lack metamorphic fabric except in the following places: 1) cleavage is locally developed in argillitic beds or argillitic tops of graded beds; 2) unusually large muscovite grains are developed in a one km wide swath east of East Fork Boulder Creek; 3) almandine garnets to 4 mm across are present in argillitic siltite north of Treble Creek near the southwest corner of the map area; 4) rocks near granitic intrusions are recrystallized to medium and coarse grain size and have schistose and gneissic fabrics; 5) bedding planes in rocks near some mafic intrusions are welded owing to contact metamorphism; 6) mylonite is developed along some faults in the southwestern part of the map area.

STRUCTURE

The Kootenai River follows the major structural discontinuity in the area through the central part of the map. East of the Kootenai River, beds as high in the section as the Mount Shields Formation generally strike north-northwest and dip to the west. West of the river, beds no higher than the middle member of the Prichard Formation strike generally north and dip to the east. Along the river and between the two areas of oppositely dipping beds is the major structure of the map area, the Moyie-Leonia fault. Calkins and MacDonald (1909) called this structure the Lenia Fault and interpreted it as a high-angle, west-dipping thrust fault with the lower plate to the east. The northward extension of the fault in Canada is the steeply-dipping, curvilinear Moyie fault of Schofield (1915). Near its junction with the Southern Rocky Mountain Trench, Benvenuto and Price (1979) interpreted it as a reverse fault with the northwest side up. Kirkham and Ellis (1926) recognized the continuity of the structure and called it the Moyie-Lenia overthrust fault. Johns (1970) speculated that Lenia was a misspelling of Leonia, the town near its best exposure. In this report the structure will be referred to as the Moyie-Leonia Fault. Within the map area, it does not appear to be a simple thrust fault.

Stratigraphic displacement across the Moyie-Leonia fault diminishes from about 13,750 m near Cranbrook, British Columbia to 7925 m in the northwest corner of the Libby Quadrangle (Erdmann, 1941). Within the map area, stratigraphic throw is approximately 8000 m.

The dip of the fault, whose trace shows no deflection where it crosses topography is steep but imprecisely known. The fault is best exposed 2 km north of Leonia (near the confluence of Boulder Creek and the Kootenai River), where west-facing, overturned beds of the Mount Shields Formation are in contact with metaigneous rock that intrudes the Prichard Formation. A shear zone, which shows discoloration of the rocks probably due to frictional heating, appears to dip steeply eastward parallel to bedding in the Mount Shields Formation. The apparent stratigraphic displacement of the fault suggests that the west side moved up with respect to the east side.

Relatively minor faults parallel the Moyie-Leonia fault on both sides. Most of these, like the Moyie-Leonia fault, are characterized by zones of gouge and slickensided breccia, and only rarely crop out. Their existence is inferred from repetition and truncation of units and structures and less commonly by the presence of drag folds.

East of the Moyie-Leonia fault, moderately to steeply dipping strata of the Wallace and Snowslip Formations are repeated along a fault that parallels the Moyie-Leonia fault but has stratigraphic throw of only a few hundred meters. Since this fault appears to be part of a complicated fold and fault structure at bend of the Moyie-Leonia fault at north edge of the map, origin as a reverse fault, or thrust before folding, is most likely.

A fault parallel to the Moyie-Leonia fault on its southwest side in the northern half of the map area repeats the middle part of Prichard Formation. It too could have originated as a thrust before folding, although its attitude and continuation to the south, are unknown. Another northwest striking fault with an apparently curved surface is inferred in the central part of the area where gently folded strata free of intrusions are on strike with steeply dipping beds and a large sill. This fault may also have developed prior to or at the same as folding.

The area also is cut my some east and northeast striking faults. One with apparently small displacement is just north of the lower reaches of Boulder Creek. It may cut the Moyie-Leonia fault and upper Belt strata to the east. If so, slip must be down to the north to account for opposite senses of offset of the map patterns across the Kootenai River. The mismatch of sills and structures seems to increase westward. The fault concealed by Quaternary deposits along Boulder Creek is probably not as simple and continuous as shown.

Atypical of the map area as a whole, but common in the southwest part, are mylonite zones associated with or involving vein quartz that makes them resistant to weathering. Lineation, asymmetry of clasts, and relations of the generally steeply-dipping foliation(s) and shear (c) surfaces (Simpson and Schmid, 1983) in these zones show dip slip movement dominates. Both east side up and down motions have been documented, but only left lateral slip is apparent in those mylonites examined in detail.

Age or timing of structural development is poorly constrained. The Moyie-Leonia and other faults with gouge zones are constrained within the map area only to have been active between deposition of the Mount Shields Formation and deposition of glacial debris in the Quaternary. However, the granitic intrusions appear to truncate dipping strata and at least some faults in the southwest part of the map indicating that some of the deformation predated intrusion. Association of the mylonite zones with quartz and their proximity to exposures of coarse-grained granitic rocks suggest that these faults were active during Cretaceous magmatism.

Much of the structure must predate the mylonites. The mylonite zones cut folded strata but appear undeformed. Away from the mylonites, cleavage is generally not parallel to that in the mylonites nor is it axial planer. Instead it bears a constant angular relationship to bedding; it dips 10 to 30 degrees eastward with respect to bedding restored to horizontal. The strain that produced this cleavage must have been more widespread and older than the mapped folds, but the cause and age of this strain are not clear at present.

REFERENCES

Benvenuto, G.L., and Price, R.A., 1979, Structural evolution of the Hosmer Thrust sheet, southeastern British Columbia, Bull. Can. Petrol. Geology 27 (3), 360-397.

Bishop, D. T., 1973, Petrology and geochemistry of the Purcell sills in Boundary County, Idaho: in Belt Symposium I, Idaho Bureau Mines and Geology Special Report 2, 1, 16-66.

Burmester, R. K., Preliminary geologic map of the Eastport area, Idaho and Montana, U.S. Geological Survey Open-File Report 85-517.

Calkins, F. C., and MacDonald, D. F., 1909, Geological reconnaissance in northern Idaho and northwestern Montana: U.S. Geol. Survey Bulletin 384, 7-108.

Erdmann, C.E., 1941, Geology of dam sites on the upper tributaries of the Columbia River in Idaho and Montana. Part 1. Katka, tunnel no. 8, and Kootenai Falls dam sites, Kootenai River, Idaho and Montana: U.S. Geological Survey Water Supply Paper 866-A, 36 p.

Edmunds, F. R., and Bishop, D. T., 1973, Field trip number 11, Belt rocks in the Clark Fork region of northern Idaho and the Purcell mountains of British Columbia: in Belt Symposium I, Idaho Bureau of Mines and Geology Special Report 2, 1, 222-227.

Hamilton, J. M., 1984, The Sullivan deposit, Kimberly, British Columbia - A magmatic component to genesis?: Montana Bureau of Mines and Geology Special Publication 90, 58-60.

Harrison, J. E., and Campbell, A. B., 1963, Correlations and problems in Belt series stratigraphy, northern Idaho and western Montana: Geol. Soc. of America Bull., 74, 1413-1428.

Huebschman, R. P., 1973, Correlation of fine carbonaceous bands across a Precambrian stagnent basin: J. Sed. Petrology, 43, 688-699.

Hunt, G., 1962, Time of Purcell eruption in southeastern British Columbia and southwestern Alberta: J. Alberta Soc. Petrol. Geol., 10, 438-442.

Johns, W. M., 1970, Geology and Mineral Deposits of Lincoln and Flathead Counties, Montana: Montana Bureau of Mines and Geology Bulletin 79, 182 pp.

Kirkham, V.R.D., and Ellis, E.W., 1926, Geology and ore deposits of Boundary County, Idaho: Idaho Bureau Mines and Geology Bulletin 10, 78 p.

Miller, F. K., and Engles, J. C., 1975, Distribution and trends of discordant ages of the plutonic rocks of northeastern Washington and northern Idaho: Geol. Soc. of America Bulletin 86, 517-528.

Schofield, S.J., 1915, Geology of the Cranbrook Map Area, B. C.: Canadian Geological Survey Memoir 76.

Simpson, C., and Schmid, S.M., 1983, An evaluation of criteria to deduce the sense of movement in sheared rocks: Geological Society of America Bulletin 94, p. 1281-1288.

Zartman, R. E., Peterman, Z. E., Obradovich, J. D., Gallego, M. D., and Bishop, D. T., 1982, Age of the Crossport C sill near Eastport, Idaho: in Reid, R. R. and Williams, G. A. (eds.), Soc. Econ. Geol. Coeur d'Alene field conference, Idaho -1977, Idaho Bureau of Mines and Geology Bulletin 24, 61-69.