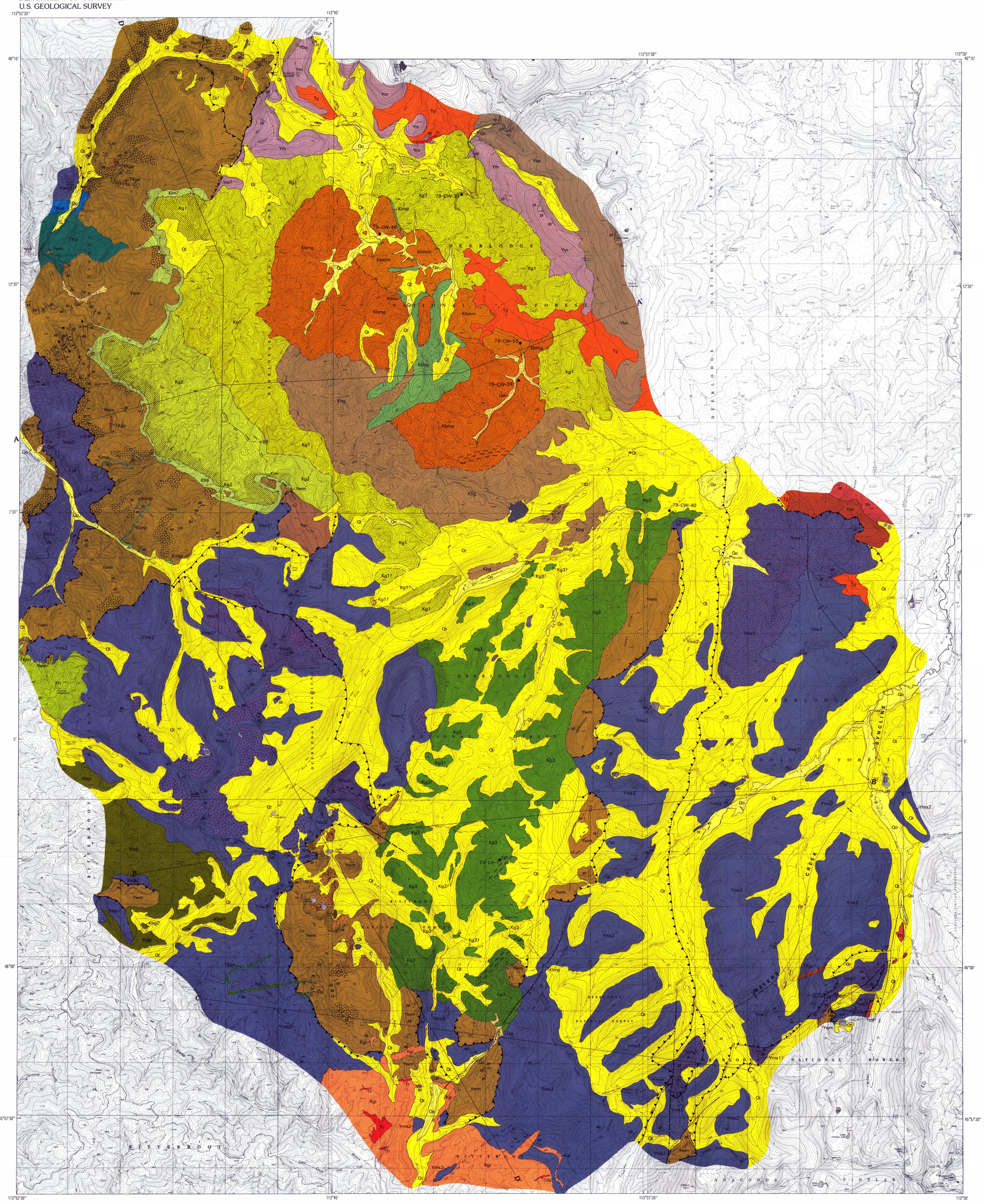
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

BULLETIN 1824
PLATE 1




Base from U.S. Geological Survey, 1:24,000
Skalkaho Pass, Mt. Emerine, Kent Peak, Whetstone Ridge, Moose Lake, Jenning Camp Creek, Lick Creek, Kelly Lake, Burnt Fork Lake, and Mauley Gulch

Geology mapped by C. A. Wallace and D. J. Lidke, 1978,1980,1982, and 1983 and by M. R. Waters, 1983

SCALE 1:50 000

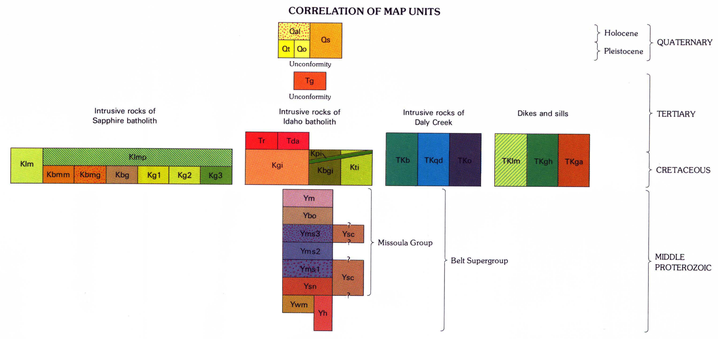
1 0 1 2 3 MILES
1 0 1 2 3 KILOMETERS

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

APPROXIMATE MEAN DECLINATION, 1983

MAP LOCATION

## CORRELATION OF MAP UNITS




## DESCRIPTION OF MAP UNITS

### QUATERNARY AND TERTIARY DEPOSITS

Qal — **Alluvial deposits (Holocene)**—Stream deposits of unconsolidated, poorly sorted, bouldery, sandy gravel. Mainly reworked till and outwash deposits

Qs — **Landslide and rockslide deposits (Holocene and Pleistocene)**—Angular rock fragments in a matrix of weathered rock and soil. Occurs only in drainage of Daly Creek near north edge of map

Qt — **Till (Pleistocene)**—Poorly sorted, bouldery, sandy to clayey gravel. Stratification poorly developed

Qo — **Outwash deposits (Pleistocene)**—Dominantly glaciofluvial deposits that consist of poorly sorted, bouldery gravel and well-sorted sand. Some outwash deposits retain a braided-stream pattern. Includes alluvial deposits of present streams in most areas

Tg — **Alluvial-fan and gravel deposits (Tertiary)**—Poorly sorted boulders and gravel in a sandy to clayey matrix. Coarse clasts locally show moderate stratification. Contains some unconsolidated beds of sand. Mainly gravel on pediment surfaces in north part of mapped area

### INTRUSIVE ROCKS[1]

Idaho Batholith

Tr — **Rhyolite (Tertiary)**—Porphyritic, hyalopilitic, hypabyssal(?) dikes and irregular bodies. Consists of fine-grained phenocrysts (3–5 percent) of plagioclase, quartz, biotite, and hornblende. Groundmass primarily lath-shaped plagioclase with interstitial glass. Plagioclase phenocrysts are slightly zoned and have an average composition of $An_{31}$. Biotite oxidized and chloritized. Hornblende present in trace amounts and commonly altered to chlorite. Forms small isolated bodies that intrude the biotite-hornblende granodiorite (Kgi)

Tda — **Dacite (Tertiary)**—Porphyritic, hypocrystalline, hyalopilitic, hypabyssal(?) rock. Fine- to medium-grained phenocrysts (20 percent) consist of plagioclase, quartz, hypersthene, biotite, and hornblende. Groundmass is mainly composed of lath-shaped plagioclase and minor hypersthene and apatite granules all enclosed in glass. Plagioclase phenocrysts are slightly zoned and have an average composition of $An_{28}$. Hornblende is oxyhornblende and is commonly altered to biotite and granular magnetite. Biotite is altered to granular magnetite. Forms a single isolated body that intrudes the biotite-hornblende granodiorite (Kgi) near the southern edge of the map area

Kgi — **Biotite-hornblende granodiorite (Late Cretaceous)**—Slightly porphyritic, medium-grained, hypidiomorphic-granular pluton and associated dikes and sills. Average composition is essential plagioclase (43 percent), quartz (31 percent), microcline (8 percent) and orthoclase (6 percent) and varietal brown and green biotite (7 percent) and green hornblende (2 percent). Accessory minerals are epidote, sphene, apatite, zircon, and clinozoisite. Average plagioclase composition ranges from $An_{32}$ (core) to $An_{26}$ (rim). Myrmekite is present along plagioclase and alkali feldspar contacts. Contains a tonalite border zone and monzogranite dikes, sills, and irregular pods. Contacts of the tonalite border zone and the monzogranite bodies with the granodiorite are gradational. The tonalite border zone contains more phenocrysts than the granodiorite and consists of essential plagioclase (48 percent) and quartz (21 percent) and varietal brown and green biotite (16 percent) and green hornblende (13 percent). Average plagioclase composition ranges from $An_{35}$ (core) to $An_{29}$ (rim). Accessory minerals are epidote, sphene, apatite, and zircon

Kbgi — **Biotite granodiorite pluton (Late Cretaceous)**—Porphyritic, medium-grained, hypidiomorphic-granular pluton consisting of essential plagioclase (47 percent), quartz (27 percent), orthoclase (9 percent), and microcline (8 percent) and varietal brown and green biotite (9 percent). Accessory minerals are sphene, epidote, apatite, zircon, and allanite. Plagioclase has an average composition of $An_{31}$ (core) to $An_{18}$ (rim), and myrmekite is common. Alkali feldspar contains poorly developed perthite. Secondary crystallization of biotite on earlier formed biotite grains common

Kti — **Tonalite pluton (Late Cretaceous)**—Slightly porphyritic, medium-grained, hypidiomorphic-granular pluton consisting of essential plagioclase (57 percent), quartz (20 percent), orthoclase (2 percent), and microcline (2 percent) and varietal green and brown biotite (17 percent) and green hornblende (3 percent). Accessory minerals are sphene, epidote, apatite, zircon, and allanite. Normal zoning in plagioclase is common, and compositions range from $An_{47}$ (core) to $An_{27}$ (rim)

Kpi — **Pegmatite dikes (Late Cretaceous)**—Coarse-grained, hypidiomorphic-granular dikes consisting primarily of microcline and quartz, with subordinate plagioclase and muscovite. Biotite occurs in trace amounts. Graphic intergrowths of quartz in microcline common. Intrudes Mount Shields Formation (Yms2) in southwestern part of map area

Intrusive rocks of Daly Creek

TKb — **Biotite-hornblende granodiorite (Tertiary or Late Cretaceous)**—Porphyritic, medium-grained, hypidiomorphic-granular pluton consisting of essential plagioclase (51 percent), quartz (24 percent), microcline (14 percent), and orthoclase (2 percent). Varietal minerals are brown and green biotite (8 percent) and green hornblende (2 percent). Accessory minerals are epidote, sphene, apatite, rutile, and zircon. Myrmekite and perthite common. Plagioclase has an average composition of $An_{31}$ (core) to $An_{17}$ (rim). Secondary crystallization of biotite on earlier formed biotite crystals is common, and rutile needles are commonly intergrown with biotite

TKqd — **Hornblende-biotite quartz diorite (Tertiary or Late Cretaceous)**—Porphyritic, medium-grained, hypidiomorphic-granular pluton consisting of essential plagioclase (44 percent) and quartz (7 percent). Varietal minerals are green hornblende (41 percent), and brown and green biotite (6 percent). Accessory minerals are epidote, sphene, apatite, rutile, and leucoxene. Plagioclase has an average composition of $An_{37}$ (core) to $An_{26}$ (rim). Rutile needles commonly intergrown with biotite and hornblende. Forms a border zone on the north side of the biotite-hornblende granodiorite (TKb) along Daly Creek

TKo — **Oligoclasite dike (Tertiary or Late Cretaceous)**—Medium-grained, equigranular, hypidiomorphic-granular dike consisting of oligoclase (80 percent), quartz (10 percent), calcite (5 percent), hematite (3 percent), and muscovite (2 percent). Quartz and muscovite are interstitial to plagioclase crystals, and hematite and calcite occur in fractures and voids as secondary minerals. A single dike cuts the Wallace Formation (Ywm) along west side of Daly Creek

Dikes and sills

TKlm — **Leucomonzogranite dike (Tertiary or Late Cretaceous)**—Fine- to medium-grained, hypidiomorphic-granular dike consisting of plagioclase, alkali feldspar, and quartz, with trace amounts of biotite, hornblende, and unidentified accessory minerals. Average plagioclase compositions are $An_{25}$ (core) to $An_{15}$ (rim). A single dike cuts the Wallace Formation (Ywm) at western edge of the map area

TKgh — **Hornblende-gabbro dikes (Tertiary or Late Cretaceous)**—Medium-grained, hypidiomorphic- to allotriomorphic-granular dikes consisting of green hornblende (60 percent), plagioclase (30 percent), and brown biotite (10 percent) and accessory sphene (trace). Compositionally zoned plagioclase, with an average composition of $An_{62}$, is poorly developed. Cuts the Mount Shields Formation (Yms2) in southwestern part of map area

TKga — **Augite-gabbro dikes and sills (Tertiary or Late Cretaceous)**—Fine-grained subophitic dikes and sills containing plagioclase (45 percent), augite (35 percent), green hornblende (15 percent), and brown biotite (5 percent). Plagioclase normally zoned, with an average composition of $An_{58}$ (core) to $An_{38}$ (rim). Hornblende and biotite are secondary alteration products of augite. Cuts the Mount Shields Formation (Yms2) in southeastern part of map area and Wallace Formation (Ywm) in northwestern part of map area

Sapphire batholith

Klmp — **Porphyritic leucomicromonzogranite (Late Cretaceous)**—Fine-grained, leucocratic, porphyritic dikes and pods with a xenomorphic groundmass. Phenocrysts (3–10 percent) are plagioclase (average composition $An_{28}$), microcline, and quartz. Groundmass consists of a microgranular intergrowth of plagioclase, microcline, orthoclase, quartz, and muscovite. Garnet commonly present as phenocrysts and as granules in groundmass. Forms pods, dikes, and veins that cut other rocks of the Sapphire batholith (Kbg, Kbmg, Kbmm, Kg1) and middle member of Wallace Formation (Ywm) in Skalkaho Creek

Klm — **Leucomonzogranite (Late Cretaceous)**—Porphyritic, medium-grained, hypidiomorphic-granular border phase consisting of plagioclase (33 percent), microcline (31 percent), quartz (30 percent), and orthoclase (6 percent), and traces of brown biotite and green hornblende. Accessory minerals are zircon, sphene, and epidote. Phenocrysts are plagioclase and alkali feldspar. Alkali feldspar is mainly anhedral and interstitial but occurs locally as subhedral phenocrysts. Plagioclase generally slightly zoned, with an average composition of $An_{28}$; commonly contains quartz inclusions. Present as western border zone to the biotite-hornblende granodiorites (Kg1 and Kg2)

Kbmm — **Biotite-muscovite monzogranite (Late Cretaceous)**—Medium-grained, hypidiomorphic-granular pluton consisting of essential plagioclase (38 percent), quartz (30 percent), orthoclase (14 percent), and microcline (11 percent) and varietal brown biotite (3 percent) and muscovite (3 percent). Accessory minerals are epidote, clinozoisite, apatite, and zircon. Average plagioclase compositions are $An_{28}$ (core) to $An_{17}$ (rim). Myrmekite and perthite common

Kbmg — **Biotite-muscovite granodiorite (Late Cretaceous)**—Slightly porphyritic, medium-grained, hypidiomorphic-granular pluton consisting of essential plagioclase (43 percent), quartz (35 percent), microcline (10 percent), and orthoclase (7 percent). Varietal minerals are brown biotite (5 percent) and muscovite (1 percent). Accessory minerals are epidote, apatite, zircon, sphene, and fluorite. Average plagioclase compositions are $An_{30}$ (core) to $An_{16}$ (rim). Biotite has prominent pleochroic haloes. Quartz may be glomeroporphyritic and smoky

Kbg — **Biotite granodiorite (Late Cretaceous)**—Porphyritic, medium-grained, hypidiomorphic-granular pluton consisting of essential plagioclase (40 percent), quartz (35 percent), orthoclase (14 percent), and microcline (5 percent) and of varietal brown biotite (5 percent) and green hornblende (trace). Common accessory minerals are epidote, apatite, zircon, and sphene. Average plagioclase compositions are $An_{37}$ (core) to $An_{13}$ (rim). Myrmekite and pink perthite common. Hornblende may be altered to intergrowths of biotite and chlorite. Distinguished from texturally similar biotite-muscovite granodiorite (Kbmg) by lack of muscovite, presence of trace amounts of hornblende, and phenocrysts of pinkish alkali feldspar

Kg1 — **Biotite-hornblende granodiorite one (Late Cretaceous)**—Porphyritic, medium-grained, hypidiomorphic-granular pluton consisting of essential plagioclase (45 percent), quartz (29 percent), orthoclase (8 percent), and microcline (8 percent), with varietal brown biotite (9 percent) and green hornblende (2 percent). Accessory minerals are sphene, epidote, apatite, zircon, and allanite. Average plagioclase compositions are $An_{31}$ (core) to $An_{17}$ (rim). Myrmekite and pink perthite are prominent. In northwest part of map area includes prominent border porphyry in gradational contact with leucomonzogranite (Klm). Distinguished from biotite granodiorite (Kbg) by having at least 2 percent hornblende, much more biotite, and trace amounts of allanite. Biotite-hornblende granodiorite (Kgl) and biotite granodiorite (Kbg) both contain phenocrysts of pink alkali feldspar

Kg2 — **Biotite-hornblende granodiorite two (Late Cretaceous)**—Slightly porphyritic, medium-grained, hypidiomorphic-granular pluton consisting of essential plagioclase (43 percent), quartz (31 percent), microcline (13 percent), and orthoclase (4 percent) and varietal green and brown biotite (8 percent) and green hornblende (3 percent). Accessory minerals are sphene, epidote, apatite, zircon, and allanite. Average plagioclase compositions are $An_{32}$ (core) to $An_{17}$ (rim). Myrmekite and perthite present, but not as common as in Kg1. Contains porphyritic border zones and has a prominent western porphyry border that is in gradational contact with leucomonzogranite (Klm). Kg2 is distinguished from Kg1 by a lack of pinkish potassium feldspar, by a more equigranular texture, and by a subtle increase in the amount of hornblende relative to biotite

Kg3 — **Biotite-hornblende granodiorite three (Late Cretaceous)**—Porphyritic, medium-grained, hypidiomorphic-granular pluton consisting of essential plagioclase (42 percent), quartz (27 percent), microcline (18 percent), and orthoclase (5 percent) and varietal green and brown biotite (7 percent) and green hornblende (2 percent). Accessory minerals are sphene, allanite, epidote, apatite, and zircon. Average plagioclase compositions are $An_{31}$ (core) to $An_{17}$ (rim). Myrmekite and perthite are common. Hornblende commonly altered to intergrowths of granular epidote, fibrous chlorite, and biotite. Secondary crystallization of biotite on pre-existing biotite crystals is especially prominent where biotite is adjacent to alkali feldspar. Has porphyritic borders and is strongly porphyritic near its western border. Kg3 is distinguished from Kg1 by a lack of pink alkali feldspar, by a more equigranular texture, and by a subtle decrease in the amount of biotite. Kg3 is distinguished from Kg2 by a slightly lower total mafic content and a lower ratio of hornblende to biotite

### SEDIMENTARY AND METAMORPHIC ROCKS OF THE BELT SUPERGROUP

Ym — **McNamara Formation (Middle Proterozoic)**—Upper part is mainly reddish-purple, cherty, argillaceous rock containing minor greenish argillite that forms zones 20 m (60 ft) thick interbedded with quartzite zones 20 m (60 ft) thick. Lower 215–250 m (700–800 ft) is grayish-green, fine- and medium-grained, massive-weathering feldspathic quartzite, which contains (1) lenticular beds of intraformational conglomerate composed of mud chips and silicified mud chips and (2) thin, lenticular, purple argillite beds. Channeled basal contacts, crossbedding, and ripple cross-lamination common in quartzite. Contact metamorphism varies in intensity. Approximate thickness as much as 760 m (2,500 ft) north of study area

Ybo — **Bonner Quartzite (Middle Proterozoic)**—Pinkish-buff, fine- to coarse-grained, thickly bedded, massive-weathering subarkose, quartzite, and minor argillite. Generally finer grained here than at its type locality (Nelson and Dobell, 1961), because conglomerate beds are rare. Planar and festoon crossbedding present; ripple cross-lamination abundant in fine-grained upper part. Contact metamorphism minor. Approximate thickness 610 m (2,000 ft)

**Mount Shields Formation (Middle Proterozoic)**

Yms3 — **Member three**—Rhythmically interbedded reddish-black or greenish-black argillite and greenish-gray, feldspathic, fine-grained quartzite and siltite. Most bedding units grade from medium- or fine-grained quartzite at base to silty argillite at top. Some quartzite has argillaceous matrix. Mud cracks, small-scale crossbeds, ripple cross-lamination, and shallow channels common. Contact metamorphism prevalent. Minimum thickness 520 m (1,700 ft)

Yms2 — **Member two**—Greenish-gray to pale-gray arkose, subarkose, and quartzite; dominantly medium- and fine-grained, with minor coarse-grained beds. Weathers in composite bedding units 0.5–1.0 m (1.5–3.0 ft) thick. Dispersed-pebble conglomerate common on bedding planes in upper part. Very small amounts of argillite present. Medium-scale crossbeds, ripple cross-lamination, planar lamination, parting lineation, and shallow channels common. Contact metamorphism prevalent. Minimum thickness about 2,290 m (7,500 ft)

Yms1 — **Member one**—Thick argillaceous zones alternate with thick quartzitic zones. Argillaceous zones are composed of rhythmically interbedded red argillite and tan-weathering silty, fine-sand-sized arkose, subarkose, and quartzite. Quartzitic zones are composed of composite sets of tan-weathering, well-sorted, fine-, medium-, and coarse-grained arkose, subarkose, and quartzite. Quartzitic zones increase in thickness upward and range between 1 and 100 m (3 and 300 ft) in thickness. In southeastern part of area the uppermost part of member one contains carbonate-rich beds interbedded with zones of argillaceous rocks and zones of quartzitic rocks. Carbonate-bearing rocks consist of zones of limestone, limy argillite and siltite, dolomite, sandy dolomite, sandy limestone, and dolomitic argillite and siltite. Zones of quartzite in the carbonate-rich sequence contain silica- or carbonate-cemented rocks. Mud cracks, water-expulsion structures, ripple cross-lamination, and small-scale crossbeds common in argillaceous zones and in fine-grained parts of quartzitic zones. Medium-scale crossbeds, ripple cross-lamination, lenticular pebble conglomerate beds, and planar lamination common in medium- and coarse-grained parts of quartzitic zones. In carbonate-rich beds thin, wavy lamination, ripple cross-lamination, small-scale crossbedding, edgewise conglomerate, and oncolites common. Metamorphism generally absent in eastern exposures, except near Senate Mine. Minimum thickness about 915 m (3,000 ft)

Yac — **Muscovite-biotite-quartz schist (Middle Proterozoic)**—Lepidoblastic schistose rock in which dark-colored bands containing abundant muscovite and biotite alternate with light-colored bands containing less mica and more quartz, plagioclase, and microcline. Porphyroblastic garnet and chlorite occur rarely. Detrital textures are absent; original bedding is preserved by differences in the amount of mica. Probably metamorphosed Mount Shields Formation (member one or three) or Snowslip Formation. Locally bedding is isoclinally folded. Contact metamorphism prevalent. Thickness not known

Ysn — **Snowslip Formation (Middle Proterozoic)**—Red and green argillite and argillaceous siltite; lenticular beds of very well sorted, medium- and coarse-grained orthoquartzite. Argillaceous quartzite, oolitic quartzite, and glauconitic beds present in basal part. Red and green beds contain uneven laminations, mud cracks, water-expulsion structures, ripple marks, flaser bedding, and small-scale crossbedding. Minimum thickness about 460 m (1,500 ft)

Ywm — **Wallace Formation, middle member (Middle Proterozoic)**—Tan-weathering dolomitic siltite, dolomitic sandstone, and silty dolomite interbedded with black-weathering argillite and minor, dark-gray-weathering argillaceous limestone. Siliceous siltite and siliceous quartzite common in some zones. Calcite forms pod structures and vertical-ribbon structures. Small-scale crossbedding, ripple cross-lamination, planar lamination, small-scale channels, and water-expulsion structures common. Sedimentary breccia common in western part of mapped area. Beds locally tightly folded. Contact metamorphism prevalent. Minimum thickness 1,050 m (3,500 ft)

Yh — **Helena Formation (Middle Proterozoic)**—Alternating thinly laminated beds of black limy argillite, tan limy siltite, and dark-gray argillaceous or silty limestone. Contains some dolomitic clastic beds. Calcite veinlets form vertical-ribbon structures. Ripple cross-laminations, mud cracks, and water-expulsion structures common. Present only in east part of the mapped area near Middle Fork Rock Creek, where bedding is commonly folded and sheared. Contact metamorphism minor. Thickness not known

[1]Percentages of mineral components are average values of modal analyses based on 1000 point counts per thin section. (See table 1). Feldspar compositions determined optically using flat-stage and universal-stage methods

**Contact**—Dashed where approximately located; dotted where concealed by younger deposits

**Gradational contact**—Dashed where approximately located; dotted where concealed by younger deposits. Contact is commonly gradational over a distance of 6–60 m (20–200 ft)

**Fault**—Dashed where approximately located; dotted where concealed by younger deposits. Ball and bar on downthrown side

**Thrust fault**—Dashed where approximately located; dotted with open sawteeth where concealed by younger deposits. Sawteeth on upper plate. A and T used only in cross-section D–D' to show movement away from (A) or toward (T) the reader

**Shear zone**—Zone of shear or breccia; displacement direction uncertain

**Anticline**—Showing trace of axial surface and direction of plunge; dashed where approximately located, dotted where concealed by younger deposits

**Syncline**—Showing trace of axial surface and direction of plunge, dashed where approximately located, dotted where concealed by younger deposits

**Overturned anticline**—Showing trace of axial surface and direction of plunge; dashed where approximately located. Limbs of anticline dip in direction of small arrows

**Overturned syncline**—Showing trace of axial surface and direction of plunge; dashed where approximately located. Limbs of syncline dip in direction of small arrows

**Generalized bedding trend**—Shown only on cross sections

**Strike and dip of beds**
- Inclined
- Overturned
- Vertical
- Horizontal

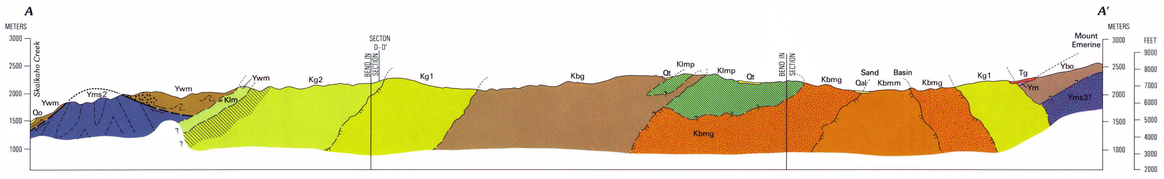
**Foliation**
- Vertical

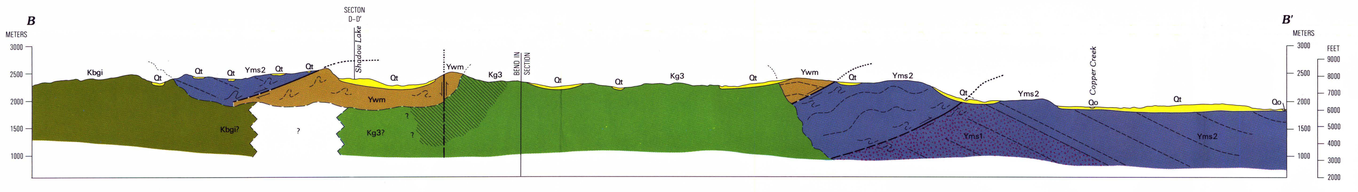
**Sedimentary breccia within middle member of the Wallace Formation**

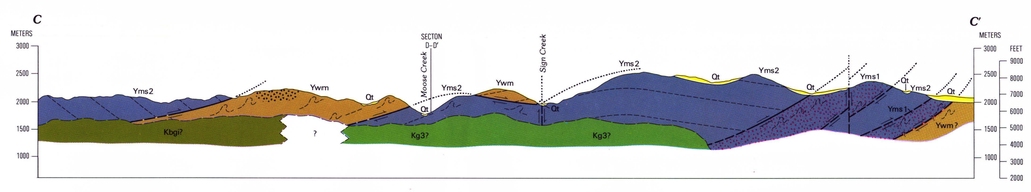
**Porphyry zone**—Approximate extent of the porphyry borders in granodiorite bodies (Kg1, Kg2 and Kg3)

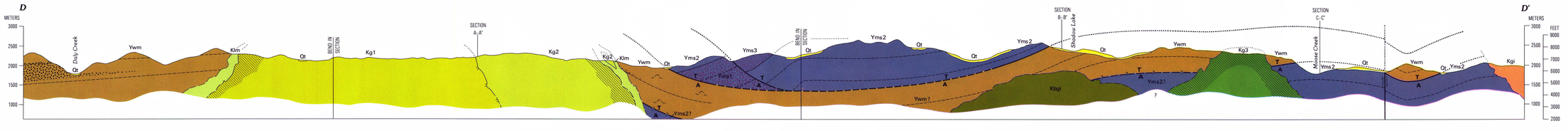
**Area of glaciated bedrock**

79-CW-40 — **Sample locality for major-element analysis or isotopic age determination, showing field number**—Data in tables 2 and 3, respectively




# GEOLOGIC MAP OF THE SOUTHERN SAPPHIRE MOUNTAINS, GRANITE AND RAVALLI COUNTIES, WESTERN MONTANA