U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

GEOLOGIC MAP OF THE ANACONDA-PINTLAR WILDERNESS AND CONTIGUOUS ROADLESS AREA, GRANITE, DEER LODGE, BEAVERHEAD, AND RAVALLI COUNTIES, WESTERN MONTANA

By

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STUDIES RELATED TO WILDERNESS

The Wilderness Act (Public Law 88-577, September 3, 1964) and related acts require the U.S. Geological Survey and the U.S. Bureau of Mines to survey certain areas on Federal lands to determine their mineral resource potential. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a geologic survey of the Anaconda-Pintlar Wilderness Area and contiguous roadless area (Rare II no. 1-001B) in the Beaverhead, Bitterroot, and Deer Lodge National Forests, Granite, Deer Lodge, Beaverhead, and Ravalli Counties, Montana. The area was established as a wilderness by Public Law (88-577, 1979). The contiguous roadless area was recommended for wildernesss designation during the Second Roadless Area Review and Evaluation (RARE II) by the U.S. Forest Service, January 1979.

INTRODUCTION

The Anaconda-Pintlar Wilderness and Contiguous Roadless Area (referred to in this report as the Anaconda-Pintlar Wilderness Area or wilderness) encompasses about 250 sq mi (650 sq km) of the Anaconda Range, which straddles the Continental Divide in southwestern Montana (fig. 1). The Anaconda-Pintlar Wilderness Area is approximately 35 mi (55 km) long and about 10 mi (16 km) wide. The wilderness trends northeast and the northeastern boundary of the wilderness is about 30 mi (48 km) west of Butte, Montana. The Flint Creek Range adjoins the Anaconda Range on its northeastern flank, and the Sapphire and John Long Mountains merge into the Anaconda Range at its northwestern flank (fig. 2). The towering peaks and deeply cut valleys of the Anaconda Range are bordered by the Big Hole Valley on the south (fig. 2).

GEOLOGIC SETTING

Rocks of the Anaconda-Pintlar Wilderness Area are mainly Middle Proterozoic and Paleozoic sedimentary formations and Late Cretaceous and early Tertiary plutonic rocks. Middle Proterozoic rocks of the middle and upper parts of the Belt Supergroup and Middle Cambrian to Permian rocks are metamorphosed where they are proximal to stocks and batholiths. In most of the Anaconda-Pintlar Wilderness Area, sedimentary rocks are metamorphosed to medium- and high-grade metamorphic rocks that contain sillimanite, garnet, and pyroxene adjacent to stocks and batholiths, but along the northern border of the wilderness the rocks are slightly metamorphosed. Most large bodies of intrusive rocks are confined to the central and southern part of the Anaconda-Pintlar Wilderness Area. Granodiorite and monzogranite bodies comprise 9 stocks and 2 batholiths. At the west end of the Anaconda Range, Late Cretaceous plutonic rocks are part of the easternmost extension of the Idaho batholith. In the central, southern, and northeastern parts of the Range, isotopically dated plutonic rocks are principally early and middle Eocene and belong to the plutonic suite in the Anaconda Range. The ages of some granodiorite and monzogranite stocks in the plutonic suite have not been determined, but geologic relations suggest that these stocks are probably Late Cretaceous or early Tertiary in age. Dikes and sills, which range from andesite to rhyolite in composition, are common throughout the map area. Granodiorite, dacite, and andesite dikes and sills probably range from Late Cretaceous to middle Eocene, whereas rhyolite dikes are middle Eocene, and represent the youngest intrusive event in the Anaconda Range. Tertiary sedimentary rocks occur mainly along the south flank of the range, where fluvial deposits (Ts) of probable late Oligocene(?) and Miocene age are faulted against plutonic rocks. Gravel deposits (Tg) of probable Pliocene age overlap older Tertiary sedimentary rocks and igneous rocks of the plutonic suite. Quaternary deposits (Qt and Qo) are mainly of glacial origin; Holocene alluvial deposits (Qal) occur in glacial valleys, but they are confined to modern underfit stream channels.

The structures in the Anaconda-Pintlar Wilderness Area are dominated by deformed thrust faults that bound sheets of rock, northerly trending folds, younger zones of imbricate thrusts, and northeast- and north-trending high-angle faults. The sheet-like thrusts, which are called sheet thrusts in this report, are the oldest identified structures in the map area. These faults are the Georgetown, East Fork, and Cutaway thrust faults and local sheet-like thrusts branch from them. Zones of imbricate thrust faults cut and refolded earlier-formed folds and thrusts. Steeply dipping faults generally show northeast trends in the south and central parts of the range, and northerly trends along the north flank of the range. These high-angle faults were active after thrust faulting because they offset the thrust faults, folds, and Late Cretaceous to Eocene stocks. Some steep faults were intruded by middle Eocene rhyolite dikes (Tr), which were later sheared. The most prominent steep faults are the

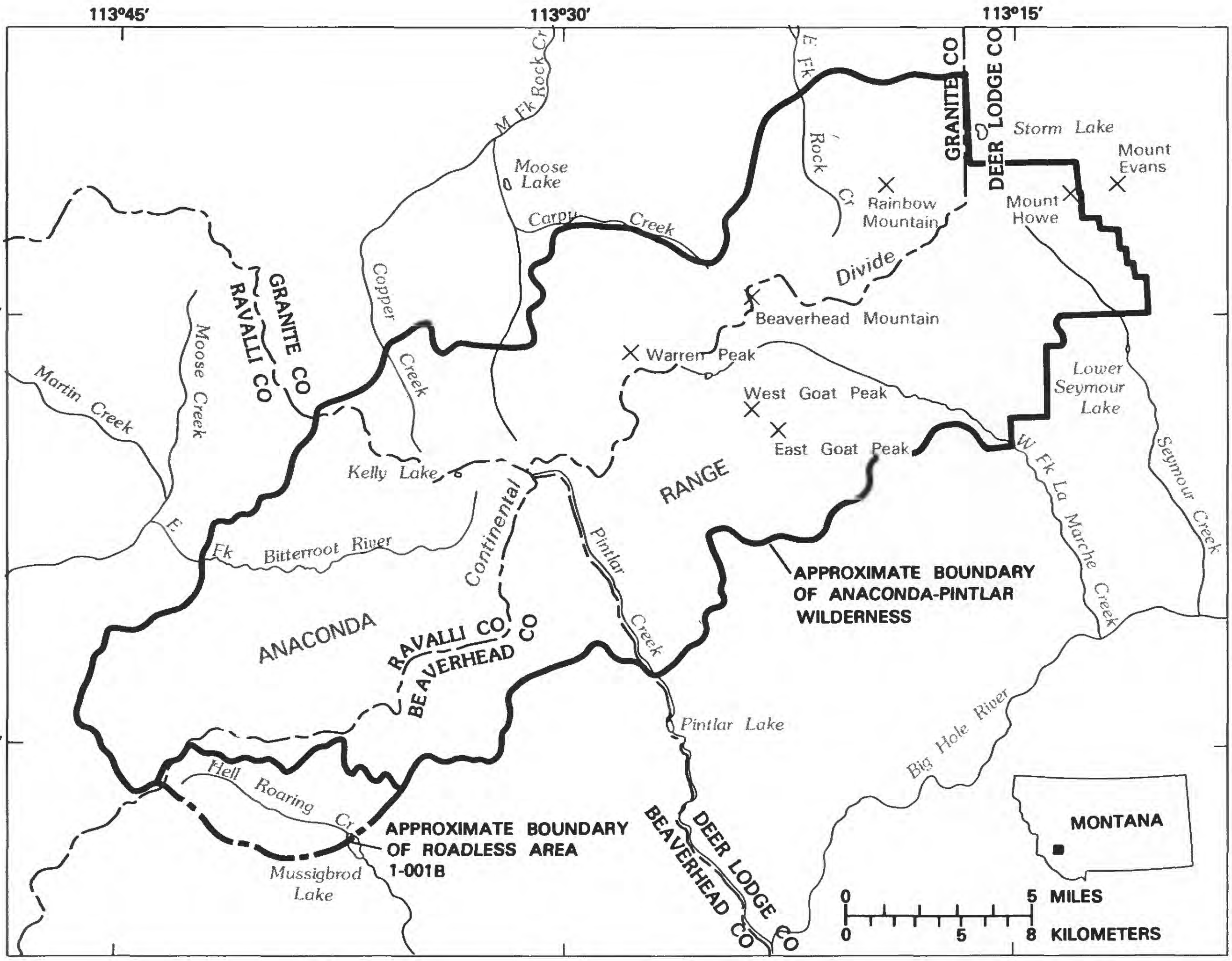
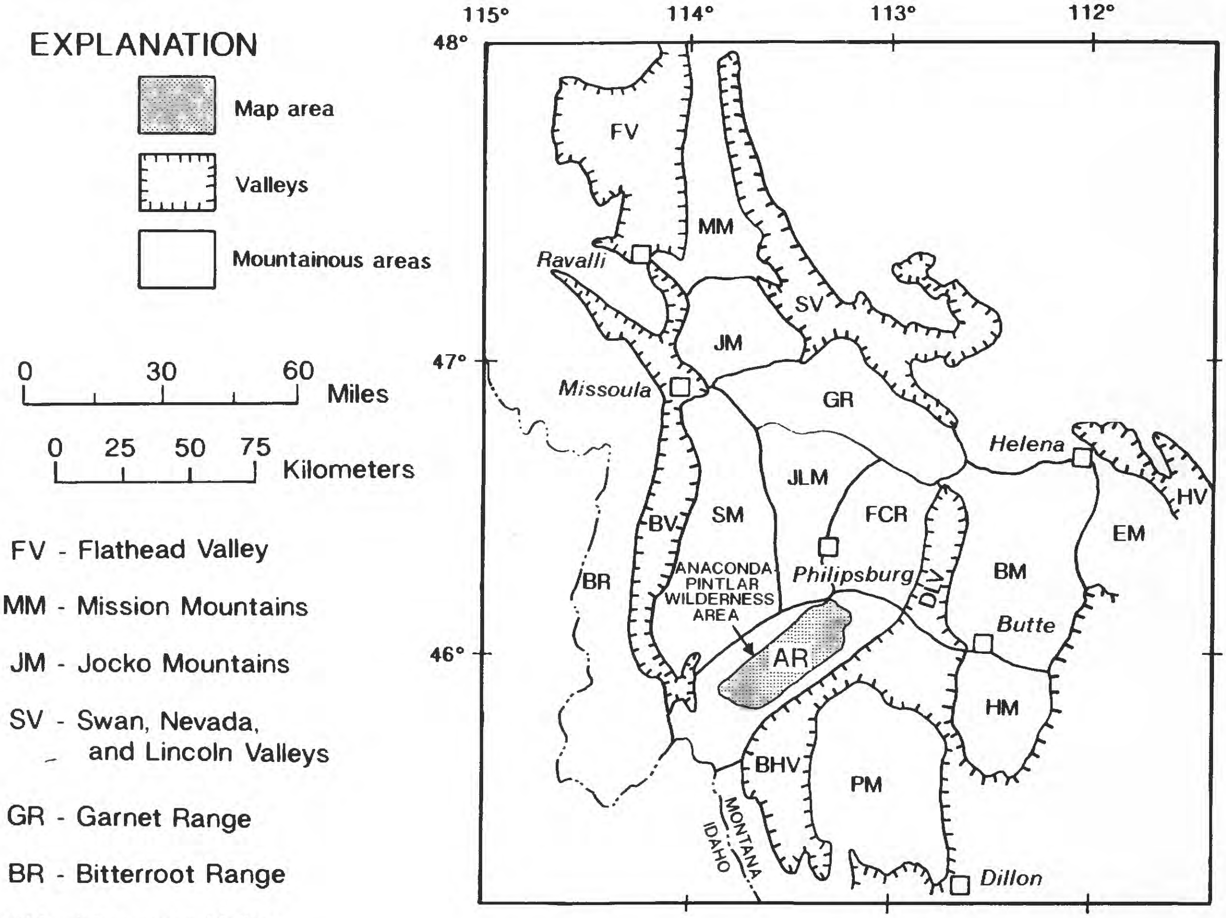


Figure 1.--Index map showing location of the Anaconda-Pintlar Wilderness and contiguous roadless area, Granite, Deer Lodge, Beaverhead, and Ravalli Counties, Montana.



FV - Flathead Valley

MM - Mission Mountains

JM - Jocko Mountains

SV - Swan, Nevada, and Lincoln Valleys

GR - Garnet Range

BR - Bitterroot Range

BV - Bitterroot Valley

SM - Sapphire Mountains

JLM - John Long Mountains

FCR - Flint Creek Range

PM - Pioneer Mountains

DLV - Deer Lodge Valley

BM - Boulder Mountains

EM - Elkhorn Mountains

HV - Helena Valley

HM - Highland Mountains

AR - Anaconda Range

BHV - Big Hole Valley

Figure 2.--Geographic features in the vicinity of the Anaconda-Pintlar Wilderness Area, western Montana.

normal faults that trend northeast along the southern flank of the range adjacent to the Big Hole Basin, and these faults are part of the Great Falls tectonic zone, as defined by O'Neill and Lopez (1985).

PREVIOUS STUDIES

The first geologic report that described rocks and structures of the Anaconda-Pintlar Wilderness Area was Emmons and Calkins' (1913) classic report on the Philipsburg 30-minute quadrangle, which defined Paleozoic rock units and described the general structural framework in the northern part of the wilderness. Poulter (1956) mapped the north-central part of the wilderness area as part of a larger study that also encompassed the area around Georgetown Lake. Flood (1974) studied complex structural relations in the Fishtrap Creek area in the central part of the wilderness. Wiswall (1976) studied structural problems in the headwaters of the Middle Fork of Rock Creek, west of Flood's study area. Pederson (1976) studied stratigraphic and structural relations and mineral occurrences in the northwestern part of the Anaconda-Pintlar Wilderness Area in Copper Creek and the Middle Fork of Rock Creek drainages.

PRESENT STUDY

Field studies were conducted during the summers of 1981-82; a generalized geologic map was compiled and used for the mineral resource evaluation (Elliott and others, 1985). Geologic maps of the following geologists have been incorporated into this report: (1) Lidke (1985) completed a geologic map (scale 1:24,000) and discussed structural and stratigraphic relations of the north-central part of the wilderness area in a M.S. thesis, the results of which were included in Lidke and Wallace (in press) and incorporated into this report; (2) Desmarais (1983) completed a geologic map and discussed structural and plutonic relations of the western part of the wilderness, west of Clifford Creek and Mussigbrod Creek, and reported his results in a Ph.D. dissertation. Desmarais' geologic data is included in this report; and (3) J.M. O'Neill and D.C. Ferris contributed geologic mapping in the southern part of the map area. O'Neill and Lopez (1985) published a report that interpreted northeast-trending structural features that were mapped during this study along the southern boundary of the wilderness; these interpretations are included in this report where pertinent. This geologic map of the Anaconda-Pintlar Wilderness Area presents new structural and stratigraphic information that could not be included on the generalized geologic map (Elliott and others, 1985). Modal analyses of igneous rocks were completed by K.R. Wirth, D.J. Lidke, N.S. Macleod, Jr., J.E. Elliott, and C.A. Wallace; C.A. Wallace, D.J. Lidke, and J.E. Elliott compiled and interpreted data on plutonic rocks. D.J. Lidke and C.A. Wallace were primarily responsible for interpretation of structural data.

STRATIGRAPHY

The stratigraphic sequence in the Anaconda-Pintlar Wilderness Area described by previous authors has been revised as a result of our geologic mapping (fig. 3). Minor revisions were made to the Paleozoic sequence as described by Poulter (1956) that make the sequence more similar to that described originally by Emmons and Calkins (1913). Substantial revisions were made to interpretations of the Middle Proterozoic stratigraphic sequence presented by Emmons and Calkins (1913) in their pioneering work in the Anaconda Range. Later geologic mapping, such as Poulter's (1956) report and the theses of Flood (1974), Wiswall (1976), and Pederson (1976) did not have the advantage of a regionally cohesive stratigraphic system for Middle Proterozoic rocks of the Belt Supergroup in this region (Harrison, 1972). New geologic mapping (Harrison and others, 1986; Mudge and others, 1982; Wallace and others, 1987; Ruppel and others, 1983) at a scale of 1:250,000 has greatly increased knowledge of the stratigraphic sequences of western Montana, and revisions to the stratigraphic sequence in the wilderness area presented here are consistent with this newly acquired information.

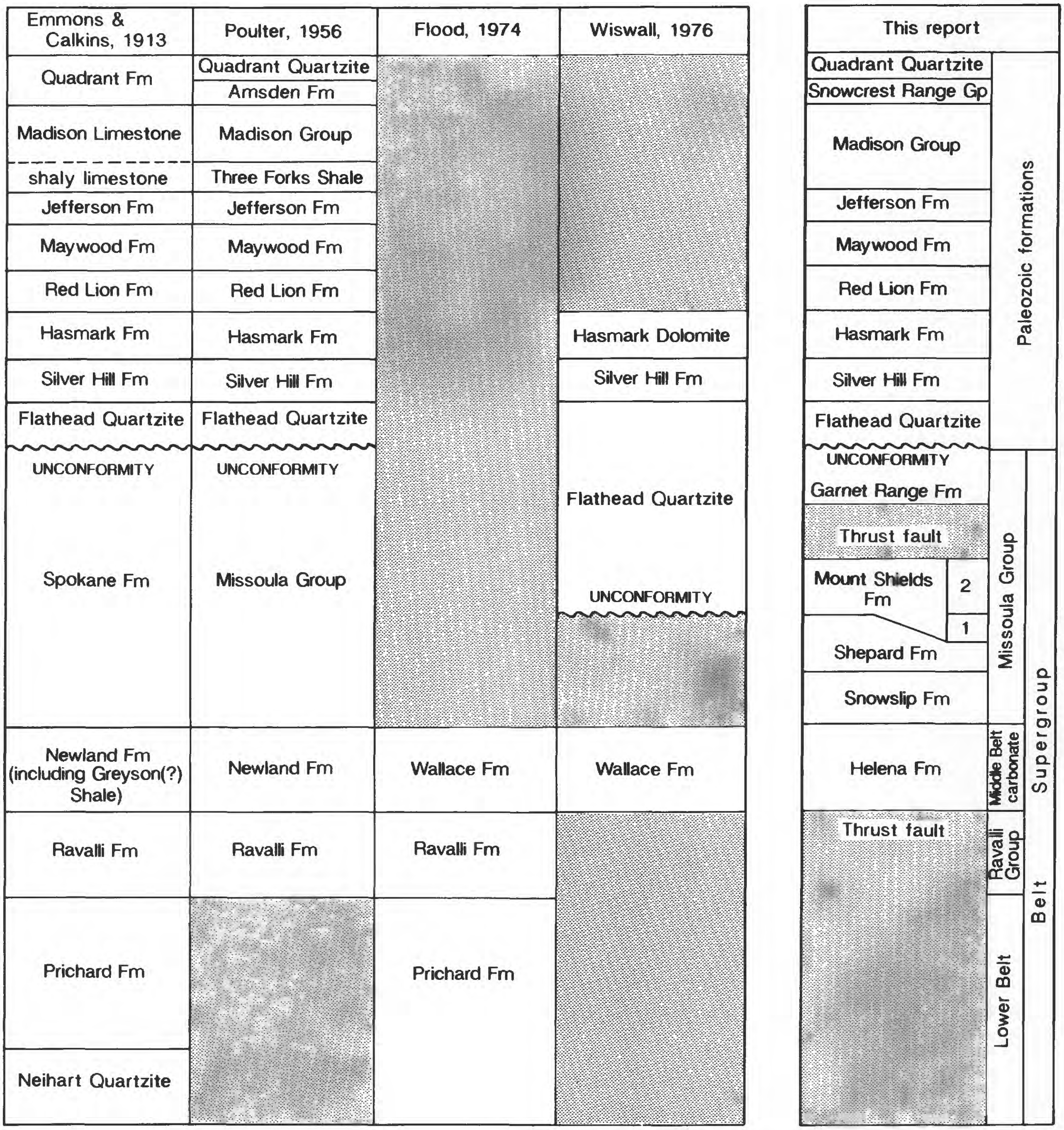


Figure 3.--Comparison of stratigraphic sequences mapped in the area of the Anaconda-Pintlar Wilderness Area, western Montana.

SEDIMENTARY ROCKS AND DEPOSITS

MIDDLE PROTEROZOIC ROCKS

Stratigraphic nomenclature applied to Proterozoic rocks in the Anaconda-Pintlar Wilderness Area by Emmons and Calkins (1913) placed the entire sequence in the lower part of the Belt Supergroup (fig. 3). However, rocks that had been designated the "Spokane formation" by Emmons and Calkins (1913) were identified as part of the Missoula Group, which is the uppermost part of the Belt Supergroup, by Poulter (1956). The carbonate-bearing sequence below Poulter's Missoula Group was still designated the "Newland Formation" (Poulter, 1956). Although stratigraphic position of the Newland is now known to be below the Ravalli Group in the eastern Belt basin, he used "Ravalli Formation" for sedimentary rocks below the "Newland Formation". Flood (1974) reassigned Poulter's "Newland Formation" to the "Wallace Formation," and thereby placed these carbonate-bearing rocks in the middle of the Belt Supergroup. Metamorphosed rocks that underlie the Wallace Formation were placed in the lower Belt by Flood (1974), in agreement with Emmons and Calkins (1913). Wiswall (1976) retained the stratigraphic designation of Wallace Formation for the carbonate-bearing unit, but included all clastic rocks above this unit in the Flathead Formation.

Our geologic mapping resulted in changes to stratigraphic names used by previous geologists who mapped in the Anaconda Range: Proterozoic rocks assigned to the lower part of the Belt sequence by Emmons and Calkins (1913), Poulter (1956), and Flood (1974) have been reassigned to the Missoula Group in this report, and the rocks designated Wallace Formation by Flood (1974) and Wiswall (1976) or assigned to the Newland Formation by Emmons and Calkins (1913) and Poulter (1956), have been reassigned to the Helena Formation in this report, which is the oldest formation recognized in the map area.

The principal lithologic criteria that support new assignments to rocks of the Helena Formation and the Missoula Group in the map area are based on regionally established critera and lithologic descriptions of Harrison (1972), Wallace and others (1987), Wallace and others (1989), and Harrison and others (1986).

The Helena Formation (Yh) consists of an upper part composed dominantly of limestone and lesser amounts of calcareous clastic rocks which dominate the Helena Formation to the north and northwest of the map area. The lower part of the Helena is composed of 3-6.5-ft- (1-2-m-) thick beds of dolomite, brownish, fine-grained sandstone and siltstone, gray limestone, and green, thinly laminated argillite and siltstone that occurs at the head of Copper Creek and west of Rainbow Lake.

A similar lower Helena has been mapped as far north as Lake Kookanusa, 200 mi (320 km) northwest of the map area. The Snowslip Formation (Ysn), which is the oldest rock unit in the Missoula Group, overlies the Helena Formation in normal sequence in the map area. The Snowslip Formation maintains the irregularly distributed beds of argillaceous siltite between thinly laminated argillite and siltite zones and this unit contains the characteristic lenticular interbeds of very well sorted, well-rounded, coarse-grained, very light gray quartzite described from Flint Creek Hill (Winston and Wallace, 1983) about 10 mi (16 km) north of the map area. Emmons and Calkins (1913) included what we assign to the Snowslip in the lower part of their Spokane Formation, but Poulter (1956) designated the rocks we assign to the Snowslip as part of the Missoula Group. Flood (1974) included what we call the Snowslip and Helena Formations with the Prichard Formation in the area of East Goat Peak, where the rocks are metamorphosed to hornblende-hornfels facies. At most places in the map area, only the lower part of the Snowslip Formation is present because the upper part was eliminated by thrust faulting. The Shepard Formation (Ysh), which overlies the Snowslip Formation in a normal succession, has been identified only in the Senate Mine area in the drainage of the Middle Fork of Rock Creek, where a normal contact separates the Shepard from the Snowslip Formation. Pederson (1976) mapped the Snowslip and Shepard Formations as the Miller Peak and Wallace Formations, but his Miller Peak rocks are now assigned partly to member 2 of the Mount Shields Formation and partly to the Shepard Formation and Snowslip Formations.

Some rocks that Pederson (1976) included in the Wallace Formation, and that Wallace and others (1987) and Wallace and others (1989) included with the Mount Shields, Helena, and Wallace Formations, are now assigned to the Shepard Formation based on new stratigraphic data provided by Don Winston (University of Montana, oral commun., 1988). The Shepard Formation in the map area is a coarser grained and more clastic-rich lithofacies than is common elsewhere; at the Senate mine the Shepard contains thick zones (6.5-65 ft; 2-20 m) of thinly laminated, interbedded green argillite and siltite couplets, gray limestone, very light gray quartzite and conglomeratic quartzite, laminated dolomite, and dark-green siltite. In the western part of the Sapphire Mountains, and as far north as the vicinity of Alberton, Montana, this unusual lithofacies directly underlies member 2 of the Mount Shields Formation, or it underlies a thin sequence of member 1 of the Mount Shields Formation; in the map area the contact between the Shepard Formation and member 2 of the Mount Shields Formation appears to be a thrust fault.

Rocks that we assign to the Mount Shields Formation (Yms), a thick sequence of argillite, siltite, and quartzite in the middle of the Missoula Group, were assigned to four different units by Emmons and Calkins (1913), the Neihart Quartzite, and the Prichard, Ravalli, and Spokane Formations. Rocks designated as "Ravalli Formation" by Poulter (1956) are now assigned to members 1 (Yms1) and 2 (Yms2) of the Mount Shields Formation. The Flathead Quartzite of Wiswall (1976) consists mostly of Missoula Group formations that include members 1 and 2 of the Mount Shields Formation and the Garnet Range Formation. Argillaceous parts of the Mount Shields Formation form thinly laminated, grayish-black and dark-gray hornfels and mica schist where metamorphosed, and these rocks were mistaken for similar-appearing grayish-black, thinly laminated rocks of the lower part of the Belt Supergroup by Emmons and Calkins (1913), Poulter (1956), and Flood (1974). Lidke (1985) distinguished three lithofacies in the Mount Shields Formation, each confined to a separate thrust sheet: (1) A western lithofacies composed of conglomeratic, feldspathic, coarse-grained quartzite occurs in Meadow Creek and west of Carpp Lakes in the hanging wall of the Georgetown thrust. (2) A centrally located lithofacies is exposed in the cores and along the flanks of the Rock Creek anticline and the Porter Ridge and Spruce Creek synclines, and this lithofacies is composed of medium- and coarse-grained quartzite that contains finer grained thinner conglomerate zones than the western lithofacies. This central lithofacies occurs as a thrust slice between the East Fork and the East Fork branch thrust. (3) A southern lithofacies near the Continental Divide is composed of fine-grained, well-sorted metamorphosed quartzite and hornfels composed of rhythmically bedded argillite, siltite, and fine-grained quartzite, and this lithofacies is confined to the footwall of the Cutaway thrust. Member 3 of the Mount Shields Formation is absent in the map area, as are the Bonner Quartzite and McNamara Formation; these units should overlie member 2 of the Mount Shields Formation in a normal stratigraphic succession.

The upper part of the Garnet Range Formation (Ygr) underlies the Flathead Quartzite or Silver Hill Formation in the map area. Greenish-gray and grayish-green, immature quartzite and sandy argillite interbedded with grayish-pink and very light gray, vitric quartzite and dusky-red, sandy argillite is a diagnostic lithic type in the upper part of the Garnet Range Formation in the northern Sapphire and John Long Mountains and in the Flint Creek Range north of the wilderness (Winston and Wallace, 1983). Rocks now identified as the Garnet Range Formation were assigned to the Missoula Group by Poulter (1956); the Garnet Range Formation was not recognized by Wiswall (1976), although we mapped rocks of the Garnet Range Formation on Porter Ridge that was also part of the area mapped by Wiswall.

These new stratigraphic assignments made for Proterozoic rocks in the Anaconda-Pintlar Wilderness Area replace previous assignments with the Ravalli Group, Prichard Formation, and Neihart Quartzite. New mapping shows that the lower Belt formations, which were thought to be present in the Anaconda Range, are metamorphosed parts of the Helena Formation and Missoula Group. Formations of the Missoula Group that are absent from the sequence in the wilderness area, such as the McNamara Formation and Bonner Quartzite, have been eliminated by thrust faulting, as discussed in the section on structural geology. The Pilcher Formation, at the top of the Missoula Group, is probably absent because it thins toward the south below the Middle Cambrian rock units; the Pilcher does not occur more than a few miles south of the Garnet Range (fig. 2) (Wallace and others, 1987).

PALEOZOIC ROCKS

Paleozoic rocks are exposed north of the Continental Divide between the Middle Fork of Rock Creek on the west and Twin Lakes Creek on the east. The nomenclature and original definitions of most Paleozoic rocks in the Flint Creek Range and on the north flank of the Anaconda Range (Emmons and Calkins, 1913) are applicable to most Paleozoic rocks in the wilderness area (fig. 3), although some changes have been made to nomenclature of upper Paleozoic rocks. The "Quadrant formation" of Emmons and Calkins (1913) included rocks later mapped as the Amsden Formation by Poulter (1956), but his Amsden Formation is now recognized as a lateral equivalent of the Snowcrest Range Group (PMs) by B.R. Wardlaw (U.S. Geological Survey, written commun., 1987). Poulter (1956) separated a medium-gray, shaly micrite at the base of the Madison Group (Mm), which had been described by Emmons and Calkins (1913) but not named, and considered these rocks to be part of the Three Forks Formation. However, at the nearest exposures of the Three Forks Formation near Elliston, Montana, 91 km (57 mi) to the northeast, the rocks are mainly greenish-gray and yellowish-gray, brown-weathering shale and siltstone that contain some shaly limestone and sandstone, which are lithologically dissimilar to the shaly micrite and micritic biosparite assigned to the Madison Group by Emmons and Calkins (1913). Emmons and Calkins (1913, p. 64) provisionally assigned a Silurian(?) age to the Maywood Formation, but Sloss and Laird (1947) determined that the Maywood was of Late Devonian age in central and northwestern Montana. The Hasmark Formation (€h) has been assigned a Middle and Late Cambrian age by Hanson (1952) and by Zen (1988), but Kauffman (1963) assigned the Hasmark to a Late Cambrian age. Biostratigraphic data is lacking that might resolve the age assignment of the Hasmark Formation, but a lithologic correlation with the Pilgrim Limestone by Schmidt and others (unpub. data, 1990) suggests that this unit could be Late Cambrian in age. Wiswall (1976) assigned a medium- and coarse-grained feldspathic quartzite and conglomeratic quartzite near Edith Lake in Falls Fork of the Middle Fork of Rock Creek to the Flathead Quartzite, but on our map the Flathead Quartzite (€f) is a fine-grained, gray- to grayish-white or tan, vitric quartzarenite that is in stratigraphic continuity with the Silver Hill Formation (€sh) on Porter Ridge, 1.5 mi (2.4 km) north of Edith Lake and 2 mi (3.2 km) southwest of Edith Lake in Wiswall's map area. At these places the Flathead Quartzite is less than about 10 ft (3 m) thick and is too thin to show at this map scale. Most of the rocks assigned to the Flathead Quartzite by Wiswall (1976) have been reassigned by us to the member 2 of the Mount Shields Formation of the (Middle Proterozic) Missoula Group. Wiswall (1976) also included rocks of the Garnet Range Formation with the Flathead.

TERTIARY AND QUATERNARY DEPOSITS

Pliocene(?) gravel, sand, and silt deposits are scattered through the central and northern parts of the map area, and an extensive tract of Tertiary fluvial deposits occur along the southern boundary of the map area, whereas Quaternary glacial and alluvial deposits occur in all modern drainages. Poulter (1956) described Tertiary clay beds and overlying gravel veneers along the north flank of the range, and Hanneman (1987) described fluvial and stream deposits near the south flank of the Anaconda Range. Poulter (1956) concluded that clay beds were mostly lacustrine in origin, and interbedded, lenticular zones of sand, pebbles, and cobbles in a clay matrix probably represented stream deposits. Poulter (1956) assigned the clay-rich deposits to Oligocene and Miocene ages, but gravel deposited on pediment surfaces was generally relegated to a Miocene, Pliocene, or early Pleistocene age. Hanneman's (1987) Oligocene and Miocene assignments of tuffaceous siltstone and sandstone beds (Ts) along the south border of the map area generally agree with Poulter's designations, and gravel (Tg) that overlies pediments was assigned to Pliocene or early Pleistocene.

Pleistocene till (Qt) and outwash (Qo) occur in all valleys and till mantles some low ridges. Poulter (1956) showed till of four ages on his map, and from oldest to youngest he correlated these tills with Bull Lake, Pinedale, Temple Lake, and Little Ice Age Alpine glacial events. Our mapping showed that an older till commonly mantles low ridges and has a subdued hummocky surface. One or more younger tills are confined to valleys, and these deposits form prominent lateral moraines in canyons and prominent recessional moraines at the mouths of canyons. Near Spruce Lake, an erosional remnant at 9,200 ft (2,800 m) may be the oldest till preserved in the range. Rock glaciers and well-develped protalus ramparts may preserve the neoglacial event. Till was mapped as one unit for this study, and rock glaciers and talus are not shown on the map. Outwash deposits occur in all glaciated drainages, and most outwash contains Holocene alluvium (Qal) where underfit streams have incised into till and outwash. Landslides (Qs) are common in till and in Oligocene and Miocene tuffaceous and clay-rich fluvial and lacustrine deposits.

IGNEOUS ROCKS

Igneous rocks in the Anaconda-Pintlar Wilderness Area are separated into: (1) plutonic bodies of the Idaho batholith, which are exposed in the western part of the wilderness area, (2) the stock of Storm Lake in the northeast part of the map area, and (3) stocks and batholiths of the plutonic suite in the Anaconda Range, which are exposed in the southern, central, and eastern parts of the wilderness. Volcanic rocks are poorly exposed in the southern part of the map area.

IDAHO BATHOLITH

In the western part of the map area, rocks of the Idaho batholith are represented by two foliated plutons, the stock of Surprise Lake (Ksl) and the stock of Jennings Camp Creek (Kjc). These plutons extend beyond the wilderness boundary to the west and northwest (Desmarais, 1983). The stock of Suprise Lake is mainly a foliated biotite granodiorite that contains some biotite tonalite. The stock of Jennings Camp Creek is mainly a foliated hornblende-biotite granodiorite that contains some tonalite. Zones of hornblende-rich tonalite occur parallel to foliation in many places in this stock, and hornblende-rich tonalite is a common rock near the border of the stock; zones of hornblende-poor tonalite and granodiorite are common between zones of hornblende-rich tonalite. Steeply dipping foliation strikes to the northwest in stocks of Surprise Lake and Jennings Camp Creek, and the northwest strike is consistent with the regional foliation in adjacent metamorphosed host rocks. According to petrologic and structural analyses of Desmarais (1983), these stocks were intruded during a period of ductile deformation under high-temperature conditions, and earlier formed northerly trending folds in the host rocks were transposed during this ductile deformation into northwest-trending folds that have steeply plunging axes. Sillimanite-grade, migmatitic, quartzo-feldspathic and calc-silicate gneiss in the metamorphic aureole adjacent to these stocks record temperatures of about 700° C in the host rocks at the time of intrusion. The best estimate of the time of intrusion of these stocks is about 78 ± 20 Ma, based on interpretation of uranium-lead concordia diagrams on samples from outside the wilderness boundary (Desmarais, 1983). Potassium-argon and fission-track ages from these stocks are younger than 78 Ma and probably reflect progressive cooling of these stocks, as interpreted from cooling curves and geologic relations (Desmarais, 1983).

STOCK OF STORM LAKE

The stock of Storm Lake (Kst), which is composed of quartz diorite, tonalite, granodiorite, quartz monzodiorite, and diorite, is exposed in the northeastern part of the map area. The stock is named from exposures at Storm Lake, but the main part of the stock is north of the map area. This stock is separated from the plutonic suite in the Anaconda Range because this stock is more mafic in composition and older than the plutonic suite. Emmons and Calkins (1913) described the western part of the stock as a Tertiary basic granodiorite, which was intruded by a Tertiary acidic diorite that composed the eastern part of the stock. Our reconnaissance geologic mapping did not confirm an intrusive contact between the two phases mapped by Emmons and Calkins (1913). At many places the stock of Storm Lake is characterized by two or more rock types in a single outcrop, in which more mafic constituents (diorite, quartz diorite, or tonalite) occur as inclusions in a younger and less mafic phase (quartz monzodiorite, granodiorite, or tonalite). These inclusion-rich zones may be intrusion breccia. Emmons and Calkins (1913, p. 92) reported that the stock of Storm Lake is characterized by "***intricate mingling of more acidic [felsic] and more basic [mafic] portions***" The stock also contains numerous inclusions of metasedimentary rocks that are as large as several hundred feet long, which, as indicated by Emmons and Calkins (1913, p. 92) "***are partially absorbed and surrounded by hornblendic reaction rims***."

Well-developed foliation and metamorphic textures and new isotopic data indicate that parts of the stock of Storm Lake have been subjected to penetrative deformation and metamorphism. A quartz diorite sill (Kqd) mapped near Mt. Evans is probably a fine-grained equivalent of the stock of Storm Lake. Discordant potassium-argon isotopic ages (table 1) of biotite and hornblende mineral pairs suggest that isotopic systems were modified after initial cooling by dynamothermal metamorphism or by heat and fluids from the nearby Hearst Lake batholith (Thl) or from the stocks at Upper Seymour Lake (Tsl) and Lake of the Isle (Tli). Analysis of Ar^{39}/Ar^{40} data from biotite suggests that the age of 78.7 Ma is most likely the correct age for the Storm Lake stock (J.D. Obradovich, unpub. data, 1989).

PLUTONIC SUITE IN THE ANACONDA RANGE

The plutonic suite, which is exposed in the southern, central, and eastern parts of the Anaconda Range, consists of early and middle Eocene, as well as Cretaceous, granodiorite and monzogranite stocks and two muscovite-biotite granodiorite batholiths. These plutonic bodies are the most extensive igneous rocks in the wilderness area, and they underlie about 35 percent of the map area. This suite includes granodiorite and monzogranite stocks of Warren Lake (TKw), Beaverhead Mountain (TKb), and Maloney Basin (TKm); muscovite-biotite granodiorite of the Pintlar Creek batholith (Tpc); biotite granodiorite of the stock of Elk Park (Tep); biotite-muscovite granodiorite and monzogranite of the Hearst Lake batholith (Thl); and biotite granodiorite stocks of Upper Seymour Lake (Tsl) and Lake of the Isle (Tli). The suite also includes dacite porphyry and granodiorite porphyry dikes (Td and TKd), granite, pegmatite, and aplite dikes (Tap and TKg), and rhyolite porphyry dikes, sills, and pods (Tr).

Granodiorite and monzogranite stocks of Warren Lake (TKw), Beaverhead Mountain (TKb), and Maloney Basin (TKm) form a cluster of nonfoliated plutons along the Continental Divide in the central part of the map area. Emmons and Calkins (1913) called the Beaverhead Mountain stock a "porphyritic biotite granite," and called the Maloney Basin stock an "acidic granodiorite." Although the stocks of Warren Lake and Beaverhead Mountain share many similarities, the modes of most samples of the stock of Beaverhead Mountain plot in the monzogranite field, whereas the modes of samples of the stock of Warren Lake plot in the granodiorite field. The granodiorite stocks of Warren Lake and Maloney Basin are mineralogically and modally similar, but rocks of the stock of Warren Lake are more porphyritic than the stock of Maloney Basin. The stock of Maloney Basin is also distinguished from the stocks of Warren Lake and Beaverhead Mountain by a larger percentage of plagioclase and hornblende, and a consistently lower percentage of potassium feldspar. Contacts among these stocks show no clear crosscutting relations, so determination of the youngest and oldest stocks is not possible. Isotopic ages were not obtained from this isolated cluster of stocks, but relative age information indicates that these stocks have Late Cretaceous to

Table 1. Analytical data for potassium-argon isotopic age determinations on samples from the Anaconda Range, Montana

[Determinations by J.D. Obradovich. Decay constants: ^{40}K $\lambda_{\epsilon}+\lambda_{\epsilon'}$ = 0.581 x $10^{-10}yr^{-1}$, $\lambda\beta$ = 4.962 x $10^{-10}yr^{-1}$. Atomic abundance: $^{40}K/K$ = 1.167 x 10^{-4} atom/atom (Steiger and Jaeger, 1977). See geologic map for sample localities.]

Sample No.	Rock name and map symbol	Mineral dated	K (pct)	Moles $^{40}Ar^*$ per gram of sample ($x10^{-10}$)	$^{40}Ar^*$ as percent of total ^{40}Ar	Age (Ma $\pm1\sigma$)
81540	Pintlar Creek batholith (Tpc)	Muscovite	8.50	8.213	82.0	54.9±0.6
		Biotite---	7.45	6.966	85.3	53.1±0.8
81642	Pintlar Creek batholith (Tpc)	Muscovite	8.33	7.309	83.7	49.9±0.5
		Biotite---	6.96	6.203	88.1	50.7±0.5
81639	Elk Park Stock (Tep)	Biotite---	7.53	7.037	84.2	53.1±0.6
AP-81-123 (from Desmarais, 1983)	Dacite or granodiorite dike (Td)	Biotite---	7.76	5.98	81.0	50.3±1.1
81640	Dacite or granodiorite dike (Td)	Biotite	7.73	7.049	87.4	51.8±0.5
E0134	Hearst Lake batholith (Thl)	Muscovite	8.15	7.254	75.5	50.6±0.5
		Biotite---	7.82	6.667	74.6	48.5±0.5
E1048	Stock of Storm Lake (Kst)	Biotite---	7.32	10.21	94.8	78.7±0.8
		Hornblende	0.602	1.256	80.1	116.4±2.3

*Radiogenic argon.

early Tertiary ages because the stocks cut Late Cretaceous thrust faults and folds and the stocks are cut by Tertiary high-angle faults and dikes.

The granodiorite of Pintlar Creek (Tpc), which is the largest plutonic body in the map area, is exposed as an elongate, northeast-trending batholith south of the Continental Divide. In the western part of the map area, the Pintlar Creek batholith intrudes older foliated granodiorite and tonalite of the Idaho batholith (Ksl and Kjc); in the central and eastern parts it intrudes thrust faulted and folded rocks of the Belt Supergroup. The southeastern border of the Pintlar Creek batholith is marked by a prominent northeast-trending zone of normal faults along which the granodiorite is faulted against or overlapped by Tertiary fluvial deposits and faulted against sheared and metamorphosed metaquartzite and schist that is assigned to the Mount Shields Formation. The Pintlar Creek batholith extends as far northeast as Seymour Creek, where it is apparently intruded by the granodiorite of Hearst Lake (Thl); the Pintlar Creek batholith extends beyond the map area to the southwest (Desmarais, 1983). Compositionally, rocks of the batholith are characterized by approximately equal amounts of varietal muscovite and biotite. Textures of rocks of the batholith are characterized by a large range in grain size and by sheets of fine-, medium-, and coarse-grained granodiorite. Porphyritic and equigranular granodiorite appear to be interlayered. Although reconnaissance mapping did not produce systematic data on the thickness and distribution of the granodiorite layers, they seem to range from tens to hundreds of feet thick. In the southwestern part of the map area, in the region of Mussigbrod Creek, the layers of granodiorite appear to form a broad arch, the axis of which trends northeasterly in the direction of elongation of the batholith. Present exposures of the Pintlar Creek batholith are probably near the original roof of the pluton because (1) numerous roof pendants are scattered thoughout the batholith, (2) microcataclastic textures, which may represent a zone of protoclasis near the roof of the batholith, are common, and (3) the arched shape of sheets of different grain size may be an original feature that reflects the original shape of the roof of the batholith. Potassium-argon ages on muscovite and biotite range from about 50 to 55 Ma, and average about 52 Ma, which places the cooling age of the Pintlar Creek batholith near the boundary between early and middle Eocene (table 1).

The stock of Elk Park (Tep), which is composed of nonfoliated to poorly foliated, fine- and medium-grained, biotite granodiorite, intrudes the Pintlar Creek batholith in the central part of the map area. This small stock is elongate to the northeast. Numerous dacite and granodiorite porphyry dikes and pods that cut Middle Proterozoic and Paleozoic sedimentary rocks north and northeast of the stock of Elk Park, and that cut the Pintlar Creek batholith near the stock of Elk Park, may be connected to part of this stock at depth. Geologic relations show that the stock of Elk Park is younger than the Pintlar Creek batholith, but a single potassium-argon age on biotite provides an age of about 53 Ma, which is not distinguishable from the range of ages obtained from the Pintlar Creek batholith (table 1). Two dacite and granodiorite porphyry dikes (Tep) connect with the stock of Elk Park, and, like the stock, these dikes intrude the Pintlar Creek batholith (Tpc). Numerous other Tertiary dacite and granodiorite porphyry dikes (Td) also intrude the Pintlar Creek batholith, but they are not known to connect with the stock of Elk Park. Other dikes of similar composition and texture (TKd) have poorly constrained ages because the dikes intrude much older sedimentary rock. A dike that intruded the Helena Formation (sample 81640) yielded a potassium-argon age from biotite of about 52 Ma (table 1).

The leucogranodiorite and leucomonzogranite of Hearst Lake (Thl) is similar in texture and composition to the Pintlar Creek batholith, and muscovite and biotite percentages are about the same as those of the Pintlar Creek batholith. The Hearst Lake batholith is exposed only in the upper drainages of Sullivan and Seymour Creeks in the map area, but this pluton is well exposed northeast and east of the map area. The batholith is named from Hearst Lake, which is about 7 mi (11 km) northeast of Sullivan Creek. This batholith has porphyritic and equigranular phases and contains abundant pegmatite and aplite dikes, sills, and pods, many of which have intruded adjacent Middle Proterozoic units and older stocks. The Hearst Lake batholith was mapped as Tertiary porphyritic muscovite-biotite granite and Tertiary nonporphyritic muscovite-biotite granite by Emmons and Calkins (1913). Potassium-argon age determinations on biotite and muscovite are about 49 and 51 Ma, respectively, which suggests that the Hearst Lake batholith is middle Eocene and slightly younger than the Pintlar Creek batholith (table 1).

The granodiorites of Upper Seymour Lake (Tsl) and Lake of the Isle (Tli) are medium-grained, biotite granodiorite stocks that may be connected at shallow depth and form a single stock beneath rocks of the Missoula Group. These stocks are the source of a system of dacite and granodiorite porphyry dikes in the vicinity of Mount Evans in the north-eastern part of the map area. Because the stocks of Upper Seymour Lake and Lake of the Isle intrude the Hearst Lake batholith, they are considered to be younger than the middle Eocene age of the Hearst Lake batholith.

Rhyolite porphyry and porphyritic rhyolite occur as dikes, sills, and pods (Tr) and occur mostly in the terrane southwest of Cutaway Pass. An extensive swarm of northeast-trending rhyolite dikes follows the Continental Divide in the southwesternmost part of the map area, where a shear zone has brecciated and sheared the rhyolite (Desmarais, 1983). Rhyolite dikes, sills, and pods are commonly altered and fractured. The youngest rock units that these dikes intrude are the stock of Elk Park (about 53 Ma) and a dacite and granodiorite porphyry dike (about 52 Ma). Fission-track ages on zircon from rhyolite dikes average about 43 Ma, about at the boundary between middle and late Eocene (Desmarais, 1983).

Granite, pegmatite, and aplite dikes (Tap) occur rarely in the map area, and these late-phase granitic dikes are related to nearby rhyolite dikes (Tr) 1 mi (1.6 km) north of Beaverhead Mountain, to the Hearst Lake batholith near Mount Evans, and to the Pintlar Creek batholith (Tpc) near the West Fork of Mudd Creek. Granite porphyry, and aplite (TKg) are scattered sparsely through the map area and the granite and aplite are similar in character to late-phase leucocratic dikes (Tap), but age relations could not be determined. About 0.5 mi (.8 km) northeast of Hicks Lake, four granite dikes (TKg) join the stock of Beaverhead Mountain (TKb) and appear to be derived from that stock. The paucity of late-phase leucocratic, siliceous dikes suggests that the stocks and batholiths of the plutonic suite in the Anaconda Range were relatively dry at the time of intrusion and crystallization.

OTHER STOCKS, DIKES, AND SILLS

Tertiary or Cretaceous granitic rocks (TKi) occur as small exposures near the mouth of the East Fork of Fishtrap Creek, and these rocks are probably related to more extensive exposures of porphyritic and equigranular, foliated, granitic rocks that are common along the Big Hole River as shown by Hanneman (1987). Intrusive relations between the granitic rocks in Fishtrap Creek and plutons that compose the plutonic suite in the Anaconda Range cannot be determined from our map data because the Mount Shields Formation covers the area between the exposures of the two plutonic bodies.

Dikes and sills of porphyritic quartz diorite and andesite (TKa) are present in the north-central part of the wilderness. The age of these dikes and sills is poorly constrained, but they are similar in composition to the quartzdiorite sill (Kgd), and like the sill, they may be related to the stock of Storm Lake.

VOLCANIC ROCKS

Small exposures of volcanic rocks are in the southeastern part of the map area. Welded tuff (Tv) and basalt (Tb) were considered to be Pliocene(?) by Hanneman (1987), but map relations suggest that the welded tuff may pre-date the Oligocene-Miocene fluvial deposits of Hanneman (1987), and the basalt appears to be interbedded with the fluvial deposits of Hanneman (1987).

METAMORPHIC ROCKS

In general, two periods of metamorphism have modified sedimentary and igneous rocks in the Anaconda Range: (1) an early period of dynamothermal metamorphism of probable Late Cretaceous age that produced high-grade metamorphic minerals, prominent foliation in igneous and sedimentary rocks, and isoclinal folds and flow folds and, (2) a later thermal metamorphic event of latest Cretaceous(?) and early and middle Eocene age that coincided with widespread intrusion of granitic plutons that locally produced low-, medium-, and high-grade metamorphic mineral assemblages under static conditions.

Most metamorphism in the map area was isochemical; metasomatism is local and is restricted to small contact zones between plutonic rocks and carbonate-rich sedimentary rocks. In pelitic and quartzofeldspathic rocks, such as the Mount Shields Formation, the principal metamorphic minerals are biotite, muscovite, quartz, and feldspar. Sillimanite, garnet, and andalusite may occur in the metamorphic mineral assemblages adjacent to intrusive masses. Cordierite has also been reported from pelitic rocks (Emmons and Calkins, 1913). In argillaceous and quartzose carbonate-rich rocks, such as the Helena Formation or upper part of the Silver Hill Formation, calc-silicate minerals, including tremolite, actinolite, chlorite, biotite, diopside, idocrase, phlogopite, and scapolite, are common. Calcite or dolomite marble, or, locally, calcic or magnesian skarns occur where plutons are in contact with carbonate-bearing host rocks such as the Hasmark Formation, the middle part of the Silver Hill Formation, or the Madison Group. Skarn zones commonly contain garnet, pyroxene, hornblende, scapolite, epidote, forsterite, phlogopite, spinel, and magnetite (Emmons and Calkins, 1913).

In general, the Late Cretaceous event produced the highest grade of metamorphism in rocks adjacent to the foliated stocks of Jennings Camp Creek (Kjc) and Suprise Lake (Ksl) in the Idaho batholith and in roof pendants within those stocks, and the older, foliated mafic parts of the stock of Storm Lake (Kst) also may be related to this early metamorphic event. In the southwestern part of the map area sillimanite-grade, dynamothermal metamorphism transposed folds to steep northwest trends and formed a prominent northwest-striking foliation in quartzofeldspathic and calc-silicate migmatite and in muscovite-biotite schist adjacent to and in the stocks of Jennings Camp Creek (Kjc) and Suprise Lake (Ksl) (Desmarais, 1983). Prograde metamorphism occurred at pressures of 3.0-7.0 Kb and temperatures of 600-700 C^{O} (Desmarais, 1983, p. 34). Static, high-temperature metamorphism recrystallized sillimanite, but a retrograde metamorphic event, which was probably related to emplacement of the 73 Ma Sapphire batholith, produced minerals of the albite-epidote hornfels facies in the metamorphic aureole around the Idaho batholith (Wallace and others, 1989). In the northeast part of the map area, metamorphic rocks adjacent to the stock of Storm Lake (Kst) are principally biotite-quartz schist, biotite-quartz gneiss, quartzofeldspathic gneiss, marble, and calc-silicate rocks that contain microcline, plagioclase, tremolite, and diopside as principal minerals. Andalusite, sillimanite, or garnet occur in some metamorphic rocks near this stock. These mineral assemblages indicate that the rocks adjacent to the stock of Storm Lake (Kst) belong to the hornblende-hornfels facies. Metamorphic minerals formed during this early event were re-equilibrated and metamorphic textures in adjacent host rocks were overprinted during intrusion of the younger, less-mafic parts of the stock of Storm Lake.

The latest Cretaceous(?) or early Tertiary metamorphic event that affected the Anaconda Range was principally a thermal event caused by intrusion of the Sapphire batholith (Wallace and others, 1989) and by the plutonic suite in the Anaconda Range. Contact metamorphic rocks around stocks of Maloney Basin, Beaverhead Mountain, and Warren Lake (TKm, TKb, and TKw) generally are of hornblende-hornfels facies closest to stocks and of albite-epidote-hornfels facies a few hundred to several hundred feet (a hundred to a few hundred meters) from the stocks (Lidke, 1985). Locally, gneiss, schist, and migmatite occur along contacts with plutons of this suite. Along the borders of the Pintlar Creek, Elk Park, Hearst Lake, Upper Seymour Creek, and Lake of the Isle plutons (Tpc, Tep, Thl, Tsl, and Tli), schist, migmatite, and quartzofeldspathic and calc-silicate gneiss form the highest grade metamorphic rocks. Roof pendants of gneiss are common in many places within the Pintlar Creek batholith. An extensive area of migmatitic schist and gneiss in La Marche Creek is probably related to the formation and emplacement of the Pintlar Creek batholith. Garnet-bearing muscovite-biotite schist and metaquartzite are common along the borders of the Hearst Lake batholith. Metamorphism around stocks and batholiths of the plutonic suite in the Anaconda Range probably occurred at temperatures of about 550-700 C° and pressures of about 1-3 Kb of water pressure based on metamorphic mineral assemblages described by Turner and Verhoogen (1960).

STRUCTURE

Structures in the map area consist of Late Cretaceous thrust faults and related folds and Tertiary high-angle faults that cut thrust faults, folds as well as Late Cretaceous and early Tertiary stocks and batholiths. Structures in the Anaconda Range are typical of structures in the southern part of the thrust-sheet terrane of the Sapphire thrust plate, which is the principal tectonic element in the region between the Idaho batholith on the west, and the Boulder batholith on the east (fig. 4). The Anaconda Range exposes intermediate and deep levels of the thrust-sheet terrane of the Sapphire thrust plate, where the most complete record of polyphase deformation is preserved. Polyphase deformation that we document in this report resulted principally from sequential thrust faulting and folding during Late Cretaceous time. Many aspects of this polyphase deformation were recognized by Emmons and Calkins (1913), Poulter (1959), and Wiswall (1976). Latest Cretaceous and early Tertiary plutons deformed some thrust-related structures, and movement on high-angle faults accompanied and followed Tertiary uplift of the Anaconda Range.

The prominent northerly plunge of large-scale folds in the map area exposes deeper parts of the folds and deeper structural levels beneath some folds from north to south across the area. Consequently, techniques of down-plunge projection (Mackin, 1950) were used to constrain the character and approximate position of contacts, folds, and faults projected in the subsurface and above the topographic surface in the structure sections.

THRUST FAULTS

Three types of thrust faults are distinguished in the map area based on the geometry of the faults and the relations of the faults to the folds: (1) sheet thrusts, (2) imbricate thrusts, and (3) out-of-syncline thrusts. The Georgetown, East Fork, and Cutaway thrusts are sheet thrusts that bound allochthonous sedimentary rock sequences that form thrust sheets; these faults have some branch thrusts and related thrust slices along them. A wide zone of anastomosing, imbricate thrust faults occurs along the northwest side of the map area, and these imbricate thrusts, which are probably listric, are associated with tight, isoclinal, and overturned folds. Out-of-syncline thrusts occur along the east limb of most synclines, but are most prominent along the east limb of the Rock Creek syncline.

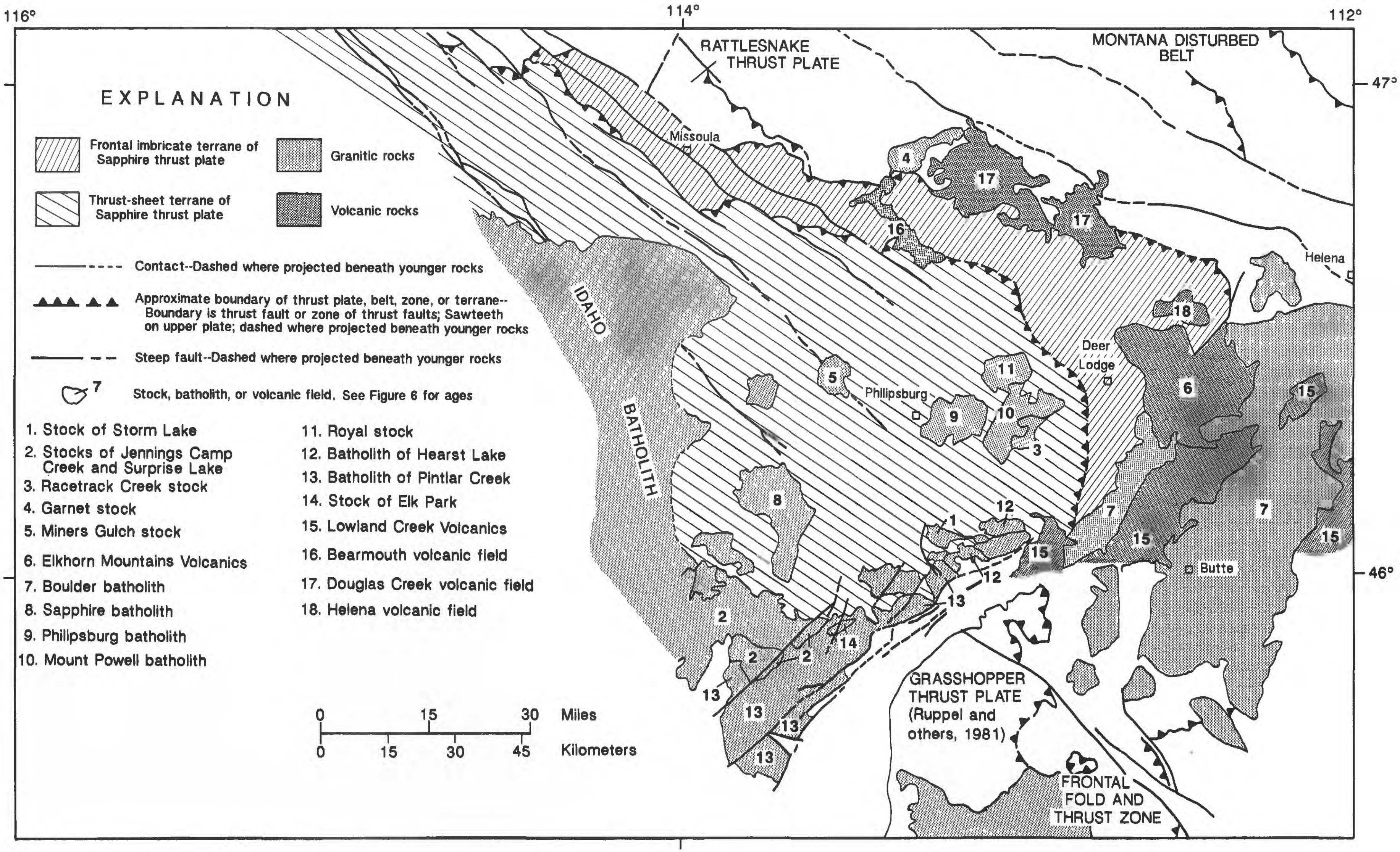


Figure 4.--Map showing principal tectonic elements, volcanic fields, and plutonic masses in the region of the Anaconda-Pintlar Wilderness Area, western Montana.

Sheet thrusts

Georgetown thrust--The Georgetown thrust was first mapped by Emmons and Calkins (1913), and this thrust can be traced for a distance of 40 mi (65 km) (Poulter, 1956), only part of which is in the map area. The Georgetown thrust is folded around the north plunging nose of the Rock Creek anticline into the core of the Rock Creek syncline. The Georgetown thrust places Middle Proterozoic rocks of the Helena Formation over Devonian, Mississippian, and Pennsylvanian formations, which suggests a minimum stratigraphic offset of about 24,000 ft (7,300 m). Locally, branch thrusts merge with the Georgetown thrust and bound lensoid slices of Paleozoic rocks of the footwall. The most prominent of these thrust slices occur in the core of the Rock Creek syncline, where brecciated and fractured Mississippian and Devonian limestone and dolomite are in fault slices beneath the Helena Formation and above Pennsylvanian rocks.

East Fork thrust--The East Fork thrust, which is structurally below the Georgetown thrust in the northern part of the map area, is nearly a bedding-plane fault that is folded harmonically with the Georgetown thrust and the adjacent sedimentary sequences. The East Fork thrust occurs within the Proterozoic succession and it has unusual relations because it puts younger rocks of the Garnet Range Formation over older rocks of the Mount Shields and Snowslip Formations. The sinuous trace of the East Fork thrust has been mapped for about 12 mi (19 km). In the map area, the east end of the thrust is truncated by the stock of Storm Lake (Kst) and the west end appears to be truncated by an imbricate fault zone. Fault zones of the East Fork thrust and the East Fork branch thrust range in thickness and character; zones of sheared and cleaved rock are most common in the fault zones, but locally consolidated breccia marks the trace of the thrusts. Along the east limbs of the Rock Creek syncline and the Dry Creek anticline, zones of intensely sheared and partly recrystallized quartzite and argillite of the Garnet Range Formation are as much as 100 ft (30 m) thick, and these sheared zones contain some protomylonite. In contrast, however, the East Fork branch thrust is as thin as about 1 in. (2.5 cm) in argillite, and quartz veins are truncated by the fault in the cirque wall south and southwest of Spruce Lake.

Cutaway thrust--The Cutaway thrust is exposed in the central part of the map area near the Continental Divide. This fault is almost a bedding-plane fault that places the Helena and Snowslip Formations over the younger Mount Shields Formation, which suggests a minimum stratigraphic separation of about 8,000 ft (2,400 m). The Cutaway thrust in the north-central part of the area, has been traced from the stock of Storm Lake (Kst), which truncates the thrust at its east end, to the stock of Maloney Basin (TKm), which cuts the thrust in the central part of the map area. The Maloney Basin stock also cuts the Cutaway Branch thrust that is well exposed in the ridge on the west side of Sauer Creek. Southern segments of the Cutaway thrust were mapped south, southeast, and southwest of the stocks of Warren Lake (TKw) and Beaverhead Mountain (TKb). Southern segments of the Cutaway thrust are cut by the batholith of Pintlar Creek (Tpc) and the stocks of Warren Lake (TKw) and Beaverhead Mountain (TKb). Northeast of the stock of Maloney Basin (TKm), the Cutaway thrust is not folded, and large-scale folds, such as the Rock Creek syncline, Rock Creek anticline, and Dry Creek anticline, terminate above the Cutaway thrust. South of the stocks of Warren Lake and Beaverhead Mountain (TKw and TKb), in the area of Fishtrap Creek and Saddle Mountain, the Cutaway thrust is tightly folded in the Fishtrap nappe complex. In the south-central part of the area, about 1 mi (1.6 km) south of West Pintlar Peak, a segment of the Cutaway thrust is exposed and imbricate thrusts in that area appear to merge with this segment, which implies that the Cutaway thrust is the sole fault for the imbricate faults. Along most of its trace, the Cutaway thrust is marked by bedding-plane shear zones that range from a few inches to tens of feet in thickness. On the ridge north of Upper Seymour Lake, the Cutaway thrust truncates bedding in the footwall more steeply as it climbs eastward over the Mount Shields Formation.

Imbricate thrust faults

A zone of anastomosing, imbricate thrust faults cuts tight and isoclinal folds and sheet thrusts and follows a southwest trend from the vicinity of East Fork Reservoir to the Middle Fork of Rock Creek, and from the Middle Fork southward to the vicinity of West Pintlar Peak, a distance of about 14 mi (22 km). Individual faults of this imbricate zone dip between 25° and 80° to the west and northwest. The imbricate thrusts are probably listric and may join the Cutaway thrust at depth under most of the map area; the only place exposed at the surface where the zone of imbricate thrusts joins the Cutaway thrust is south and southwest of West Pintlar Peak on the ridge west of Sawed Cabin Lake. In that area, a complex zone of thrust slices, which are bounded by imbricate thrusts, is structurally above the Cutaway thrust and these imbricate thrusts merge with the Cutaway thrust. The zone of imbricate thrusts strikes nearly at a right angle toward the Cutaway thrust, and imbricate thrusts do not extend south of the Cutaway thrust west of Sawed Cabin Lake. Stratigraphic offset along individual faults in the imbricate zone ranges from about 500 to 5,000 ft (150 to 1,500 m). These imbricate thrusts are among the youngest thrust faults identified in the map area, and the zone formed during late phases of compression because faults of the zone cut large-scale folds that deformed the Georgetown and East Fork sheet thrusts. The East Fork branch thrust is folded into a tight syncline that is overturned to the east and cut and overridden by the easternmost imbricate fault of the imbricate thrust zone about 1 mi (1.6 km) west of Johnson Lake. Faults of the imbricate zone, however, are older than the Late Cretaceous or early Tertiary stock of Maloney Basin (TKm) that cuts these faults. Many imbricate thrusts in the zone cut the tight and isoclinal folds, which are associated with these faults, and several imbricate thrusts place younger rocks on older rocks because the faults cut rocks that were tightly folded before imbricate thrust faulting began or before thrust faulting ceased.

Out-of-syncline thrust faults

Out-of-syncline thrust faults (terminology of Dahlstrom, 1977) occur along the east limbs of most of the synclines in the map area. The most prominent of these occur along the east limb of the Rock Creek syncline and show stratigraphic displacement of Paleozoic rock units in the east limb. Near the hinge of that syncline these faults appear to become bedding-plane detachment faults that dip east on the west limb of the syncline. Younger-on-older stratigraphic relations occur across some out-of-syncline thrust faults where gently dipping faults cut steeply dipping strata. These faults apparently represent brittle deformation related to continued shortening during the waning stages of folding.

FOLDS

Large-scale, open, upright parallel folds are prominent in the north-central part of the map area, and large-scale, tight to isoclinal overturned folds are cut by thrust faults of the imbricate zone in the northwestern part of the map area. Small folds are present locally in sedimentary rocks throughout the area and they are particularly common in the region of the Fishtrap nappe complex (large- and small-scale folds of the Fishtrap nappe complex are described in the "Fishtrap nappe complex" section of this report).

The Rock Creek, Dry Creek, and Sauer Creek anticlines and the Rock Creek, Spruce Creek and Porter Ridge synclines (Emmons and Calkins, 1913; Poulter, 1956; Lidke, 1985) are open, upright folds that plunge north and strike north or north-northeast. These folds deform the Georgetown and East Fork thrusts, but must terminate at the Cutaway thrust (see section A-A'). The Rock Creek and Dry Creek folds have amplitudes of about 7,500 ft (2,300 m) and wavelengths of about 26,000 ft (8,000 m). The Spruce Creek syncline and Sauer Creek anticline, in the north-central part of the map area, have smaller amplitudes and wavelengths than do the Rock Creek and Dry Creek folds, and the Spruce Creek and Sauer Creek folds appear to be a large-scale, subsidiary fold pair that deforms the east limb of the Rock Creek anticline. The Spruce Creek syncline and Sauer Creek anticline may represent late-formed kink folds that developed across the Rock Creek folds during formation of tight folds and young imbricate thrusts of the imbricate thrust zone. The Porter Ridge syncline occurs southwest of the Maloney Basin stock that isolates the syncline from the other broad, open folds in the north-central part of the area. Tight folds and imbricate thrusts deform the Porter Ridge syncline, and it may be entirely overridden by thrust faults and folds of the central part of the imbricate thrust zone, as shown in section B-B'.

In the northwest and west-central part of the map area, a zone of tight and isoclinal folds is associated with the zone of imbricate thrust faults, and these folds deformed Paleozoic and Proterozoic rocks and deformed the Georgetown and East Fork thrusts. The axial traces of most of the tight folds in the zone is difficult or impossible to locate with precision, because exposures are poor and because the axial regions of many folds are faulted; furthermore, and most important in the central part of the zone, the crests and troughs of the folds do not coincide with the hinge of the folds, which is characteristic of overturned folds (Hobbs and others, 1976, p. 169-170). In the northern and southern parts of this zone of tight folds and imbricate thrusts, the folds verge east (sections A-A' and C-C'), but in the central part of this zone the tight folds verge west (section B-B') (Lidke and Wallace, in press). Sedimentary rocks deformed in the west-verging folds in the central part of the zone apparently were folded and then cut by imbricate thrust faults; the resulting fault-amputated fold segments probably rotated counterclockwise to become west-verging structures as they moved up the steep, west dipping, frontal segments of the imbricate thrusts (Lidke and Wallace, in press).

Small folds occur commonly in this faulted and intruded terrane, but these folds were not systematically recorded or compiled on the map. Small folds vary in amplitudes and wavelengths from a few tenths of an inch (a few millimeters) to folds that have amplitudes of as much as 1,000 ft (300 m). Most of these small structures occur in sedimentary rocks near contacts with stocks and batholiths or near faults, and these folds commonly produce anomalous strikes and dips that are not coincident with nearby structures or sedimentary contacts.

FISHTRAP NAPPE COMPLEX

In the south-central part of the map area, large- to small-scale, tight and isoclinal folds are common in the region of the Fishtrap nappe complex; these folds deformed the Cutaway thrust and an unnamed sheet-like thrust that underlies it (section C-C'). Although the region of the Fishtrap nappe complex was previously described and interpreted by Flood (1974, p. 52) as a single, southerly plunging, recumbent synform ("Fishtrap Creek nappe"), our mapping suggests that this region includes folded thrust sheets (thrust nappes) and more than one southerly plunging, large-scale, recumbent fold (fold nappe). Flood interpreted that the synform initially formed as an anticline that ductiley rotated under itself, at least 120° clockwise, to form a synformal anticline with a westerly dipping axial surface and an overturned eastern limb. The entire region of the Fishtrap nappe complex is pervasively folded at all scales, and in many localities it is difficult to distinguish overturned bedding related to large-scale folds from overturned bedding related to smaller scale folds. Even so, the geometry and position of the synform in the western part of the nappe complex is well constrained by spectacular exposures in the cirque wall at the head of Maloney Basin, in the northern cirque wall near the head of the West Fork of Fishtrap Creek, and along the southern cirque wall of the West Fork of Fishtrap Creek just east of Rainbow Lake. At those localities the axial surface of the synformal anticline dips moderately to the northwest or gently to moderately to the southwest. Flood extended the synformal anticline eastward into the Saddle Mountain area, but we identified an upright section of the Helena and Snowslip Formations overlying the Cutaway thrust at Saddle Mountain, which suggests that the synformal anticline probably does not extend into the Saddle Mountain area. Our interpretation of the synformal anticline and its relation to structures in the Saddle Mountain area is shown in section C-C', where we show the synformal anticline confined to the western limb of a large, broad dome or anticline. An alternative to Flood's explanation for the formation of the synformal anticline is that the structure may have not rotated much and, instead, may have initially formed in about its present orientation from extremely ductile folding along a major, west-dipping ramp of a deep, blind, and late-formed sheet thrust such as the one inferred at depth in section C-C' and discussed in the "Regional interpretation of structure and plutonic rocks" section of this report. The synformal anticline probably did not form from ductile folding related to local compression between the surrounding large plutonic bodies, because the folds and folded thrust sheets of the Fishtrap nappe complex are cut discordantly by the stocks, which implies the folds are older than the stocks.

HIGH-ANGLE FAULTS

High-angle faults are the youngest structures identified in the map area; these faults offset thrust faults, folds, sedimentary rocks, and they offset intrusive rocks as young as middle or late Eocene in age. Most high-angle faults trend northeast, and they have relatively small displacement when compared to displacement on thrust faults. The most prominent high-angle faults are the Page Creek, Dry Creek, Bear Lake, and Buck Creek faults, and they are discussed below, but other high-angle faults that have short traces and small separations will not be discussed. The Page Creek fault is a northeast-striking, steeply west-dipping to nearly vertical fault that offsets sedimentary rocks and the Late Cretaceous or early Tertiary stocks of Maloney Basin, Warren Lake, and Beaverhead Mountain (TKm, TKw, and TKb). This fault has as much as 700 ft (215 m) of stratigraphic separation and is down on the west, and it can be traced for about 15 mi (24 km). The Dry Creek fault is an arcuate fault that transverses the eastern part of the map area. The north part of the Dry Creek fault strikes northeast whereas the south part of the fault strikes southeast, and it has an offset of about 1,500 ft (460 m) down on the east block. In the saddle at the head of Dry Creek the fault appears to dip steeply to the west, but at and southwest of Kurt Peak, the Dry Creek fault splits into several splays, some of which dip to the east, and one that shows drag that is reversed from that expected from downward slip of the east block. Farther to the southeast the splays form shear zones in metamorphosed rocks of the Mount Shields Formation and in the middle Eocene batholith of Pintlar Creek; separation is small along the southern part of the Dry Creek fault. The Bear Lake fault, in the central part of the map area, strikes northeast for about 8 mi (13 km), offsets middle Eocene rocks of the batholith of Pintlar Creek (Tpc) and the stock of Elk Park (Tep) at its south end, and offsets folded sheet thrusts and imbricate faults of the imbricate thrust zone at its north end. Separation is small on the Bear Lake fault. The Buck Creek fault is a prominent northeast-striking fault and shear zone that traverses the southwestern part of the map area. The trace of this fault is about 22 mi (35 km) long. Along its southwestern segment, the Buck Creek fault is intruded by a rhyolite dike (Tr) (middle or late Eocene). This dike is sheared and brecciated by subsequent slip along the fault, which suggests that the fault had at least two periods of slip. The northern segment of the Buck Creek fault cuts thrust-faulted Middle Proterozoic rocks and Late Cretaceous stocks of Suprise Lake (Ksl) and Jenny Camp Creek (Kjc). Apparent movement of the northwest block is down and to the left. A system of steep and southeasterly dipping faults border the Anaconda Range along the southeast flank. These northeast-striking faults represent a segment of the Great Falls tectonic zone (O'Neill and Lopez, 1985). Most faults of this zone offset the southeastern block down to the south. Rocks of the batholith of Pintlar Creek (Tpc) are faulted against Oligocene(?) to Pliocene fluvial deposits (Hanneman, 1987) or against metamorphosed rocks assigned to the Mount Shields Formation. Granitic rocks and metasedimentary rocks are sheared, brecciated, and penetratively deformed for distances of as much as 0.2 mi (0.32 km) from the trace of the faults.

REGIONAL INTERPRETATION OF STRUCTURE AND PLUTONIC ROCKS

In the Anaconda Range and adjacent areas, multiple events of Late Cretaceous thrust faulting and folding were followed by episodes of plutonism that continued into Eocene time; early plutonic events may have overlapped waning stages of thrust faulting, and high-angle faults and uplift of the Anaconda Range may have accompanied waning phases of plutonism.

The thrust faults in the Anaconda Range are part of the thrust-sheet terrane of the Sapphire thrust plate (fig. 4), which is characterized by stacked thrust sheets that were transported eastward and later folded and cut by younger imbricate thrusts; the Anaconda Range shows the deepest exposed levels of the thrust-sheet terrane in the Sapphire thrust plate. In the thrust-sheet terrane, the sequence of polyphase thrust faulting and folding can generally be divided into three main phases (Lidke and Wallace, 1988): (1) an early phase of overthrusting that stacked thrust sheets; (2) an intermediate phase of folding that deformed the stacked thrust sheets; and (3) a late phase that tightened and overturned some folds, and that locally cut and offset folds along imbricate and out-of-syncline thrusts. The precise ages are not known for individual thrust faults and folds, but relative ages define the sequence of the phases. In the thrust-sheet terrane of the Sapphire thrust plate, the presence of large-scale, parallel folds and late-phase imbricate thrust faults, which deformed stacks of thrust sheets, predicts the presence of still deeper thrust faults that served as sole faults for those folds and imbricate thrusts (Lidke and Wallace, 1988). At the deep levels of the thrust-sheet terrane exposed in the Anaconda Range, large-scale folds and imbricate thrust faults of the northern part of the area terminate above the Cutaway thrust that served as the sole fault for those large-scale folds and imbricate thrust faults that deformed stacked thrust sheets above the Cutaway thrust. The Cutaway thrust is the basal fault of that folded thrust-sheet stack in the northern part of the area (section A-A' and B-B'), and the Cutaway thrust is relatively younger than the over-lying folded thrusts in that stack.

The folded stack of thrust sheets in the northern part of the area contains the Georgetown and East Fork thrusts, which are folded harmonically into the large-scale folds above the Cutaway thrust. Lidke and Wallace (in press) interpret the Late Cretaceous kinematic development of this thrust-sheet stack to be: (1) an early phase of deformation stacked thrust sheets during episodes of overthrusting along the Georgetown and East Fork thrusts, and (2) intermediate and late phases of deformation folded and faulted the stacked thrust sheets during an episode of overthrusting along the Cutaway thrust. The principal structural and stratigraphic relations among the stacked thrust sheets could have resulted from the following sequence of overthrusts (fig. 5): (1) The Georgetown thrust formed first, (2) the East Fork thrust formed beneath the Georgetown thrust, but farther east the East Fork thrust ramped across, stepped over, and duplicated the Georgetown thrust, and (3) the Cutaway thrust formed last. The western part of the Cutaway thrust formed beneath the East Fork thrust as a reactivated, old segment of the Georgetown thrust that had been stepped over by the East Fork thrust; the eastern part of the Cutaway thrust formed as a new fault segment that may have ramped across, stepped over, and duplicated eastern segments of the Georgetown and East Fork thrusts.

Although the Cutaway thrust is the basal fault of the thrust-sheet stack in the northern part of the area, the Cutaway thrust apparently does not represent a basal decollement for the thrust-sheet terrane because the Cutaway thrust is folded harmonically with an underlying, unnamed sheet thrust in the Fishtrap nappe complex (section C-C'), and about 5 mi (8 km) east of the map area the Cutaway thrust is folded above a deeper, less-deformed and relatively younger thrust mapped on Mount Haggin by Emmons and Calkins (1913). The unnamed folded thrust fault in the Fishtrap nappe complex may represent a branch fault of the Cutaway thrust or the unnamed thrust may represent an eastern segment of the East Fork thrust that was stepped over by the Cutaway thrust (fig. 5). The large-scale folds that deformed the unnamed thrust and the Cutaway thrust in the Fishtrap nappe complex and those folds that deformed the Cutaway thrust east of the area near Mount Haggin are younger than the Cutaway thrust and they are older than the early Eocene stocks that cut them.

The Fishtrap nappe complex may locate a ramp along a blind thrust below that may connect to the thrust mapped by Emmons and Calkins (1913) on Mount Haggin. Flood (1974, p. 45 and 52) suggested that the synformal anticline of the Fishtrap nappe complex was a western part of an overturned anticline that directly overlies the thrust mapped on Mount Haggin by Emmons and Calkins (1913; section E-E'). The overturned anticline on Mount Haggin has a similar geometry to the recumbent anticline at Saddle Mountain shown in the eastern part of the Fishtrap nappe complex in section C-C'. We infer that the thrust at Mount Haggin cuts the East Fork and Cutaway thrusts, which are folded in the hanging-wall. The blind thrust inferred at depth, beneath the broad anticline that contains the Fishtrap nappe complex (section C-C'), probably has a ramp that rises to the east to reach structural levels at which the East Fork thrust is encountered by the thrust at Mount Haggin.

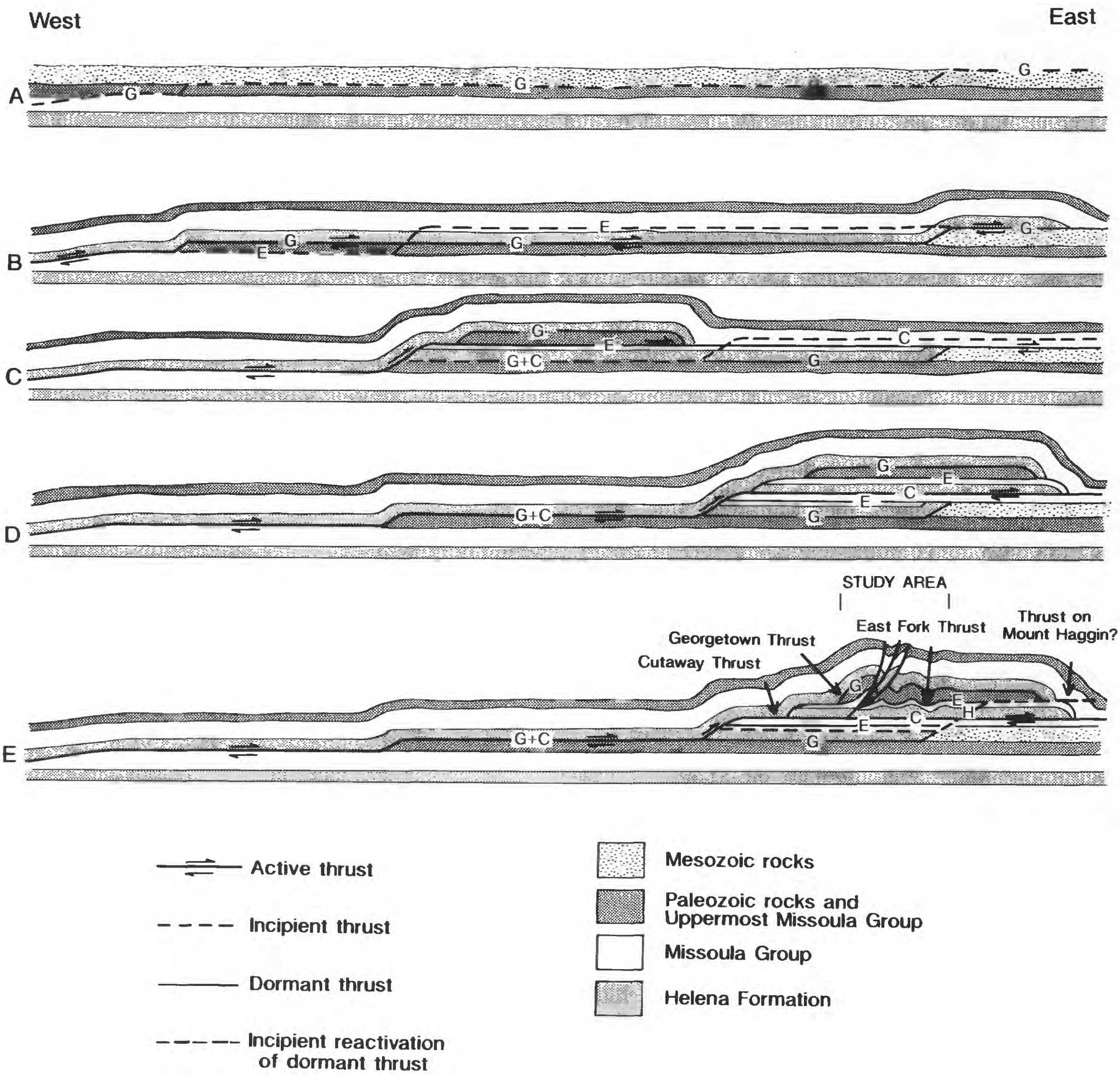


Figure 5.--Diagrammatic sections showing interpretation of the sequential development of thrust faults and folds in the study area. Scale is approximate: study area, shown in section E, about 9 mi (14.5 km) long; rock units are generalized. A, undeformed; B, movement along the Georgetown thrust; C, movement along the East Fork thrust; D, movement along the Cutaway thrust; E, folding and movement along the imbricate and out-of-syncline thrusts during some movement along the Cutaway thrust.

Northeast of the Fishtrap nappe complex, between the east border of the map area and the thrust on Mount Haggin farther to the east, another prominent broad anticline occurs (Emmons and Calkins, 1913; section E-E'), and that anticline may also mark a buried, northeasterly continuation of the ramp inferred beneath the Fishtrap nappe complex. Figure 5E suggests that the thrust on Mount Haggin is present at depth in the map area and figure 5E also shows the probable position of the principle ramp and flat segments of this blind thrust with respect to the position of the Cutaway thrust and the overlying stacked thrust sheets of the northern part of the area.

Relative age relations among the stacked and folded thrust sheets in the Anaconda Range suggest that this region was tectonically thickened by continued stacking and restacking of thrust sheets along master thrusts that formed at progressively deeper structural levels (fig. 5), and as a consequence of progressive thickening and loading, the youngest and deepest thrusts may have deformed rocks that behaved in a more ductile manner than did rocks folded and faulted at higher structural levels. Deformation that formed the tight, recumbent folds in the Fishtrap nappe complex was more ductile than the deformation that formed the broad, open folds that overlie the Cutaway thrust in the northern part of the area (Flood, 1974), and those tight folds are relatively younger than the folds and thrusts above the Cutaway thrust. Flood (1974, p. 52) suggested that the synform of the Fishtrap nappe complex resulted from extremely plastic behavior of the rocks at deep tectonic burial depths, combined with a buttressing effect in the Anaconda Range that apparently inhibited eastward transport of these deeply buried, ductile rocks during regional folding and thrust faulting. Our interpretation of the folds in the Fishtrap nappe complex builds on those two aspects suggested by Flood (1974), and we suggest the buttress could have been the ramp that we infer is beneath the Fishtrap nappe complex. The buttressing effect of that ramp might have formed the synformal anticline and the related tight folds in the western part of the Fishtrap nappe complex without requiring substantial clockwise rotation that Flood (1974) suggested. The synformal anticline and an underlying antiform shown in section C-C' could have formed when rocks below and west of the ramp became too plastic to transfer stress and movement to rocks above and east of the ramp. Waning movement of rocks along the basal, western part of the fault and movement of those rocks up the face of the ramp may have been accommodated by ductile shortening of rocks along the west side of the ramp. The plastically deformed rocks that continued to move up the ramp may have been pushed and folded into the western limb of the broad anticline to form the synformal anticline. These folds may mark the depth at which a local or regional brittle-ductile transition occurred during late stages of overthrusting in the thrust-sheet terrane of the Sapphire thrust plate. Although the tectonic burial depth may have been adequate to enhance the ductile behavior of rocks in the Fishtrap nappe complex as suggested by Flood (1974, p. 43-44), the early pulses of Late Cretaceous plutonism may have provided heat sources that also contributed to the ductile behavior of rocks at these deep levels of the thrust-sheet terrane.

In the Anaconda Range the earliest Late Cretaceous stocks are prominently foliated, and waning phases of thrust faulting and folding may have overlapped with emplacement of those stocks at deep structural levels. Slip on younger and deeper-formed thrusts, like the thrust on Mount Haggin (Emmons and Calkins, 1913), might have produced foliation in older stocks intruded at deep structural levels. In the southwestern part of the map area, Desmarais (1983, p. 123) related development of foliation in the stocks of Surprise Lake and Jennings Camp Creek plus ductile deformation of previously thrust-faulted and folded host rocks to syntectonic intrusion of magma that occurred during late stages of thrust faulting along deep, buried faults of the Sapphire thrust plate. Although uranium-lead ages of about 78 $\pm$ 20 Ma from those foliated syntectonic stocks of the Idaho batholith have a large analytical error and do not firmly establish the precise age of cooling of syntectonic plutons in that part of the Anaconda Range, potassium-argon ages from those same stocks indicate that the emplacement age of the stocks does predate about 70 Ma and is probably closer to the 78 Ma uranium-lead ages than the analytical error might suggest (Desmarais, 1983, p. 92 and 99). In the northeastern part of the map area, the foliated stock of Storm Lake has a potassium-argon age on biotite of about 78 Ma, which is supported by an $Argon^{39}/Argon^{40}$ analysis, and this stock cuts the Cutaway thrust. Relations between the stock of Storm Lake and the thrust on Mount Haggin are not known, but it appears that a western projection of the thrust on Mount Haggin would encounter the stock of Storm Lake at depth in the northeastern part of the map area (Emmons and Calkins, 1913, section E-E'). In the Flint Creek Range, about 20 mi (32 km) to the north of the stock of Storm Lake (fig. 4), the granodiorite stock of Racetrack Creek has a prominent flat foliation that apparently formed as the magma cooled and then was intruded during slip on a low-angle thrust (C.M. Trautwein, U.S. Geological Survey, 1988, oral commun.). Although isotopic ages are lacking from the stock of Racetrack Creek, the nonfoliated, 60-64 Ma Mount Powell batholith (figs. 4 and 6) cuts the foliated stock of Racetrack Creek.

Foliated Late Cretaceous stocks in the Anaconda Range apparently were emplaced during slip at deep levels of the thrust-sheet terrane during the same time that other nonfoliated stocks and batholiths were emplaced at tectonically inactive, higher levels in the thrust-sheet terrane. Nonfoliated stocks at Garnet and Miners Gulch have concordant potassium argon ages on biotite and hornblende of about 81 and 82 Ma; the nonfoliated Boulder, Philipsburg, and Sapphire batholiths have potassium-argon ages of between about 78 and 73 Ma (figs. 4 and 6). The Miners Gulch stock and the Philipsburg and Sapphire batholith penetrated high into folded thrust-sheet stacks, well above predicted sole faults for those folded stacks. Isotopic ages of the plutonic rocks that cut thrust faults and folds in the Sapphire thrust plate suggest that structures in the upper levels of the thrust-sheet terrane and structures of the frontal imbricate terrane formed prior to about 78 Ma, and perhaps prior to 81 or 82 Ma, whereas structures near the base of the thrust-sheet terrane may have formed at about 78 Ma or later. The deep structures of thrust-sheet terrane exposed in the Anaconda Range were inactive during about 54-50 Ma when the early to middle Eocene stocks and batholiths intruded, and probably were inactive during about 66-60 Ma when the nonfoliated, early to late Paleocene plutons of the Mount Powell batholith and Royal stock intruded similarly deep levels of the thrust stack in the Flint Creek Range (figs. 4 and 6)

Our data suggest that the period of regional uplift that affected west-central Montana may have been partly coincident with intrusion of Late Cretaceous to Paleocene plutons into the Sapphire thrust plate. Although evidence of this regional uplift in the Anaconda Range is sparse, lithified conglomerate of Paleocene or Eocene age occurs on the north flank of the Anaconda Range, north of the wilderness area boundary, and similar conglomerate occurs on the east flank of the Flint Creek Range and in lower drainages of the southern Sapphire Mountains (Emmons and Calkins, 1913; Csejtey, 1963; Poulter, 1956). The distribution of these deposits indicate that the Anaconda and Flint Creek Ranges and the southern Sapphire Mountains were positive topographic features by Paleocene or Eocene time. Interpretation of isotopic data and mineral equilibria from plutons in the Anaconda Range suggests that plutons of the Idaho batholith were uplifted from a depth of about 9.5-12.5 mi (15-20 km) between Late Cretaceous and middle Eocene time (Desmarais, 1983). About 6-9.5 mi (10-15 km) of the uplift occurred before early and middle Eocene time, when stocks and batholiths of the plutonic complex in the Anaconda Range were intruded (Desmarais, 1983); the uplift was probably regional because the Idaho batholith and its metamorphic aureole in Belt rocks show no structural discontinuity.

During early and middle Eocene time (54-46 Ma) a large volume of granitic magma was emplaced at epizonal levels in the map area, which formed the batholiths of Pintlar Creek and Hearst Lake (Tpc and Thl), and the stocks of Elk Park (Tep), Upper Seymour Lake (Tsl), and Lake of the Isle (Tli). These stocks and batholiths have concordant potassium-argon ages from mineral pairs that span 55 to 46 Ma (table 1 and fig. 6). The Lowland Creek Volcanics, an extensive volcanic field east and northeast of the wilderness area, are 53-51 Ma (early to middle Eocene) (H.H. Mehnert, U.S. Geological Survey, written commun., 1987), and these volcanics were erupted at about the same time the principal batholiths of the plutonic complex in the Anaconda Range were emplaced at depth. Emplacement and crystallization of the plutonic suite appears to be partly contemporaneous with the Challis Volcanic Group (51-45 Ma, middle Eocene) (Ekren, 1985; Fisher and others, 1991), a period during which several isolated volcanic fields, such as the Douglas Creek and Bearmouth Volcanic fields (47-44 Ma), were erupted about 48 mi (77 km) north of the Anaconda Range (Carter, 1982). The extensive rhyolite dikes and pods (43 Ma) that occur in the southwestern part of the map area probably represent the final phases of the early to middle Eocene magmatic event in the Anaconda Range and the rhyolite appears to post-date the Challis Volcanic Group and the isolated volcanic fields to the northwest, north, and northeast of the map area.

Local uplift of the Anaconda Range after early Eocene time followed emplacement of the Eocene plutons and probably was accompanied by slip along northeast-striking, high-angle faults of the southern part of the range. Local uplift of about 0.5-3 mi (1-5 km) in the Anaconda Range exposed granodiorite of the batholiths of Pintlar Creek and Hearst Lake and smaller granodiorite stocks to erosion; these batholiths are unconformably overlain by Oligocene to Pliocene fluvial and alluvial deposits. The position and prominent northeasterly trend of the exposed parts of these batholiths is mimicked by the position and trend of the uplift, and by the topographic expression of the Anaconda Range. The northeast-trending uplift appears to have been dome-like, but the rocks and Late Cretaceous structures are more strongly tilted on the northern flank of the range than they are along the southern flank of the range, apparently because the uplift was asymmetrical and accompanied by some movement along range-front faults that bound the southern flank of the range. The northeast-striking high-angle faults, which include the range-front faults, postdate the early and middle Eocene stocks and batholiths that they cut; some sheared rhyolite dikes (43 Ma) emplaced along these faults indicate that the high-angle faults both predate and postdate intrusion of the rhyolite. After about 43 Ma, the high-angle fault system that borders the Anaconda Range on the south displaced the granodiorite of Pintlar Creek (early and middle Eocene) upward against Oligocene to Pliocene fluvial and alluvial deposits (Henneman, 1987). O'Neill and Lopez (1985, p. 439) indicated that some movement along this bounding range-front fault system is as young as Quaternary in age, inasmuch as glacial deposits are locally offset along the south flank of the Range.

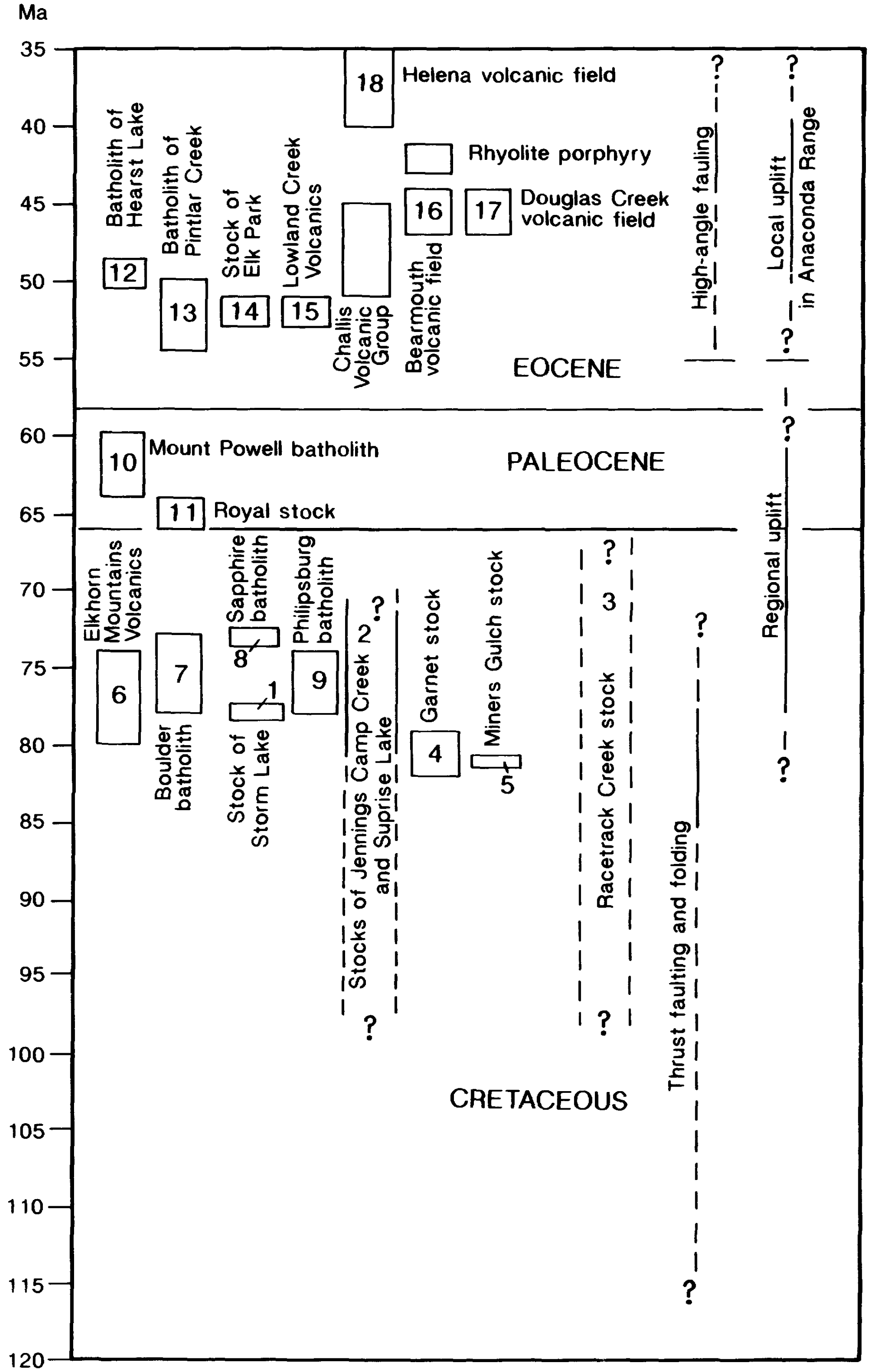


Figure 6.--Principal plutonic and tectonic events in the region of the Anaconda-Pintlar Wilderness Area, western Montana. Time-scale from the Geological Society of America, 1983, Decade of North American Geology, Boulder, CO. See Figure 4 for locations of plutons and volcanic fields.

DESCRIPTION OF MAP UNITS[1]

QUATERNARY AND TERTIARY DEPOSITS

Qal **Alluvial deposits (Holocene)**--Stream deposits of non-consolidated, poorly sorted, bouldery, sandy gravel. Mainly reworked till and outwash deposits. In most glaciated valleys, alluvium is confined to active stream channels and is not shown on map as a separate deposit

Qs **Landslide deposits (Holocene and Pleistocene)**--Angular to rounded, pebble- to boulder-size rock fragments in a matrix of sand and finer material, weathered rock fragments, or till

Qo **Outwash (Pleistocene)**--Mainly glacio-fluvial deposits of poorly to moderately sorted, bouldery gravel, sand, and silt. Stratification poorly to well developed. Outwash deposits generally have braided channel pattern on surface. Includes Holocene alluvium in active stream channels

Qt **Till (Pleistocene)**--Poorly sorted and poorly stratified bouldery, sandy, silty, and clay-rich gravel. Includes older till preserved mainly as erosional remnants mantling sides and tops of ridges; hummocky surface poorly preserved on older till. Younger till fills much of present drainages and hummocky surface well-preserved on younger till. Till of different ages not separated on map. Locally includes Holocene alluvium in most active stream channels

Tg **Gravel deposits (Pliocene?)**--Moderately to poorly stratified and poorly sorted sandy and silty gravel, and poorly sorted boulder and cobble gravel in a matrix of sand, silt, and clay. Clasts are rounded to subrounded. Deposited as alluvial fans on pediments. Thickness not known

Ts **Sedimentary deposits (Miocene and late Oligocene(?))**--Buff, pale-orange, and yellowish-brown interbedded tuffaceous sandstone, siltstone, and mudstone. Contains some beds of coarse pebble and cobble conglomerate. Probable fluvial deposits (Hanneman, 1987). Thickness not known

IGNEOUS ROCKS[2]

Tertiary volcanic rocks

Tb **Basaltic rocks (Miocene or late Oligocene(?))**--Dark-gray, fine-grained, porphyritic basalt that contains phenocrysts of olivine and plagioclase. Flows are vesicular to scoriaceous. Occurs only in southeast part of map. Thickness 6-30 ft (1.8-9 m) (Hanneman, 1987)

Tv **Rhyolite tuff (Miocene or late Oligocene(?))**--Brown, reddish-brown, and gray welded tuff that contains phenocrysts of biotite, feldspar, and quartz. Pumice fragments partly collapsed and fused. Occurs only in East Fork of Fishtrap Creek. Thickness not known (Hanneman, 1987)

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[1] Plutonic and volcanic rocks named according to the IUGS classification (Streckeisen, 1973 and 1978).

[2] Percentages of mineral components are average volumes determined from 1,000 point-counts per thin section or stained rock slab; therefore, the total percent of mineral components may not equal 100%. Plagioclase composition determined by flat-stage and universal-stage optical methods.

Plutonic Suite in the Anaconda Range

Includes the following major units: granodiorite and monzogranite stocks of Warren Lake (TKw), Beaverhead Mountain (TKb), and Maloney Basin (TKm), muscovite-biotite granodiorite of the Pintlar Creek batholith (Tpc), biotite granodiorite of the stock of Elk Park (Tep), biotite-muscovite granodiorite and monzogranite of the Hearst Lake batholith (Thl), and biotite granodiorite of the stock of the Upper Seymour Lake (Tsl). The suite also includes dacite porphyry and granodiorite porphyry dikes (Td and TKd), granite, pegmatite, and aplite dikes (Tap and TKg), and rhyolite porphyry dikes, sills, and pods (Tr)

Tertiary stocks, dikes, and sills

Tr **Rhyolite porphyry and porphyritic rhyolite (middle Eocene)**--Pinkish-brown, reddish-brown, buff, or light-gray dikes, sills, and pods that commonly contain 20-40 percent phenocrysts and glomerophenocrysts of potassium feldspar, plagioclase, and quartz and lesser amounts of biotite. Microgranular and felted groundmass consists mainly of quartz, plagioclase, and potassium feldspar. Spherulitic texture in groundmass is common. Accessory minerals include sphene, allanite, apatite, zircon, and opaque minerals. Some quartz and potassium feldspar phenocrysts have conspicuous resorption features, and quartz is commonly smoky. Coronas of quartz, feldspar, and muscovite surround quartz and feldspar phenocrysts. Locally contains two types of potassium feldspar, one that shows simple Carlsbad twinning (orthoclase), and one that shows faint grid twinning and zonation (zoned microcline?). Plagioclase is altered to sericite; biotite is commonly altered to chlorite or to aggregates of muscovite, secondary biotite, and opaque minerals. Occurs as dikes, sills, and irregular pods in most of map area. Dikes are as wide as about 1,000 ft (305 m) but most range between 10-50 ft (3-15m) wide

Td **Dacite and granodiorite porphyry (middle Eocene)**--Light- to medium-gray porphyry dikes that vary in texture from granodiorite to dacite. Phenocrysts and glomerophenocrysts (25-70 percent, commonly 45-55 percent) consist of plagioclase, quartz, biotite, potassium feldspar, and rarely hornblende. Microgranular to felted groundmass consists of plagioclase, quartz, biotite, and potassium feldspar. Quartz phenocrysts commonly are rounded and embayed. Phenocrysts of potassium feldspar are embayed and rimmed by plagioclase (rapakivi texture). Coronas of radial or granular intergrowths of quartz, feldspar, and muscovite commonly surround phenocrysts and glomerophenocrysts. Some dikes are aphyric at contact and grade inward to porphyritic dacite, dacite porphyry, and to fine-grained granodiorite near the center. Some dikes also change in texture along strike. Most dikes are 5-50 ft (1.5-15 m) wide

Tap **Granite, granodiorite, pegmatite, and aplite (middle Eocene)**--Light-gray, pink, and buff, fine- to coarse-grained dikes. Composed of quartz, plagioclase, potassium feldspar, and muscovite; fine-grained, orange-red garnet is a common accessory mineral. Textures vary from fine- to coarse-grained and from slightly porphyritic to pegmatitic. Rocks are probably late-crystallizing phases of batholiths of Hearst Lake and Pintlar Creek

Tsl **Granodiorite of Upper Seymour Lake (middle Eocene)**--Very light gray, medium-grained, allotriomorphic- to hypidiomorphic-granular, and commonly slightly porphyritic, leucocratic, biotite granodiorite. Contains essential plagioclase (45 percent), quartz (28 percent), and potassium feldspar (19 percent); varietal biotite (7 percent) and hornblende (less than 1 percent); and accessory magnetite-ilmenite, sphene, allanite, zircon, apatite, and epidote. Plagioclase shows normal zoning, commonly oscillatory, from An 31 (core) to An 19 (rim). Most potassium feldspar is microcline and microcline perthite; patch and string perthite are common. Fine-grained hornblende commonly occurs as glomerophenocrysts with biotite and sphene. Forms a stock in the east part of map area. Many granodiorite and dacite porphyry dikes in vicinity of Mount Howe and Mount Evans originated from granodiorite stocks of Upper Seymour Lake and Lake of the Isle

Tli **Granodiorite of Lake of the Isle (middle Eocene)**--Composition and texture of this stock is same as granodiorite of Upper Seymour Lake. Stocks may be connected at depth, but are separated at the surface by metasedimentary rocks of the Belt Supergroup

Thl **Granodiorite of Hearst Lake (middle Eocene)**--Very light gray, medium- to coarse-grained, allotriomorphic- to hypidiomorphic-granular, seriate and porphyritic, biotite-muscovite leucomonzogranite and leucogranodiorite. Contains essential plagioclase (40 percent), quartz (30 percent), and potassium feldspar (22 percent); varietal muscovite (4 percent) and biotite (3 percent); and accessory magnetite-ilmenite, zircon, apatite, epidote, allanite, rutile, and fluorite. Plagioclase is faintly zoned from An 28 (core) to An 18 (rim), is slightly altered to sercite, and commonly contains inclusions of biotite and muscovite. Potassium feldspar is mostly microcline that contains patch and string perthite. Porphyritic rocks contain subhedral to euhedral phenocrysts of potassium feldspar that are as long as 1 cm; phenocrysts contain abundant inclusions of plagioclase and biotite. Biotite is slightly altered to chlorite. Muscovite, mostly primary, is intergrown with biotite, although some muscovite formed from deuteric alteration. Forms a batholith, most of which is located east and northeast of map area. This granodiorite is exposed in the Sullivan and Seymour Creek areas, but is named for exposures at Hearst Lake, 7 mi (11 km) northeast of northeastern corner of map area

Tep **Granodiorite of Elk Park (middle to early Eocene)**--Medium- to fine-grained, slightly porphyritic, hypidiomorphic granular, biotite granodiorite. Contains essential plagioclase (40 percent), quartz (28 percent), and potassium feldspar (19 percent); varietal brown biotite (9 percent); and trace amounts of accessory hornblende, allanite, apatite, zircon, and opaque minerals. Plagioclase is commonly zoned from about An 36 (core) to An 22 (rim), but some crystals have reverse zoning that produced low An cores. Resorption boundaries and reaction rims poorly developed in plagioclase. Microcline is dominant over orthoclase, perthite is mainly en-echelon strings, and myrmekitic intergrowths are rare. Biotite is commonly altered to chlorite, and cores of plagioclase phenocrysts are altered to fine-grained mica or clay. Microcataclastic textures are common; potassium feldspar is pervasively strained and sheared, quartz forms polycrystalline grains and lenticular feathered grains, biotite is crenulated, and plagioclase twins are bent

Tpc **Granodiorite of Pintlar Creek (middle to early Eocene)**--Batholith composed of fine-, medium-, and coarse-grained, porphyritic to equigranular, hypidiomorphic-granular, muscovite-biotite granodiorite. Contains essential plagioclase (42 percent), quartz (29 percent), and potassium feldspar (21 percent); varietal green and brown biotite (3 percent) and muscovite (3 percent); and trace amounts of accessory zircon, garnet, apatite, epidote, rutile, and opaque minerals. Plagioclase is weakly zoned from about An 28 (core) to An 19 (rim); zoning is progressive and oscillatory. Resorption boundaries and reaction rims are poorly defined. Potassium feldspar is mainly microcline, but lesser amounts of orthoclase occur. Myrmekitic borders are poorly developed. Perthite is mainly string, bleb, and patch types. Potassium feldspar is commonly fractured and shows wavy extinction. Plagioclase and potassium feldspar are partly altered to fine-grained mica and epidote, and biotite is partly altered to chlorite, opaque minerals, and secondary muscovite. Microcataclastic textures are common in rocks near contact zones of pluton; these textures consist of sutured and microbrecciated quartz, internal dislocations and microbrecciated zones in potassium feldspar, bent twin lamellae in plagioclase, and fluxion textures in mica. Contacts are generally discordant with host rocks

Early Tertiary or Late Cretaceous stocks

TKm **Granodiorite stock of Maloney Basin**--Medium- and fine-grained, equigranular and slightly porphyritic, hypidiomorphic-granular hornblende-biotite granodiorite. Contains essential plagioclase (48 percent), quartz (24 percent), and orthoclase (16 percent); varietal brown and green biotite (7 percent) and green hornblende (about 1 percent); and trace amounts of accessory allanite, zircon, apatite, sphene, epidote, and opaque minerals. Plagioclase is zoned from about An 31 (core) to An 19 (rim); progressive and oscillatory zoning are common. Myrmekitic intergrowths, reaction rims, and resorption borders are common at orthoclase-plagioclase boundaries. Bleb and string perthite are common. Some alteration affected plagioclase and alteration consists of fine-grained mica and rare epidote in crystal cores. Biotite is altered to chlorite along cleavages, and cores of hornblende crystals are replaced by biotite. Fine-grained, porphyritic, leucocratic zones occur adjacent to contacts of the stock. Contacts with metasedimentary rocks are concordant and discordant

TKb **Monzogranite stock of Beaverhead Mountain**--Medium- and coarse-grained, equigranular and porphyritic, hypidiomorphic-granular biotite granodiorite. Contains essential plagioclase (41 percent), quartz (27 percent), and potassium feldspar (27 percent); varietal brown biotite (5 percent); and trace amounts of zircon, apatite, allanite, sphene, fluorite, and opaque minerals, such as pyrite, chalcopyrite(?), and limonite. Plagioclase is zoned from about An 26 (core) to An 16 (rim); prominent zoning is oscillatory and progressive. Potassium feldspar is mainly orthoclase; myrmekite and reaction rims are poorly developed at plagioclase-potassium feldspar boundaries. Bleb, string, and patch perthite are common. Cores of plagioclase are altered to fine-grained mica. Biotite is altered to chlorite and fine-grained mica. Some contacts with metasedimentary rocks are concordant and some are discordant

TKw **Granodiorite stock of Warren Lake**--Fine- and medium-grained, equigranular to slightly porphyritic hypidiomorphic-granular biotite granodiorite. Contains essential plagioclase (46 percent), quartz (26 percent), and potassium feldspar (20 percent); varietal brown biotite (7 percent); and trace amounts of accessory zircon, allanite, sphene, green hornblende, apatite, and opaque minerals. Plagioclase is zoned from about An 28 (core) to An 16 (rim); conspicuous zoning is oscillatory and progressive. Prominent resorption boundaries occur in plagioclase. Potassium feldspar is mainly sheared orthoclase; myrmekitic intergrowths are well-developed at interfaces between orthoclase and plagioclase. Minor alteration of plagioclase cores to fine-grained mica is common. Biotite is altered to chlorite at grain edges and along cleavages. Quartz grains are polycrystalline. Contact between stock and host rocks is discordant

Early Tertiary or Late Cretaceous dikes, sills, and pods

TKg **Granite porphyry and aplite**--Light-gray, fine-grained, porphyritic sills, dikes, and pods composed of plagioclase, potassium feldspar, quartz, and biotite. Accessory minerals are sphene, apatite, zircon, opaque minerals, and allanite. Texture varies between fine-grained porphyry and porphyritic, fine-grained holocrystalline rocks. Contains smoky quartz and some zoned microcline(?). Includes rare dikes and pods of aplite. Possibly comagmatic with rhyolite porphyry (Tr) or late-phase product of monzogranite of Beaverhead Mountain (TKb) or granodiorite of Warren Lake (TKw)

TKd **Dacite porphyry and granodiorite porphyry**--Light-gray to medium-gray porphyry that varies in texture and composition from granodiorite to dacite. These dikes, sills, and pods have the same variation in texture and composition as dacite porphyry and granodiorite porphyry (Td), but age control of these dikes, sills, and pods is less precise

Other Tertiary or Cretaceous stocks, dikes, and sills

TKa **Porphyritic quartz diorite and andesite**--Dark-gray and greenish-gray, slightly porphyritic dikes, sills, and pods that are characterized by phenocrysts of plagioclase and hornblende. Felted texture dominates. Plagioclase phenocrysts show faint normal zoning and late-stage reaction rims; plagioclase partly altered to fine-grained mica. Hornblende, which occurs as prismatic phenocrysts and as interstitial minerals, is commonly altered to epidote, chlorite, sericite, calcite, and opaque minerals. Quartz and calcite occur as interstitial material. Exposed only in north-central part of wilderness and may be related to the stock of Storm Lake (Kst) and quartz diorite sill (Kqd)

TKi **Granitic stocks**--Medium-grained, foliated granitic rocks. Occur as small exposures near mouths of East Fork Fishtrap and La Marche Creeks

Cretaceous stock of Storm Lake and related dikes and sills

Kst **Granodiorite stock of Storm Lake**--Medium-gray to dark-greenish-gray, mainly medium-grained, hypidiomorphic-granular to slightly or moderately porphyritic, hornblende- and biotite-rich granodiorite, tonalite, quartz monzodiorite, quartz diorite, and diorite. Compositions, textures, and intrusive relations of components of this stock vary greatly; compositions are given as ranges and averages for all rock types. Contains essential plagioclase (average 38 percent, range 16-63 percent), hornblende (average 24 percent, range 6-59 percent), biotite (average 12 percent; range 0-28 percent), and quartz (average 12 percent, range 3-21 percent); varietal augite (average 4 percent, range 0-35 percent) and potassium feldspar (average 3 percent, range 0-18 percent); and trace amounts of accessory magnetite-ilmenite, sphene, zircon, apatite, allanite, and epidote. Augite commonly occurs as cores in hornblende crystals. Plagioclase has normal, reverse, and oscillatory zoning, and generally ranges in composition from An 45 (core) to An 35 (rim); maximum An content for plagioclase cores is An 60 and the minimum An content in rims is An 22 for all rock types in the stock. Alteration is slight to moderate in some rocks; secondary epidote, chlorite, sericite, calcite, and zoisite-clinozoisite are most common. Mafic phases commonly cut by dikes and irregular pods of less mafic phases. Includes breccia that contains subangular to rounded fragments of more mafic rocks in a matrix of less mafic rock. Less mafic rocks are dominant west of Storm Lake and Storm Lake Creek. Foliation of some rocks suggests that metamorphic recrystallization occurred after crystallization of some phases of magma. Xenoliths of metasedimentary rocks are common in most phases of the stock; xenoliths range from a few feet to several hundred feet in diameter

Kqd **Quartz diorite**--Dark-gray to dark-greenish-gray, hypidiomorphic-granular to granoblastic sill composed of plagioclase, hornblende, biotite, and quartz. Sill is metamorphosed near contacts with younger batholiths and stocks west of Mount Evans where it occurs in Middle Proterozoic metasedimentary rocks; sill is probably related to the stock of Storm Lake (Kst)

Late and Early(?) Cretaceous stocks of the Idaho batholith

Ksl **Granodiorite stock of Surprise Lake**--Medium-grained, equigranular to slightly porphyritic, hypidiomorphic granular, foliated biotite granodiorite and biotite tonalite. Contains essential plagioclase (54 percent), quartz (24 percent), and potassium feldspar (7 percent); varietal brown biotite (14 percent); and trace amounts of accessory green hornblende, zircon, sphene, apatite, tourmaline, and opaque minerals. Plagioclase is weakly zoned; average composition is about An 37. Potassium feldspar (orthoclase and microcline) forms anhedral interstitial masses or subhedral phenocrysts. Myrmekitic intergrowths are well developed at crystal contacts between potassium feldspar and plagioclase. Alteration of plagioclase to fine-grained mica ranges from moderate alteration of cores and crystal boundaries to slight alteration of cores. Potassium feldspar shows little alteration. Biotite and hornblende are altered slightly to chlorite. Prominent foliation is defined by aligned biotite grains. Contacts with migmatitic metasedimentary rocks are concordant and discordant

Kjc **Granodiorite stock of Jennings Camp Creek**--Medium-grained, equigranular to slightly porphyritic, foliated hornblende-biotite granodiorite and hornblende-biotite tonalite. Contains essential plagioclase (47 percent), quartz (25 percent), and potassium feldspar (4 percent); varietal brown biotite (13 percent) and green hornblende (7 percent); and trace amounts of accessory zircon, sphene, epidote, clinozoisite, apatite, allanite, and opaque minerals. Plagioclase is weakly zoned from An 37 (core) to An 32 (rim). Potassium feldspar (mainly microcline) forms anhedral interstitial masses. Myrmekitic intergrowths are well developed at some contacts between postassium feldspar and plagioclase. Alteration of plagioclase, potassium feldspar, and biotite is similar to that of stock of Suprise Lake. Hornblende is moderately to slightly altered to biotite, chlorite minerals, and opaque minerals. Rocks are conspicuously foliated; zones of hornblende-biotite tonalite and granodiorite alternate with biotite tonalite and granodiorite. Contacts with migmatitic metasedimentary rocks are concordant and discordant

PALEOZOIC SEDIMENTARY ROCKS

IPq **Quadrant Quartzite (Pennsylvanian)**--White, buff, or tan, massive-weathering, fine- to medium-grained quartzarenite composed of subangular to rounded, well-sorted quartz; small percentage of lithic fragments. Detrital grains are cemented by quartz. Light-red, orange, and rusty patina formed from weathering. Prominent ridge-forming unit. Not metamorphosed in map area. Approximate thickness 300 ft (90 m)

IPMs **Snowcrest Range Group (Early Pennsylvanian and Late Mississippian)**--Grayish-red and dark-red weathering, calcareous shale and interbedded siltstone, some olive-drab shale, and some white to gray limestone nodules and thin, discontinuous beds of limestone. Lower 100 ft (30 m) contains a few lenticular beds of reddish, fine-grained, dolomite-cemented sandstone as thick as 2 ft (0.6 m). Small yellow or green reduction spots are common in red shale. Unit represents thin lateral equivalents of the Kibbey Sandstone (at base), Lombard Limestone, and Conover Ranch Formation (at top) (B.F. Wardlaw, U.S. Geological Survey, written commun., 1987). Not metamorphosed in map area. Approximate thickness 330 ft (100 m)

Mm **Madison Group (Late and Early Mississippian)**--Upper 1,500 ft (460 m) is dominantly light-bluish-gray, thickly bedded crinoidal limestone composed mainly of biosparite, biosparmicrite, and some beds of biomicrite and micrite. Upper part probably equivalent to Upper and Lower Mississippian Mission Canyon Formation. Lower 400 ft (120 m) is composed of dark- and light-gray, shaly and silty, fossiliferous limestone and calcareous shale that is correlative with the Lower Mississippian Lodgepole Formation. Flaggy partings and black chert stringers and nodules are common in the lower part. Madison Group contains crinoids, rugose corals, brachiopods, gastropods, and bryozoans in micrite and biosparite. North and west of stock of Storm Lake (Kst), the Madison Group is metamorphosed to medium- and coarse-grained, white and light-gray marble. Thickness about 1,900 ft (580 m)

Dj **Jefferson Formation (Late Devonian)**--Dark-gray to black, fetid, porous, coarsely crystalline, thickly bedded dolomite and some interbeds, as thick as 5 ft (1.5 m), of bluish-gray to cream-colored limestone; limestone beds more common in upper part than in lower part. Locally, lower part contains a zone of pale-bluish-gray sedimentary breccia that consists of dispersed limestone clasts as much as 2 in. (5 cm) in diameter. Breccia zone can be several feet thick. Metamorphosed in Page Creek where slightly recrystallized rocks are striped in gray colors. Metamorphosed to medium-grained, gray and light-gray marble near granodiorite of Maloney Basin (TKm) in Carpp Creek. Thickness about 800-850 ft (245-260 m)

Dm **Maywood Formation (Late Devonian)**--Light-red, yellowish-orange, and yellowish-gray, thinly bedded dolomitic shale and siltstone. Contains some zones of pinkish-gray, sandy and argillaceous dolomite interbeds as thick as 10 ft (3 m) and contains some thin, gray limestone interbeds. Upper part contains a pinkish-light-gray, medium-grained quartzite that is about 15-30 ft (5-9 m) thick. Dark-gray, coarsely crystalline dolomite interbeds occur in the upper part and are transitional into the overlying Jefferson Formation. Beds of dolomite-cemented, oolitic, crossbedded sandstone near basal contact. Metamorphosed Maywood Formation is not exposed in map area. Thickness about 350 ft (107 m)

Ꞓrl **Red Lion Formation (Late Cambrian)**--Light-gray limestone that contains conspicuous unevenly bedded, yellow-, red-, or orange-weathering, siliceous and argillaceous dolomite and calcite laminae; laminae are thicker and more abundant in lower part. Basal 15-30 ft (5-9 m) is grayish-red calcareous and silty shale that contains thin, gray limestone lenses about 0.5 in. (1 cm) thick. A pale-brown-weathering sedimentary breccia, 3-6 ft (1-2 m) thick, occurs near the top of this unit at several places; the breccia is composed of subangular clasts of calcareous shale in a calcareous silt and clay matrix. Metamorphism is limited to slight recrystallization of limestone beds to fine-grained marble near granodiorite of Maloney Basin (TKm). Thickness about 350 ft (107 m)

Ꞓh **Hasmark Formation (Late Cambrian)**--Light-bluish-gray to light-gray, thickly bedded to massive-weathering, fine-grained dolomite. A 5-10 ft (1.5-3 m) thick, grayish-brown shale zone occurs in middle part, and some beds of grayish-brown shale as thick as 3 ft (1 m) occur in lower part. The upper 330 ft (100 m) is mainly pale-greenish-yellow- or light-gray-weathering, thickly bedded, fine-grained dolomite; bedding is generally well-defined on weathered surfaces by white to very light yellow laminations that are slightly argillaceous and about 1 mm thick. Lower 650-700 ft (200-215 m) is mainly bluish-gray, fine-grained, crystalline dolomite; weathered surfaces show irregular light- and dark-gray mottling, granular surface texture, and light-gray twig-like protrusions that stand in relief. Oolitic and pisolitic zone occurs near base and locally near the top. Metamorphosed to fine- and medium-grained, light-gray to very light gray marble near granodiorite of Maloney Basin (TKm) and near stock of Storm Lake (Kst). Thickness about 1,000 ft (305 m)

€sh **Silver Hill Formation (Middle Cambrian)**--Upper part mainly light-bluish-gray limestone that contains conspicuous interbeds of reddish-brown and yellowish-orange, dolomite-cemented, wavy, siliceous and argillaceous laminae; upper part is similar in outcrop appearance to much of the Upper Cambrian Red Lion Formation. Lower part is dark-greenish-gray and greenish-black shale and siltstone interbedded with yellowish-gray quartzite; quartzite beds are thin and unevenly bedded, and flaser structure is common in fine-grained quartzite and siltstone. Light-green shale, 3-15 ft (1-5 m) thick, which forms the uppermost Silver Hill, was not identified in this area because of poor exposures, although the shale occurs 4.5 mi (about 7 km) to the northeast at the type section. Near granodiorite of Maloney Basin (TKm) and stock of Storm Lake (Kst), shaly rocks have been metamorphosed to dark-green and dark-gray hornfels, and limestone has been metamorphosed to very light gray, medium-grained marble in which yellowish-orange laminae were obliterated. Thickness about 150 to 200 ft (45 to 60 m)

€f **Flathead Quartzite (Middle Cambrian)**--White- to tan-weathering, fine- to medium-grained, silica-cemented quartzarenite; detrital grains rounded to well rounded. Very thin partings of light-green shale occur between some quartzarenite beds. Ripple cross-lamination and some moderate-angle, medium-scale crossbeds occur locally. Disconformity at base. Locally, formation may be absent. Metamorphosed to very light gray vitric quartzite that lacks bedding structures. Maximum thickness about 100 ft (30 m)

MIDDLE PROTEROZOIC SEDIMENTARY ROCKS OF BELT SUPERGROUP

Missoula Group

Ygr **Garnet Range Formation**--Grayish-green, olive-drab, and grayish-red siliceous quartzite and siltite, and argillaceous quartzite and siltite interbedded with grayish-red and olive-drab silty and sandy argillite. Zone of well-sorted, grayish-red and grayish-pink, slightly feldspathic quartzite contains argillaceous laminae near top. Ripple cross-laminations and planar and trough crossbeds common in quartzite beds. Siliceous quartzite near top contains abundant reduction spots that are very light gray, grayish pink, and light greenish gray. Only upper part of formation exposed in study area, and unit is in fault contact with underlying units. Metamorphosed to very light gray vitric quartzite and olive-gray and dark-gray hornfels near granodiorite of Maloney Basin (TKm) and to very light gray quartzite, schistose quartzite, and interbedded muscovite-biotite schist near stock of Storm Lake (Kst). Minimum thickness about 300 ft (90 m)

Yms **Mount Shields Formation**--Consists of three members in the region, the lower two of which occur in the map area. Principal sedimentologic characteristics of Mount Shields Formation are rhythmic bedding; flat, aggradational basal contacts of beds; and fining upward cycles

Yms2 **Member 2**--Grayish-pink, pale-red, buff, or very light-gray, fine-, medium-, and coarse-grained, poorly to moderately sorted, silica-cemented arkose, subarkose, and quartzarenite. Reddish or greenish argillite partings separate normally graded bedding units, which are about 1-10 ft (0.3-3 m) thick. Planar lamination, ripple cross-lamination, and low-angle planar and tangential crossbeds are common. Scattered red and green mud chips occur in some beds. Lower part contains several zones of dispersed pebble and cobble conglomerate. Soft-sediment deformation structures are common near base of member in exposures along Continental Divide and near Seymour Lake. Metamorphosed to very light-gray and light-greenish-gray massive-weathering quartzite, feldspathic micaceous quartzite, and thin zones of muscovite-biotite schist near Tertiary and Tertiary or Cretaceous stocks and batholiths. Metamorphosed to quartzofeldspathic migmatite near Cretaceous stocks in western part of area. Because of faulting, only incomplete sections are present. Thickness as much as 7,000 ft (2,135 m)

Yms1 **Member 1**--Argillaceous zones composed of rhythmically interbedded, moderate-red to dusky-red argillite, very pale-orange siltite, and fine-grained arkose, subarkose, and quartzarenite. Quartzitic zones composed of grayish-red, pale-orange, and light-red, well- to poorly sorted, fine- to medium-grained arkose, subarkose, and quartzarenite. Argillaceous zones contain some calcareous and dolomitic beds. Alternating argillaceous and quartzitic zones range in thickness from about 25-200 ft (8-60 m) in middle part of member one; argillaceous rocks dominate in lower part of member one, whereas quartzitic rocks dominate in upper part of member one. Mud cracks, water-expulsion structures, ripple cross-lamination, and small-scale, low-angle, planar and tangential crossbeds are common in argillite and siltite sequences. Medium-scale crossbeds and ripple cross-lamination are common in arkose, subarkose, and quartzite zones. Upper part of member contains lenticular beds of pebble conglomerate in some argillite and siltite sequences. Rocks are metamorphosed to sequences of light-colored, massive-weathering vitric quartzite and sequences of laminated dark-green and greenish-black hornfels and calc-silicate hornfels near Tertiary and Tertiary or Cretaceous stocks and batholiths. Near stock of Storm Lake (Kst), argillaceous rocks are metamorphosed to garnet-bearing schist, and quartzitic rocks are metamorphosed to quartzofeldspathic gneiss and schist. Because of faulting, only incomplete sections are present. Thickness as much as 3,000 ft (915 m)

Ysh **Shepard Formation**--Pale-green and grayish-yellow-green argillite, light-gray and greenish-gray calcareous siltite and argillite, grayish-yellow nonlaminated and laminated dolomite, very light gray and pale-yellowish-brown calcareous, dolomitic, and siliceous quartzite, medium-gray limestone, and grayish-olive-green laminated siltite. Zones of quartzite are 65-165 ft (20-50 m) thick, and some quartzite is conglomeratic. Green argillite zones are laminated and microlaminated. Shallow channels, edgewise conglomerate composed of rounded dolomite clasts, water-expulsion structures, and ripple cross-lamination are common in fine-grained rocks, and small- and medium-scale crossbeds are common in quartzite. Blackish-red, rhythmically interbedded, laminated and microlaminated argillite and dusky-red siltite occur as zones in dominantly green and dark-gray argillite and siltite. Rocks are metamorphosed to chlorite- and actinolite-bearing argillite, siltite, impure marble, and vitric quartzite. Shepard Formation occurs only west of Middle Fork of Rock Creek. Because of faulting at the top of the formation, only incomplete sections exposed in map area. Minimum thickness about 1,700 ft (520 m)

Ysn **Snowslip Formation**--Consists of variegated red and green finely laminated argillite, argillaceous siltite, siltite, and some very light gray lenticular beds and laminae of medium- and coarse-grained, well-sorted, to very well sorted, quartzarenite; grains are well rounded. Thin, lenticular, oolitic, glauconite-bearing sandstone beds, and dolomitic and calcareous argillite and siltite are common near the base. Dusky-red, moderate-yellowish-green, and grayish-green beds of argillite and siltite contain uneven and continuous laminae, mudcracks, fluid-escape structures, ripple marks, flaser bedding, and some small-scale crossbeds. Metamorphosed to blackish-red and blackish-gray phyllitic hornfels, greenish-gray phyllitic hornfels and calc-silicate beds, and very light gray, vitric, quartzite near Tertiary and Tertiary or Cretaceous stocks and batholiths. Lower part of Snowslip occurs in most of map area, but upper part occurs near the Senate Mine in the northwest part of the map area. Metamorphosed to schistose quartzite and biotite-muscovite schist near stock of Storm Lake (Kst). Minimum thickness at least 3,000 ft (915 m) at head of Copper Creek in west-central part of map area, but only about 650 ft (200 m) of the lower part is exposed throughout northern part of map area

Middle Belt carbonate

Yh **Helena Formation**--Upper part consists of beds and laminae of tan-weathering, calcareous siltite interbedded with dark-gray, argillaceous limestone and massive-weathering, laminated, medium-gray limestone zones. Some laminae and thin lenticular interbeds of calcareous and siliceous quartzite, as thick as 4 in. (10 cm), are interbedded with siltite, argillite, and limestone. In upper part, zones of impure limestone are common, whereas zones of calcite-cemented argillite, siltite, and quartzite are common in the lower part. At the top of the formation, a sequence of interbedded and microlaminated, green argillite and light-green siltite and interbedded limestone and dolomite is transitional into the variegated red and green argillite, siltite, and quartzite of the overlying Snowslip Formation. Contact between the Helena and Snowslip is placed above the calcareous, laminated, green argillite and siltite and below the lowest red argillite beds of the Snowslip. About 300 ft (90 m) below the top is a 200 ft (60 m) thick zone of argillaceous limestone that contains algal mat structures. Microlamination, ripple cross-lamination, uneven and laterally continuous beds, water-expulsion structures, and vertical-ribbon structures are common. Metamorphosed to low-, medium-, and high-grade, light-grayish-green, calc-silicate hornfels and dark-gray marble near Tertiary and Tertiary or Cretaceous(?) stocks and batholiths and near stock of Storm Lake (Kst). Minimum thickness of the upper part of the formation north of the Continental Divide is about 6,000 ft (1,830 m). Intense internal deformation in remainder of map area precludes thickness estimates.

Lower part of formation consists of five interbedded rock types: (1) dark-gray and medium-gray laminated limestone that contains abundant vertical ribbon structures; (2) very pale orange, moderate-brown, and dark-gray laminated dolomite that contains very light gray pods of dolomite; (3) dark-yellowish-brown, noncalcareous or calcareous, ripple cross-laminated and planar-laminated, dark-yellowish-brown siltite and fine-grained quartzite; (4) dark-yellow-brown, noncalcareous, thinly laminated argillite and very pale orange siltite; and (5) medium-green and light-green, noncalcareous, laminated argillite and siltite. Beds of these rock types are generally 3-6 ft (1-2 m) thick. Metamorphosed to calcite and dolomite marble, hornfels, phyllitic hornfels, chlorite-actinolite schist, and calc-silicate hornfels near Tertiary and Tertiary or Cretaceous stocks and batholiths. Lower part is equivalent to the lower member of Helena Formation as mapped by J.E. Harrison (U.S. Geological Survey, oral commun., 1983) near Libby, Montana. Base of Helena is not exposed in the map area. A minimum of about 800 ft (240 m) exposed west of Rainbow Lake above Cutaway thrust fault

METAMORPHOSED ROCKS OF THE MIDDLE PROTEROZOIC BELT SUPERGROUP

Ymq **Quartzofeldspathic gneiss**--Includes medium- and coarse-grained leucocratic layers dominated by quartz, piagioclase, microcline, and orthoclase separated by mesocratic and melanocratic layers that contain biotite, muscovite, and fibrous sillimanite. Also includes migmatitic rocks that contain very coarse grained leucocratic veins composed of quartz, plagioclase, microcline, orthoclase, and muscovite or biotite; veins are commonly intricately folded. Biotite-muscovite schist and amphibolite are interlayered with gneissic rocks at several places. Gneiss forms roof pendants and adjoins contacts with granodiorite of Jennings Camp Creek (Kjc) and granodiorite of Surprise Lake (Ksl). Most quartzofeldspathic gneiss probably formed from metamorphism of middle part of Missoula Group during emplacement of Late Cretaceous plutons of Idaho batholith

Ymc **Calc-silicate gneiss and schist**--Alternating layers of calc-silicate gneiss and calc-silicate schist and less common quartzofeldspathic layers. Calc-silicate gneiss layers composed of nematoblastic diopside, plagioclase, and quartz. Schist layers are mainly lepidoblastic hornblende, plagioclase, and biotite. Schist and gneiss contain randomly oriented amphibole, diopside, scapolite, and epidote as porphyroblasts and poikiloblasts. Unit occurs in roof pendants along contacts with granodiorite of Jennings Camp Creek (Kjc) and granodiorite of Surprise Lake (Ksl). Stratigraphic and structural relations to quartzofeldspathic gneiss not certain. Calc-silicate gneiss could be metmorphosed equivalent of Helena (Yh) or Shepard Formations (Ysh). Metamorphosed during emplacement of Late Cretaceous plutons of Idaho batholith

REFERENCES CITED

Carter, B.A., 1982, Geology of the Eocene volcanic sequence, Mt. Baldy-Union Peak area, central Garnet Range, Montana: Missoula, University of Montana, M.S. thesis, 55 p.

Csejtey, Bela, 1963, Geology of the southeast flank of the Flint Creek Range, western Montana: Princeton, New Jersey, Princeton University, Ph.D. dissertation, 175 p.

Dahlstrom, C.D.A., 1977, Structural geology in the eastern margin of the Canadian Rocky Mountains: Wyoming Geological Association Guidebook of 29th Annual Field Conference, p. 407-439.

Desmarais, N.R., 1983, Geology and geochronology of the Chief Joseph plutonic-metamorphic complex, Idaho-Montana: Seattle, Washington, University of Washington, Ph.D. dissertation, 150 p.

Ekren, E.B., 1985, Eocene cauldron-related volcanic events in the Challis quadrangle, *in* McIntyre, D.H., ed., Symposium on the geology and mineral deposits of the Challis 1^{o} x 2^{o} quadrangle, Idaho: U.S. Geological Survey Bulletin 1658-A-S, p. 43-58.

Elliott, J.E., Wallace, C.A., O'Neill, J.M., Hanna, W.F., Rowan, L.C., Segal, D.B., Zimbelman, D.R., Pearson, R.C., Close, T.J., Federspiel, F.E., Causey, J.D., Willett, S.L., Morris, R.W., and Huffsmith, J.R., 1985, Mineral resource potential map of the Anaconda-Pintlar Wilderness and contiguous roadless area, Granite, Deer Lodge, Beaverhead, and Ravalli Counties, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1633-A, scale 1:50,000.

Emmons, W.H., and Calkins, F.C., 1913, Geology and ore deposits of the Philipsburg quadrangle, Montana: U.S. Geological Survey Professional Paper 78, 271 p.

Fisher, F.S., McIntyre, D.H., and Johnson, K.M., 1991, Geologic map of the Challis 1^{o} x 2^{o} quadrangle, Idaho: U.S. Geological Survey Miscellaneous Investigations Map I-1819, scale 1:250,000.

Flood, R.E., Jr., 1974, Structural geology of the upper Fishtrap Creek area, central Anaconda Range: Missoula, Montana, University of Montana, M.A. thesis, 71 p.

Hanneman, D.L., 1987, Geologic map of the Pine Hill quadrangle, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1930.

Hanson, A.M., 1952, Cambrian stratigraphy in southwestern Montana: Montana Bureau of Mines and Geology Memoir 33, 46 p.

Harrison, J.E., 1972, Precambrian Belt basin of northwestern United States; Its geometry, sedimentation, and copper occurrences: Geological Society of America Bulletin, v. 83, p. 1215-1240.

Harrison, J.E., Griggs, A.B., and Wells, J.D., 1986, Geologic and structure maps of the Wallace 1^{o} x 2^{o} quadrangle, Montana and Idaho: U.S. Geological Survey Miscellaneous Investigations Series Map I-1509-A, scale 1:250,000.

Hawley, K.T., 1975, The Racetrack pluton--A newly defined Flint Creek Pluton: Northwest Geology, v. 4, p. 1-8.

Hobbs, B.E., Means, W.D., and Williams, P.F., 1976, An outline of structural geology: New York, John Wiley, 571 p.

Hyndman, D.W., Obradovich, J.D., and Ehinger, Robert, 1972, Potassium-argon age determinations of the Philipsburg batholith: Geological Society of America Bulletin, v. 83, p. 473-474.

Kauffman, M.E., 1963, Geology of the Garnet-Bearmouth area, western Montana, *with a chapter on* Metallic Resources by F.N. Earll: Montana Bureau of Mines and Geology Memoir 39, 40 p.

Lidke, D.J., 1985, Geology, structure, and geometrical analysis of structural relations along the south part of the Georgetown thrust, southwest Montana: Boulder, Colorado, University of Colorado, M.S. thesis, 104 p.

Lidke, D.J., and Wallace, C.A., 1988, Polyphase deformation and a regional perspective on the Sapphire thrust plate, Montana, *in* Weidman, R.M., ed., Guidebook of the greater Missoula area: Tobacco Root Geological Society 13th Annual Field Conference, p. 78-80.

_______ in press, Rocks and structure of the north-central part of the Anaconda Range, Deer Lodge and Granite Counties, Montana: U.S. Geological Survey Bulletin 1993.

Mackin, J.H., 1950, The down structure method of viewing geologic maps: Journal of Geology, v. 58, no. 1, p. 55-72.

Mudge, M.R., Earhart, R.L., Whipple, J.W., and Harrison, J.E., 1982, Geologic and structure maps of the Choteau 1^{o} x 2^{o} quadrangle, western Montana: U.S. Geological Survey Miscellaneous Investigations Series Map I-1300, scale 1:250,000.

O'Neill, J.M., and Lopez, D.A., 1985, Character and regional significance of Great Falls tectonic zone, east-central Idaho and west-central Montana: American Association of Petroleum Geologists Bulletin, v. 69, p. 437-447.

Pederson, R.J., 1976, Geology of the upper Rock Creek drainage, Granite County, Montana: Butte, Montana, Montana College of Mineral Science and Technology, M.S. thesis, 238 p.

Poulter, G.J., 1956, Geology of the Georgetown thrust area, southwest of Philipsburg, Montana: Montana Bureau of Mines and Geology, Geologic Investigations Map No. 1.

______1959, Structural synthesis of an area in southeastern Granite County, Montana, *in* Hammond, C.R., and Trapp, Henry, Jr., eds., Sawtooth-Disturbed Belt area: Billings Geological Society Guidebook, 10th Annual Field Conference, p. 23-33.

Robinson, G.D., Klepper, M.R., and Obradovich, J.D., 1968, Overlapping plutonism, volcanism, and tectonism in the Boulder batholith region, western Montana, *in* Coats, R.R., Hay, R.L., and Anderson, C.A., eds., Studies in Volcanology: Geological Society of America Memoir 116, p. 557-576.

Ruppel, E.T., O'Neill, J.M., and Lopez, D.A., 1983, Preliminary geologic map of the Dillon 1° x 2° quadrangle, Montana: U.S. Geological Survey Open-File Report 83-168.

Ruppel, E.T., Wallace, C.A., Schmidt, R.G., and Lopez, D.A., 1981, Preliminary interpretation of the thrust belt in southwest and west-central Montana and east-central Idaho, *in* Tucker, T.E., ed., Montana Geological Society Field Conference and Symposium Guidebook to Southwest Montana: p. 139-159.

Sloss, L.L., and Laird, W.M., 1947, Devonian system in central and northwestern Montana: American Association of Petroleum Geologists Bulletin, v. 31, p. 1404-1430.

Steiger, R.H., and Jaeger, E., 1977, Subcommission on geochronology--Convention and use of decay constants in geo- and cosmochronology: Earth and Planetary Science Letters, v. 36, p. 359-362.

Streckeisen, A.L., 1973, Classification and nomenclature recommended by the IUGS Subcommission on the systematics of igneous rocks: Geotimes, v. 18, no. 10, p. 26-30.

______1978, Classification and nomenclature of volcanic rocks, lamprophyres, carbonatites, and melilitic rocks: Neves Jahrbuch fur Mineralogie, Abhandlungen 134, p. 1-14.

Turner, F.J., and Verhoogen, J., 1960, Igneous and metamorphic petrology: McGraw-Hill, Inc., New York-Toronto-London, 694 p.

Wallace, C.A., Schmidt, R.G., Lidke, D.J., Waters, M.R., Elliott, J.E., French, A.B., Whipple, J.W., Zarske, S.E., Blaskowski, M.J., Heise, B.A., Yeoman, R.A., O'Neill, J.M., Lopez, D.A., Robinson, G.D., and Klepper, M.R., 1987, Preliminary geologic map of the Butte 1° x 2° quadrangle, western Montana: U.S. Geological Survey Open-File Report 86-292.

Wallace, C.A., Lidke, D.J., Waters, M.R., and Obradovich, J.D., 1989, Rocks and structure of the southern Sapphire Mountains, Granite and Ravalli Counties, western Montana: U.S. Geological Survey Bulletin 1824, 29 p.

Winston, Don, and Wallace, C.A., 1983, The Helena Formation and the Missoula Group at Flint Creek Hill, near Georgetown Lake, western Montana, *in* Hobbs, S.W., ed., Guide to Field Trips, Belt Symposium II: Department of Geology, University of Montana, Missoula, Montana, p. 66-81.

Wiswall, G., 1976, Structural styles of the southern boundary of the Sapphire tectonic block, Anaconda-Pintlar Wilderness Area, Montana: Missoula, Montana, University of Montana, M.A. thesis, 62 p.

Zen, E-An, 1988, Bedrock geology of the Vipond Park 15-minute, Stine Mountain 7-1/2-minute, and Maurice Mountain 7-1/2-minute quadrangles, Pioneer Mountains, Beaverhead County, Montana: U.S. Geological Survey Bulletin 1625, 49 p.