

GEOLOGIC MAP OF THE NELSON QUADRANGLE, LEWIS AND CLARK COUNTY,  
MONTANA

By  
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2003

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Base from U.S. Geological Survey, 1962  
Polyconic projection; longitude of central meridian 111° 48' 45"  
Latitude of projection origin 46° 45' 00"  
North American Datum of 1927; 10,000-foot grid based on  
Montana coordinate system, central zone; 1,000-meter grid ticks, zone 12

Geology mapped by Mitchell W. Reynolds in July 1976, August 1977, and  
August 1988. William H. Hays assisted by William D. Quinlivan in 1959

Digital map layout and design by Gayle Dumonceaux

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CONTOUR INTERVAL 40 FEET  
NATIONAL GEODETIC VERTICAL DATUM OF 1929

**DESCRIPTION OF MAP UNITS**

[Terminology for carbonate rocks from Folk (1962)]

- Qa Alluvium (Holocene)**—Unconsolidated, stratified to unstratified sand, gravel, silt, clay, and some boulders, deposited primarily by streams; locally includes some colluvium in talus cones and alluvial fan deposits on valley sides, and gravel on low terraces in stream valleys. Thickness as much as 15 m
- Ql Landslide deposits (Holocene and Pleistocene)**—Angular rock fragments, blocks, and soil that have moved downslope as a single unit. Some large blocks bounded by arcuate faults. Superimposed generations of landslide deposits shown locally by common internal map contacts. Thickness as much as 95 m
- Qog Old gravel (Holocene and Pleistocene)**—Gravel, sand, and some silt, generally unconsolidated, stratified and unstratified; deposited by streams; clasts rounded to subrounded; at altitudes 15–75 m above recent stream channels. Thickness 1–5 m
- QTg Older gravel (Pleistocene and Pliocene)**—Gravel, sand, and some silt, unconsolidated to weakly consolidated; stratified; deposited dominantly by streams, some deposited as colluvium; clasts rounded to subrounded, subangular and angular adjacent to Soup Creek fault. Locally contains sandy tuffaceous sediment reworked from underlying Tertiary sedimentary deposits. Thickness as much as 25 m
- Ts Sandstone, conglomerate, and tuff (Miocene?)**—Lithic and feldspathic lithic sandstone, interbedded conglomerate that has well-rounded clasts as much as 17 cm across, and interbedded vitric and feldspathic vitric tuff. Locally dips east into Soup Creek fault and is commonly masked by unit of older gravel (**Qog**). Thickness as much as 75 m
- Khd Hornblende diorite (Upper Cretaceous)**—Sills and irregular intrusive bodies of hornblende diorite; dark olive gray to olive black; weather medium to light olive brown; fine to coarsely crystalline, equicrystalline. Unit is biotiferous and locally contains abundant epidote. Large intrusive bodies have altered host carbonate and shale units to hornfels. Intrusive body on the east side of Stump Gulch contains thin intrusive pods of quartz diorite; rock unit is friable on weathered outcrop. Sills 1–30 m thick
- Kk Kootenai Formation (Lower Cretaceous)**—Siltstone and silty mudstone that contains beds of lithic sandstone and lenticular beds of limestone. Siltstone and mudstone are pale grayish red to grayish red, locally olive gray, split platy to shaly; sandstone is pale grayish red and yellowish brown; limestone, pale greenish-gray to light gray. Siltstone and mudstone. Sandstone units as thick as 18 m are fine to dominantly medium and coarse grained, split platy; abundant rounded black chert grains among quartz, feldspar, and light-colored lithic grains produce a salt-and-pepper appearance. Limestone beds are laminated and very thin bedded, aphanocrystalline and very finely crystalline, silty and sandy, and locally contain small gastropods and possible algal filaments. Exposed partial thickness approximately 180 m
- Jme Morrison Formation and Ellis Group, undivided (Jurassic)**—Morrison Formation: siltstone, minor mudstone, and thin sandstone are greenish gray to grayish red; sandstone, grayish orange; discontinuous silty and clayey limestone beds contain sand grains, charatophytes, and possible algal filaments. Thickness approximately 65 m. Disconformity at base. Ellis Group, undivided, includes the Swift Formation at the top and Sawtooth Formation at the base. Swift Formation: sandstone, siltstone and discontinuous very thin basal conglomerate; light olive gray to pale brownish gray, medium and medium dark gray; splits platy and flaggy, locally shaly. Sawtooth

Formation: calcareous sandstone, sandy limestone, and lenticular calcareous pebble conglomerate containing oyster fossils at base; yellowish gray to grayish orange, weather same color; crosslaminated and laminated; splits flaggy. Ellis Group is approximately 75 m thick

**PIPpq Phosphoria and Quadrant Formations, undivided (Permian and**

**Pennsylvanian)**—Phosphoria Formation (Permian): chert, light brownish gray and medium gray, locally contains microfossils; medium-brownish-gray dolomitic limestone containing chert nodules. Generally removed by pre-Sawtooth Formation erosion; only discontinuous remnants less than 2 m thick preserved along Jme—PIPpq boundary within quadrangle. Quadrant Formation (Pennsylvanian): sandstone and sandy dolomitic limestone, very light gray and light yellowish gray; weathers yellowish gray and pale grayish orange; common quartz cement; very thin and thin laminae and cross laminae; splits platy and flaggy; forms ledges and local low cliffs. Thickness 75–105 m

**IPMab Amsden Formation and Big Snowy Group, undivided (Pennsylvanian and Upper**

**Mississippian)**—Amsden Formation (Pennsylvanian): Sandstone and interbedded silty mudstone: grayish red and light-reddish brown; interbedded pinkish-gray limestone and sandstone at top; limestone-pebble conglomerate at base; rests unconformably on underlying rocks of the Big Snowy Group. Thickness 78–100 m. Big Snowy Group (Upper Mississippian): in upper part, mudstone and silty mudstone that contains thin beds of sandy limestone and dolostone; medium light gray to medium dark gray and dark olive gray; limestone beds are yellowish gray, weather pale grayish orange; limestone beds contain crinoid columnals and brachiopod fragments. In middle part, silty mudstone and very thin limestone, dolostone, and sparse dolomitic sandstone beds; mudstone is pale-greenish gray to olive gray; limestone, dolostone, and sandstone are light brownish gray to olive gray; laminated and very thin bedded; split shaly and flaggy. In lower part, siltstone, sandy siltstone, and limestone, with limestone and dolostone breccia at base; yellowish gray; pale-grayish red and grayish red calcareous siltstone interbeds; subangular pebbles and fragments of underlying Mississippian rocks in basal part; sandy limestone beds are locally stromatolitic. Group is 165–185 m thick

**Mm Mission Canyon Limestone (Upper and Lower Mississippian)**—Limestone, medium light to medium dark gray and light olive gray; weathers light gray, very light gray, and white; locally dolomitic; scattered nodules of brownish-gray chert; generally recrystallized and fractured; coarsely crystalline; pressure solution surfaces common; columns and pods of collapse breccia present in upper third; thin bedded with local thin sets of cross-laminae; splits thick or massive; limestone pellets and fragments, crinoid, brachiopod, and coral fossils and fossil fragments and oolites visible locally; thin bedded, local current cross-bedding; forms cliffs or rugged slopes. Thickness 290–530 m; variable as a result of deformation and dissolution

**MI Lodgepole Limestone (Lower Mississippian)**—Limestone and interbedded silty limestone and highly calcareous siltstone; medium light to medium dark gray, light brownish gray to yellowish gray; weathers light gray, very light gray, and white, and moderate orange pink to pale yellowish orange in silty intervals; laminated and very thin bedded; fine- to medium-crystalline biosparite, oosparite, and intrasparite limestone; splits platy, shaly, and flaggy, with intervals of thick beds near center that split slabby; contains abundant fossils including brachiopods, crinoid fragments, bryozoa, corals, rare trilobite fragments, and trace fossils, including unidentified burrows, scattered *Scalerotuba* in lower part and rare *Zoophycus* in upper half. Thickness 215–285 m; variable as a result of deformation and dissolution

- MDt Three Forks Formation (Mississippian and Devonian)**—Includes Cottonwood Canyon Member of Lodgepole Limestone at top: carbonaceous mudstone brownish black to grayish black; weathers pale yellowish brown and very pale orange. Three Forks Formation: silty dolostone, calcareous siltstone, limestone, and mudstone; medium olive gray and olive gray; weather pale grayish orange, grayish orange, and pale olive; contains intervals of calcareous mudstone, medium light gray, and carbonaceous silty mudstone, olive black to brownish gray. In lower part, limestone and calcareous siltstone are medium brownish gray; weather yellowish gray, pale orange pink, and light brown. Local thin lenses of solution-collapse limestone breccia at base. Limestone beds in upper part contain common brachiopods and crinoid columnals, some oncolites, and trace fossils, including *Scalerotuba* and unidentified smooth-walled small burrows. High total organic content within brownish- and grayish-black mudstone units. Splits shaly and flaggy; commonly covered by debris from overlying formation. Thickness variable as a result of deformation, 38–67 m
- Djb Jefferson Formation (Devonian)**—Dolostone, light- and medium- to medium-dark brownish gray, locally medium gray; weathers medium brownish gray, pale yellowish brown, and yellowish gray; fine- to medium-crystalline; strong petroliferous fetid odor on fresh surface; local wavy crosslaminae, but generally structureless; thin beds of pelletoid limestone; rare very thin beds of dolomitic sandstone; contains lenses of brachiopod and trilobite(?) fragments and very thin intervals of stromatoporoid algae. Splits flaggy and blocky. Birdbear Member (Djb) mapped at top of formation in western part of map area: limestone, medium- and medium-dark gray; weathers very light gray and white; forms white ledges or low cliff at top of formation. Formation thickness variable as a result of deformation and dissolution, 165–190 m; Birdbear Member 20–28 m thick
- Dm Maywood Formation (Upper and Middle Devonian)**—Dolostone, light gray, yellowish gray and light brownish gray; weathers very pale orange and pale grayish orange; very thin intervals of dolomitic siltstone and sandy dolostone; laminated, wavy laminated and thin bedded; a few laminae contain halite crystal casts; splits platy and flaggy. At base includes discontinuous unit as thick as 6 m of thin beds and laminae of silty dolostone that contain siltstone partings and very thin limestone and dolostone beds; grayish red and greenish gray; weather yellowish gray and grayish red; lenticular beds contain pebbles reworked from underlying Upper Cambrian beds and probable fish(?) bone fragments. As mapped in steep exposures, locally includes some beds of Late Cambrian age. Total thickness 16–23 m
- €pp Pilgrim Formation and Park Shale, undivided (Upper and Middle Cambrian)**—Pilgrim Formation (Upper Cambrian) forms upper part: pebbly limestone and silty limestone, light gray to light olive gray, weathers light gray, pale grayish orange, and grayish orange; interbedded silty claystone and claystone, light olive gray, olive gray, weather light olive, dusky yellow green and grayish green; pebbly limestone and limestone beds 0.3–2 m thick; silty claystone and claystone intervals 0.1–5 m thick. Limestone is biopelsparite, containing common to abundant trilobite fragments, pelmatozoan fragments, small chitinous brachiopods, ooliths and pellets, and glauconite pellets in sparry calcite matrix. Flat pebbles of laminated aphanocrystalline to silty fossiliferous limestone, 1–8 cm in largest dimension, are subrounded to rounded and are generally supported at high angles to bedding in silty, biopelsparite matrix. Claystone and silty claystone are very thinly laminated; split fissile and platy. Park Shale (Middle Cambrian) forms lower part: silty claystone and claystone, sparse very thin channels filled with pebbly biosparite limestone; light olive gray and light olive; weathers olive gray and grayish green; fissile and platy. Total thickness of mapped unit varies as a result of

strong deformation in claystone and silty claystone intervals and lenticularity of pebbly limestone beds; generally 145–190 m thick

- €m **Meagher Limestone (Middle Cambrian)**—Limestone, medium gray, medium dark gray, and medium brownish gray, weathers medium light gray; common grayish-orange, moderate-brown, and pale-grayish-red silty mottles, particularly in basal 30 m and in upper 50 m. Finely crystalline limestone with channels and beds of medium to coarsely crystalline biosparite and biopelsparite limestone. Discontinuous wavy laminae and beds 0.2–4 cm thick, with discontinuous silty limestone partings; weathers with knobby, locally chicken-wire texture, especially in the lowest quarter and uppermost part; forms steep slopes or low cliff. Contains abundant small trilobite fragments, some pelmatozoan(?) plates, and sparse chitinous brachiopod fragments. Thickness about 110 m, but as much as 177 m, likely as a result of deformation
- €w **Wolsey Shale (Middle Cambrian)**—Silty mudstone and siltstone, light olive to light grayish green, locally olive black; weathers light olive gray, dusky yellow gray, and grayish red. Thin beds of silty sandstone, pale grayish red, are interbedded in olive green siltstone in basal 5 m. Interval of medium-gray and medium-brownish-gray limestone, 3 m thick, is present about 60 m above base; weathers grayish red, brownish gray, and medium light gray; limestone is medium to coarsely crystalline sandy biosparite, with sparse to abundant pellets of glauconite; fossils are trilobite, brachiopod, and pelmatozoan(?) fragments. Limestone laminae, 0.2–3 cm thick, are scattered throughout the siltstone. In top 30 m is light-gray to light-greenish-gray limestone; weathers pale yellowish brown to grayish orange; trilobite biosparite; some greenish-gray siltstone chips on parting surfaces. Siltstone in lower third contains scattered *Cruziana* and annelid(?) trace fossils. Strata split shaly and platy; limestone is platy and flaggy. Numerous hornblende diorite sills intrude the Wolsey in the upper plate of the Moors Mountain thrust, but only one sill was identified in the unit in underlying plates. Apparent thickness varies as a result of local intrusion of mafic sills and local strong internal deformation; approximately 65 m thick in south-central part of quadrangle to 245 m thick in northeast part
- €f **Flathead Sandstone (Middle Cambrian)**—Sandstone and pebbly sandstone, that contains very thin siltstone beds at top: pinkish gray, yellowish gray, and very pale red; weathers pale reddish brown, yellowish gray, and light brownish gray; siltstone beds at top are greenish gray and light olive gray, weather greenish gray. Sandstone is fine to coarse grained; contains locally abundant pebbles as large as 2 cm across. Grains and pebbles are quartz, quartzite, red and gray siliceous siltite and chert, and minor feldspar; grains generally well rounded but modified by pressure solution and quartz overgrowths; weakly to firmly indurated; common to abundant glauconite grains in uppermost 12 m; cross-laminae to very thin beds; herringbone cross-bedding near base and in top 15 m; thin sets of trough cross-laminae common; ripple laminae in upper part; splits flaggy and slabby, locally platy; forms resistant ledges and ridge. Thickness 80–140 m
- Ys **Spokane Formation (Belt Supergroup, Middle Proterozoic)**—Siltite and argillite, pale red and moderate reddish brown, weathers moderate reddish brown, grayish red, and dusky red; laminated and very thin bedded, cross-laminated, locally ripple cross-laminated; dominantly silt and clay on partings surfaces; locally common ripup clasts and fluid escape structures; scattered lenses of fine-grained quartz sandstone as thick as 6 cm; beds of sandy limestone and rare stromatolitic limestone 20–35 cm thick interbedded with greenish-gray siltite in basal 45 m. Formation is truncated north across the Beaver Creek area in the upper plate of the Moors Mountain thrust plate and absent in lower

thrust plates as a result of Upper Proterozoic-pre-Middle Cambrian erosion. Thickness 0-865 m

**Yg Yg Greyson Formation (Belt Supergroup, Middle Proterozoic)**—In upper plate of Moors Mountain thrust fault: olive gray, light greenish gray, and medium olive to medium dark gray; weathers greenish gray, pale olive, dusky yellow, and pale yellowish brown; even parallel laminae, discontinuous wavy laminae, and cross-laminae; contains very thin beds of silty fine-grained quartzite, and in lower and upper middle parts, thin concretionary lenses of dolomitic and calcareous siltite; splits shaly and platy. In lower plate of Moors Mountain fault and upper plate of Hogback Mountain fault (secs. 1 and 12, T. 12 N., R. 2 W.; secs 6 and 7, T. 12 N., R. 1 W., and SE<sup>1</sup>/<sub>4</sub>SE<sup>1</sup>/<sub>4</sub> sec. 20, T. 13 N., R. 1 W.): medium-gray and medium-dark-gray to dark-gray siltite and argillitic siltite, scattered lenses of brownish-gray very fine grained quartzite; weathers olive gray, dark greenish gray and olive black; even parallel and discontinuous wavy parallel laminae; very thin sets of graded laminae; cut by thin quartz veins; local intense small- and intermediate-scale folding associated with thrusting; splits shaly and platy. Formation truncated downward by Upper Proterozoic-pre-Middle Cambrian erosion from south to north on upper plate of Moors Mountain fault; only middle part of the formation exposed beneath Middle Cambrian rocks in the lower plate of the Moors Mountain fault and upper plate of the Hogback Mountain fault. Thickness about 1,070–2,000 m

**Yn Newland Formation (Belt Supergroup, Middle Proterozoic)**—Calcareous and dolomitic silty argillite and argillitic siltite that contains limestone and rare arkosic sandstone intervals in uppermost part. Silty argillite and argillitic siltite are medium gray and medium dark gray, weather pale grayish orange and grayish orange; very thin even parallel laminated producing a varvelike appearance on weathered surface; local very thin low-angle inclined laminae. Limestone is medium light gray and medium gray, weathers light and medium light gray; aphanocrystalline and very finely crystalline, locally silty; sparry calcite ribbons along some curved surfaces; scattered to common coarse calcite fills fracture cleavage; beds locally highly contorted 0–800 m from Moors Mountain fault. Intervals of limestone beds 0.5–5 m thick. Arkosic sandstone is grayish orange pink, weathers very pale orange and light brown; fine to medium grained, local coarse grains and granules; clasts of quartz, microcline feldspar, polycrystalline quartz, and rare laminated limestone; beds range from structureless to low-angle cross laminated; local internal slump structures; beds 0.04–0.3 m thick. Lower exposed part of formation splits shaly and platy and forms steep slopes; upper part splits shaly; limestone splits platy to slabby, and forms ledges on steep slopes and ridge crest. Formation structurally truncated from top downward by Moors Mountain fault. Thickness 0–620 m

**Contact**—Dashed where approximately located, short dashed where inferred, dotted where concealed

**Fault**—Dashed where approximately located; short dashed where inferred; dotted where concealed. U and D show upthrown and downthrown sides of fault; arrows show relative direction of movement on oblique-slip fault. On oblique-slip fault in cross section B–B', T shows relative movement toward observer, A away from observer

**Thrust fault**—Dashed where approximately located; short dashed where inferred; dotted where concealed. Sawteeth on upper plate. In cross sections, arrow shows relative direction of displacement; A, movement away from observer; T, movement towards observer; T with arrow indicates oblique movement towards observer

**Overtaken thrust fault**—Base of sawteeth on upper plate of Hogback Mountain thrust fault in SE<sup>1</sup>/<sub>4</sub> sec. 20, T. 13 N., R. 1 W. Dashed where approximately located. In cross sections, arrow shows relative direction of displacement

**Anticline**—Showing trace of axial surface and direction of plunge of axis. Dashed where approximately located; short dashed where inferred; dotted where concealed

**Asymmetric anticline**—Showing trace of axial surface and direction of plunge of axis. Short arrow indicates steeper limb. Dashed where approximately located; short dashed where inferred; dotted where concealed

**Overtured anticline**—Showing trace of axial surface, direction of dip of limbs, and direction of plunge of axis. Dashed where approximately located; short dashed where inferred; dotted where concealed

**Syncline**—Showing trace of axial surface and direction of plunge of axis. Dashed where approximately located; short dashed where inferred; dotted where concealed

**Asymmetric syncline**—Showing trace of axial surface and direction of plunge of axis. Short arrow indicates steeper limb. Dashed where approximately located; short dashed where inferred; dotted where concealed

**Overtured syncline**—Showing trace of axial surface, direction of dip of limbs, and direction of plunge of axis. Dashed where approximately located; short dashed where inferred; dotted where concealed

**Inverted syncline**—Beds in both limbs are overtured and dip away from the trace of the axial surface shown. Dashed where approximately located

**Strike and dip of bedding**—In areas of complex structure, ball on end of strike line shows top of beds determined from sedimentary features

**Inclined**

**Overtured**

**Overtured more than 180°**

**Vertical**

**Inclined and crenulated beds**—Showing approximate strike and dip

**Strike and dip of cleavage**—Combined with symbol for strike and dip of bedding at coincident site of measurement

**Inclined**

**Vertical**

**Minor vein**—Showing strike

**Minor vein**—Showing strike and vertical dip

**Quartz**—Mineral in veins, or mineral extracted from shafts, adits, and prospects

**Minor anticline**—Showing bearing and plunge

**Minor crenulated beds**—showing form

**Lineation**—Showing bearing and plunge

**Inclined adit**

**Vertical mine shaft**—Abandoned

**Prospect**

**Outcrop of unit Ts too small to show at map scale**—Includes some float indicative of formation underlying slope covered by unit QTg

**Spring**

## GEOLOGIC SETTING

The Nelson quadrangle is near the north end of the Big Belt Mountains in west-central Montana, about 30 km northeast of the capital city of Helena (fig. 1). The Big Belt Mountains rise as a north-northwest-trending range between the Smith River valley on the east and the Helena valley on the west. The Missouri River flows through a narrow canyon and valley incised through the northwest edge of the

mountains. Northwest of the Nelson quadrangle, the canyon of the Missouri River was named the Gates of the Rocky Mountains by Lewis and Clark in 1805.

The Big Belt Mountains strike across two prominent west-northwest-trending elements: the north end of the Helena valley on the west, and the south margin of the Dry Range and Little Belt Mountains on the east (fig. 1). The north edge of Helena valley marks a strand of a major tectonic zone, the Lewis and Clark Line, a zone of recurrent major strike-slip and vertical fault movement through geologic time (Billingsley and Locke, 1939; Hobbs and others, 1965; Harrison and Reynolds, 1976; Reynolds, 1977, 1979; Reynolds and Kleinkopf, 1977). Similarly, the south flank of the Little Belt Mountains and Dry Range is a zone of recurrent faulting that occurred from Middle Proterozoic to at least middle Miocene time. The zone is likely contiguous in the basement with the Lewis and Clark line. Thus, the Nelson quadrangle occupies a geologically significant position at the junction between the Big Belt Mountains and major cross-trending tectonic elements.

Rocks of the Nelson quadrangle are predominantly sedimentary strata that range in age from Middle Proterozoic (about 1,400 million years) to Recent. Pre-Tertiary (pre-66 million years) rocks are mostly marine in origin (refer to Description of Map Units). However, some strata, such as the Middle Proterozoic Spokane Formation, parts of the Middle Cambrian Flathead Sandstone, and some Upper Devonian, Upper Mississippian Big Snowy, Pennsylvanian Amsden, Jurassic Morrison, and Lower Cretaceous Kootenai strata, originated in nonmarine continental environments. Tertiary and Quaternary deposits accumulated on alluvial plains and as fan, talus, and landslide deposits on steep mountain slopes. Beds of air-fall and weakly indurated ash-flow volcanic tuff of possible Miocene(?) age (24–26 million years) are present in the Tertiary strata.

Igneous intrusive rocks of Late Cretaceous age [about 68–73 million years ago] intrude Middle Proterozoic through Devonian rocks. On the upper plate of the Moors Mountain thrust fault in Big Log and Left Fork Gulches (secs. 3 and 4, T. 12 N., R. 2 W., and sec. 34, T. 13 N., R. 2 W.), small plutons intrude the Cambrian and Devonian strata (geologic section A–A') along and adjacent to strike-slip faults that displace strata within the upper plate. Thin sills extend laterally north and south from the plutons into the same host rocks, but are most abundant in shaly and very thin bedded units such as the Wolsey Shale (geologic sections A–A', B–B'). Structurally low thrust plates contain few sills (sec. 31, T. 13 N., R. 1 W., sec. 36; T. 13 N., R. 2 W., and sec. 1, T. 12 N., R. 2 W.; geologic section A–A').

Several notable stratigraphic and structural-stratigraphic changes are present in the Nelson quadrangle: (1) North across the quadrangle, the Middle Proterozoic Spokane Formation thins rapidly beneath the Middle Cambrian Flathead Sandstone from about 865 m at the south edge of the quadrangle to a wedge edge north of Beaver Creek in sec. 3, T. 12 N., R. 2 W. North and northeast of that area, the underlying upper part of the Greyson Formation is also truncated from its top downward beneath the Flathead Sandstone. The thinning results from Late Proterozoic (post 825 million years ago) to pre-Middle Cambrian (pre-Flathead, estimated 540 million years ago) uplift and erosion across a west-trending arch, probably areally coincident with the general west-northwest trend of the Lewis and Clark line (fig. 1; Reynolds, 1977; Reynolds and Kleinkopf, 1977). Such thinning is not evident in the Spokane Formation of the structurally higher and more westerly Eldorado thrust plate (fig. 2; Robinson and others, 1969; Robinson and McCallum, 1991). (2) The Middle Cambrian Flathead Sandstone and Wolsey Shale thicken from Soup Creek, near the southeast corner of the quadrangle, northward, independent of the thickening by intrusion of the Upper Cretaceous sills. (3) The Permian Phosphoria Formation is mostly removed by erosion from this quadrangle, from the Upper Holter Lake quadrangle adjacent on the west (Robinson and others, 1969), and from quadrangles to the east. (4) In secs. 7, 8, T. 12 N., R. 1 W., and sec. 12, T. 12 N., R. 2 W., the Moors Mountain fault cuts abruptly upward through, and structurally truncates, the Middle Proterozoic Newland Formation and the overlying lower part of the Greyson Formation. From the south-central part of the Hogback Mountain quadrangle (Reynolds, 1999), adjacent on the east to the Nelson quadrangle, the Moors Mountain fault cuts north and west up through nearly 2,800 m of the Newland Formation and 1,100 m of Greyson Formation. This structurally truncated edge of the Newland Formation in the Nelson Quadrangle is the most northerly and westerly known exposure of the Newland in the

overthrust belt of Montana. The position of this structural truncation coincides with the stratigraphically higher, but older, truncation of the Spokane Formation and the trend of the Lewis and Clark Line (fig. 1).

The geologic structure of the Nelson quadrangle is complex. Three principal structural plates, each deformed internally, are exposed at the surface in the quadrangle (fig. 2). The structurally lowest plate, here called the Avalanche Butte plate (fig. 2), is exposed east from Nelson in the canyon of Beaver Creek and on adjacent mountain ridges. This lowest plate is a complex sequence of recumbent anticlines and synclines that trend northwest near the east edge of the quadrangle and are deformed to west-northwest trends in the east-central part of the quadrangle. The folds are generally overfolded northeast and are locally folded, in turn, about east-trending axes (Checkerboard Creek area, south of Beaver Creek; geologic sections *A-A'*, *B-B'*, and *D-D'*). A series of folded thrust faults in the upper part of the Avalanche Butte plate contains folded fault duplexes. The folded thrust faults repeat carbonate strata of the Mississippian Mission Canyon Limestone and Lodgepole Limestone. Devonian strata are folded recumbently in the core of one duplex (N1/2 sec. 32, NE1/4 sec. 31, and SE1/4 sec. 30, T. 13 N., R. 1 W.; geologic sections *A-A'* and *D-D'*). About 20 km east-southeast of the Nelson quadrangle (fig. 2), Middle Precambrian strata are exposed at the surface up-plunge along strike in the core of the Avalanche Butte structural plate.

The intermediate structural plate in the Nelson quadrangle is bounded below by the overturned Hogback Mountain thrust fault (E1/2 SE1/4 sec. 20, T. 13 N., R. 1 W.; geologic section *D-D'*). Both in the Nelson quadrangle and continuously for about 19 km to the southeast (fig. 2), recumbently folded siltite and argillite strata of the Greyson Formation rest along the folded thrust fault on the sequence of fault duplexes of the Avalanche Butte structural plate. From near Sawtooth Mountain on the north (NE1/4 sec. 36, T. 13 N., R. 2 W.; geologic section *A-A'*), to the Moors Mountain fault southeast of Nelson, recumbently folded Greyson strata and overlying Paleozoic rocks form the lowest exposed part of the upper plate of the Hogback Mountain thrust fault (fig. 2). Although it now occupies an intermediate structural position, the Hogback Mountain and associated faults likely formed before the Avalanche Butte fault duplexes. However, the Hogback Mountain and associated faults are older than, and are clearly truncated by, the structurally higher Moors Mountain thrust fault (SE1/4 sec. 20, T. 13 N., R. 1 W., and N1/2 sec. 8, T. 12 N., R. 1 W.; fig. 2; geologic sections *A-A'*, *B-B'*, and *D-D'*).

The Moors Mountain fault forms the sole of the highest structural plate. Along the fault, Middle Proterozoic strata of the Newland and Greyson Formations are thrust over all lower structural plates. The stratigraphic succession on the Moors Mountain plate is generally tilted uniformly southwest along the western half of the Nelson quadrangle. In lower Beaver Creek and Big Log Gulch, east-southeast- and east-trending high-angle faults, which have dominant strike-slip movement, offset the uniformly dipping Paleozoic strata and some Middle Proterozoic strata but do not displace the basal thrust fault. In the southwest corner of the quadrangle, Mississippian and younger rocks are faulted over folded Mississippian and older rocks on an unnamed thrust fault system (geologic section *C-C'*).

Rocks of the Moors Mountain plate rest on a major lateral structural ramp, formed by the structural high of the deformed Hogback Mountain and Avalanche Butte structural plates (geologic sections *A-A'* through *D-D'*). The lateral ramp seems to trend and plunge west and has structural relief of at least 3,000 m. Based on the geometry of the folded lower plate, erosional reentrants in the edge of the thrust plate, and extent of a klippen of the Moors Mountain fault east of the Nelson quadrangle, the horizontal displacement on the fault is at least 45 km (fig. 2; Reynolds, unpublished mapping, 1976-78). West and northwest of the Nelson quadrangle in the Upper Holter Lake and Beartooth Mountain quadrangles, respectively, rocks of the Middle Proterozoic Greyson and Spokane Formations on the Eldorado fault are part of the structurally highest plate in the area. The Eldorado plate rests on strongly deformed Mesozoic and Paleozoic rocks in the upper part of the Moors Mountain plate (fig. 2).

The youngest principal structure in the Nelson quadrangle is the Soup Creek fault (geologic sections *A-A'* through *D-D'*). Along the fault, pre-Miocene(?) strata of the Moors Mountain plate are faulted down on the west. Overlying Miocene(?) beds are tilted as much as 8° east into the fault. The coincidence of the trace of the Soup Creek fault with a reentrant in the Moors Mountain fault suggests that the Soup Creek fault flattens at depth to merge with the Moors Mountain fault. The age of the faulting is Miocene(?) and

Pliocene, and the fault is interpreted as a basin-range fault associated with extension in and along the transform fault zone of the Lewis and Clark Line during middle and late Cenozoic time (Reynolds, 1977, 1979; Reynolds and Kleinkopf, 1977).

#### REFERENCES CITED

- Billingsley, P.R., and Locke, Augustus, 1939, Structure of ore deposits in the continental framework: New York, American Institute of Mining and Metallurgical Engineers, 51 p.
- Folk, R. L., 1962, Spectral subdivision of limestone types, *in* Ham, W. E., ed., Classification of carbonate rocks—A symposium: American Association of Petroleum Geologists, Memoir 1, p. 62–84.
- Harrison, J.E., and Reynolds, M.W., 1976, Western U.S. continental margin—A stable platform dominated by vertical tectonics in the late Precambrian [abs.]: Geological Society of America Abstracts with Programs, v. 8, no. 6, p. 905.
- Hobbs, S.W., Griggs, A.B., Wallace, R.E., and Campbell, A.B., 1965, Geology of the Coeur d'Alene District, Shoshone County, Idaho: U.S. Geological Survey Professional Paper 478, 139 p.
- Reynolds, M.W., 1977, Character and significance of deformation at the east end of the Lewis and Clark line, Montana [abs.]: Geological Society of America Abstracts with Programs, v. 9, no. 6, p. 758–759.
- Reynolds, M.W., 1979, Character and extent of basin-range faulting, western Montana and east-central Idaho, *in* Newman, G. W., and Goode, H. D., eds., RMAG and UGA 1979 Basin and Range Symposium: Denver, Colorado, Rocky Mountain Association of Geologists, p. 185–193.
- Reynolds, M.W., and Kleinkopf, M.D., 1977, The Lewis and Clark line, Montana-Idaho—A major intraplate tectonic boundary [abs.]: Geological Society of America Abstracts with Programs, v. 9, no. 7, p. 1140–1141.
- Robinson, G.D., and McCallum, M.E., 1991, Preliminary geologic map of the Beartooth Mountain quadrangle, Lewis and Clark County, Montana: U.S. Geological Survey Open-File Report 91–113, scale 1:24,000.
- Robinson, G.D., McCallum, M.E., and Hays, W.H., 1969, Geologic map of the Upper Holter Lake quadrangle, Lewis and Clark County, Montana: U.S. Geological Survey Geologic Quadrangle Map GQ–840, scale 1:24,000