
Structural and Stratigraphic Transect of South-Central Idaho: A Field Guide to the Lost River, White Knob, Pioneer, Boulder, and Smoky Mountains

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INTRODUCTION

The mountains of south-central Idaho expose a cross section of the Cordilleran orogenic system including a Mesozoic fold-thrust belt on the east and Cretaceous and Tertiary intrusive complexes on the west. The orogenic belt is overprinted by Basin and Range extensional faulting and bimodal volcanism of the Snake River Plain. Major tectonic events in the development of the Cordilleran orogenic system in south-central Idaho include:

(1) The late Paleozoic Antler orogeny: uplift of the Antler highland was followed by flysch deposition in a foreland basin to the east.

(2) The Mesozoic Cordilleran orogeny: east-directed thrusting of the Sevier orogeny in east-central Idaho was accompanied by intrusion of the Idaho batholith farther

west and deep-seated ductile deformation and metamorphism in rocks now exposed in the core of the Pioneer Mountains.

(3) Paleogene extensional tectonism and the Eocene Challis magmatic episode: these two tectonic events overlapped in time and space. Paleogene formation of the Wildhorse detachment system of the Pioneer Mountains core complex was accompanied by low-angle normal faulting in areas to the west, and overlapped the volcanism, intrusion, faulting, and sedimentation of the Challis magmatic episode. Challis Volcanics include voluminous ash-flow tuffs, lavas, and hypabyssal intrusives interbedded with continental fluvial and lacustrine sedimentary rocks.

(4) Neogene basin and range extension and Snake River Plain bimodal volcanism: the eastward migration of rhyolitic and basaltic volcanism on the Snake River Plain during the last 15 million years overlapped with basin and range extensional faulting. The faulting continues to the present in south-central Idaho.

DEDICATION

This article is dedicated to the late Wayne E. Hall (1920-1986) upon whose pioneering geologic studies of

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the central Idaho black-shale mineral belt much of our work is based.

PURPOSE

This field trip examines the stratigraphic, structural, and igneous record of some of these tectonic events as reflected in lateral changes in Paleozoic sedimentary units, Mesozoic deformational style, and Paleogene and Neogene volcanism and extensional tectonism of the Lost River, White Knob, Pioneer, and Smoky Mountain Ranges. Field trip stops and their purposes are listed in Table 1. The route of the field trip is shown in Figures 1, 2, and 5. Figure 4 is a geologic map of the eastern part of the area.

The purposes of this field trip are:

(1) To demonstrate the contrasts in Paleozoic stratigraphy from east to west across the Mesozoic thrust belt in south-central Idaho from the Lost River Range to the Smoky Mountains on the west, where the thrust belt is intruded by Cretaceous rocks of the Idaho batholith. The stratigraphic and structural framework is from the work of many people including Betty Skipp, Wayne Hall, Jim Dover and others over the last 30 years, and from work by Link, Burton, and others in the rocks of the Wood River basin over the last few years. Devonian and Mississippian strata record a westward progression from an outer carbonate platform (Stop 1-8) to the Antler flysch trough (Stop 1-6), and then west to the Antler highland (Stop 2-2). Pennsylvanian-Permian strata record a similar westward progression from a carbonate bank to the Copper Basin highland, bordered on the west by the Wood River basin (Stops 1-7, 2-3, 2-7).

(2) To discuss recent work by Skipp near Fish Creek Reservoir (Stops 1-7 and 1-8) and by Skipp and Link in the Wood River Valley in which faults formerly thought to be Mesozoic thrusts are reinterpreted as Tertiary normal faults (Stops 1-8, 2-1, 2-2, 2-4, 2-7, 2-8, 2-9). This interpretation bears on the larger issues of regional Paleogene tectonics including the relations between the rise of the Pioneer Mountains core complex (Stop 2-6) and tectonism associated with the Eocene Challis magmatic episode (Stop 2-9).

(3) To discuss concepts developed by Hait and now being tested by Janecke about the timing and style of Tertiary extension in the Lost River Range (Stops 1-1 to 1-3). Important questions remain about the relation of extensional faulting to the Eocene Challis magmatic episode, Basin and Range deformation, and downwarp of the Snake River Plain.

STRATIGRAPHY OF THE FIELD TRIP AREA

The area of the field trip contains rocks of several Mesozoic thrust plates (Figs. 2 and 4). These thrust plates, as modified from Skipp (1987), include from east

Table 1: Summary of field trip stops and their purpose.

DAY ONE: ARCO TO FISH CREEK RESERVOIR	
Stop	Purpose
1-1	View from mouth of Antelope Creek: stratigraphy, Tertiary structure
1-2	Pass Creek detachment fault: Tertiary structure
1-3	Pass Creek view: Tertiary structure, stratigraphy
1-4	Arco Park: Paleozoic stratigraphy
1-5	Copper Basin thrust: Mesozoic structure, Paleozoic stratigraphy, Neogene Snake River Plain volcanism
1-6	Copper Basin Formation turbidites: sedimentology and stratigraphy
1-7	Wood River Formation at Fish Creek Reservoir: stratigraphy
1-8	Roberts Mountains Formation and Carey Dolomite: stratigraphy, structure, mineral deposits
DAY TWO: WOOD RIVER VALLEY	
Stop	Purpose
2-1	Overview of Hailey area: Tertiary structure
2-2	Colorado Gulch: Milligen Formation, Tertiary structure.
2-3	Hailey Conglomerate Member type area: stratigraphy, sedimentology
2-4	Quigley Creek: Wood River thrust, reactivated?
2-5	Deer Creek: Dollarhide Formation contact with Deer Creek stock: structure, magmatism
2-6	East Fork, Wood River: view of Pioneer Mountains Tertiary structure
2-7	Wood River Formation in Trail Creek: stratigraphy
2-8	Wood River thrust in Trail Creek: structure
2-9	Boulder Mountain view: Tertiary structure, magmatism, mineral deposits

to west: Lost River-Arco Hills; Grouse; White Knob; Copper Basin; Devonian, Silurian and Ordovician undivided; Milligen-Wood River; and Dollarhide and Grand Prize. Rocks of the Grand Prize Formation are included with the Milligen-Wood River plate on Figure 2. Stratigraphic columns for five of these thrust plates are shown on Figure 3 (also see Isaacson, 1983).

Precambrian and Lower Paleozoic Rocks

Precambrian gneisses are found only in the Pioneer Mountains metamorphic core complex (Dover, 1981; 1983; Wust and Link, 1988, this volume) where they may be the basement of either the White Knob thrust plate (Fig. 2) or the Copper Basin thrust plate, as suggested here (Fig. 3). Large (6 meter-long) xenoliths of granitic gneiss are found in the Challis Volcanics above the Grouse plate, suggesting that the Grouse plate also contains crystalline basement.

Metasedimentary rocks believed to be of Middle Proterozoic age include foliated pebbly quartzites in the Borah Peak area of the Lost River-Arco Hills plate and gneissose quartzite and calc-silicate rocks of the Pioneer

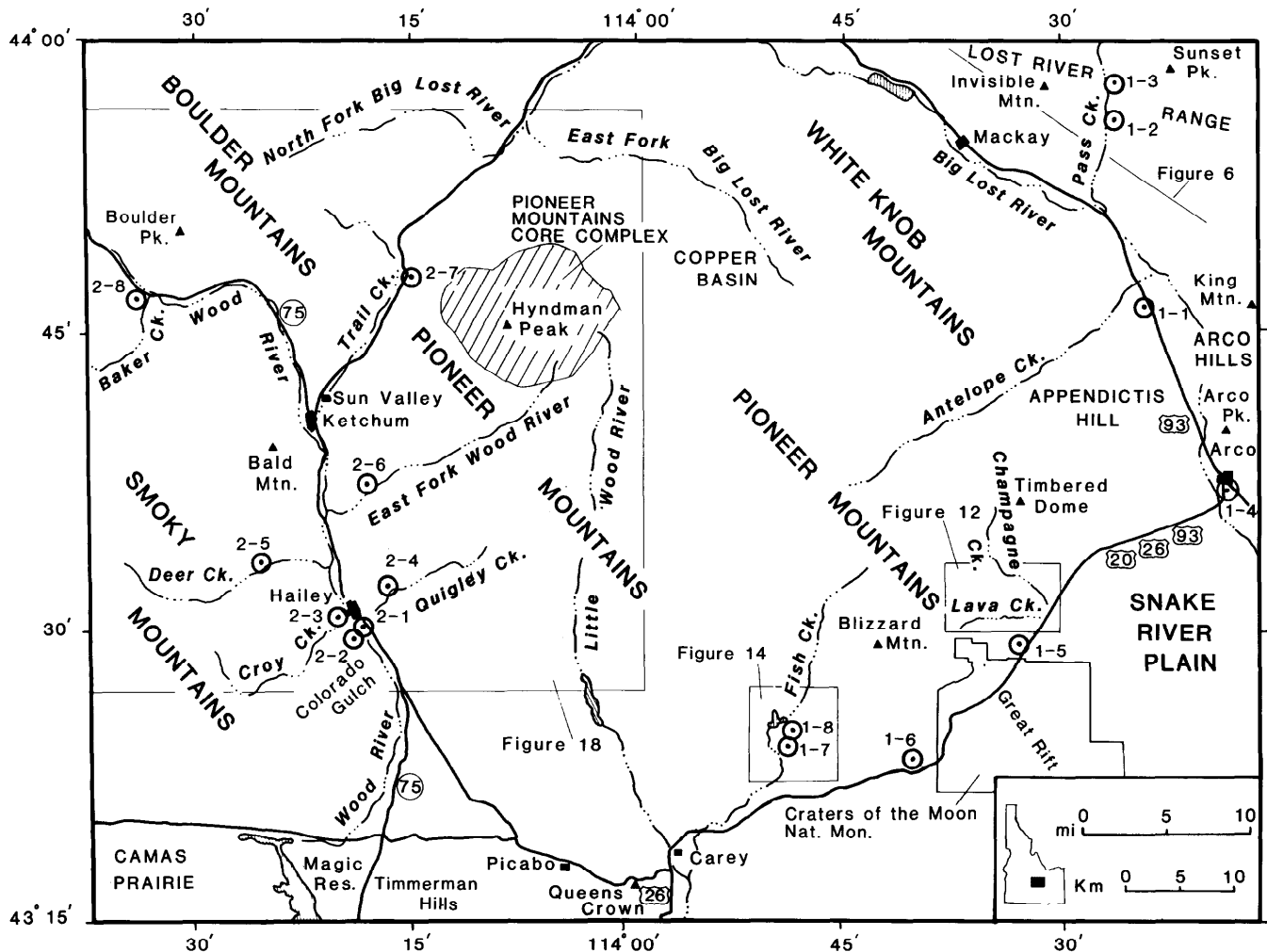


Figure 1. Generalized index map showing field trip route and stop locations for structural and stratigraphic transect of south-central Idaho: Lost River, White Knob, Pioneer, and Smoky Mountains.

Mountains core complex (Dover, 1983) (Fig. 3). These correlations are tentative, especially in the Pioneer Mountains.

In the Lost River-Arco Hills plate, Late Proterozoic and lower Paleozoic quartzose detrital strata are found in the Borah Peak area (Fig. 5) (Ruppel and others, 1975; McCandless, 1982; Ingwell, 1980; Skipp, unpublished mapping, 1987). Silurian and Devonian rocks are continental margin carbonates (McFadden and others, 1988, this volume). Lower Paleozoic outer shelf successions similar to those of the Lost River-Arco Hills plate thin westward but are present at least as far west as Fish Creek Reservoir, where they are interpreted to be part of the Copper Basin thrust plate (Fig. 3) (Stop 1-8).

Thick Devonian argillite, limestone and quartzite of the Milligen Formation are present in the Milligen-Wood River plate (Sandberg and others, 1975; Otto and Turner, 1987; Turner and Otto, 1988, this volume). The undated Paleozoic Carriatown sequence (Darling, 1988, this volume) of the Dollarhide plate may contain Devonian rocks (Geslin, 1986; Darling, 1987).

Mississippian Rocks

Mississippian strata are present in Mesozoic thrust plates from western Montana westward to the Copper Basin plate. These rocks record a westward interfingering of carbonate bank limestones of the outer cratonic platform with flysch of the foreland basin that formed during the Antler orogeny (Nilsen, 1977; Skipp, Sando, and Hall, 1979; Skipp and Hall, 1980; Dover, 1980). In the Lost River-Arco Hills and Grouse plates, Mississippian formations of the Upper Mississippian carbonate bank complex of Skipp, Sando, and Hall (1979) (Fig. 3) overlie eastward-thinning Mississippian turbidites of the McGowan Creek Formation in the position of the outer cratonic platform. Rocks of the White Knob plate were also deposited on the outer cratonic platform and consist of Upper Mississippian limestones and interbedded clastic sequences of the White Knob Limestone above thick turbidites of the Lower Mississippian McGowan Creek Formation. Upper and Lower Mississippian conglomeratic flysch of the

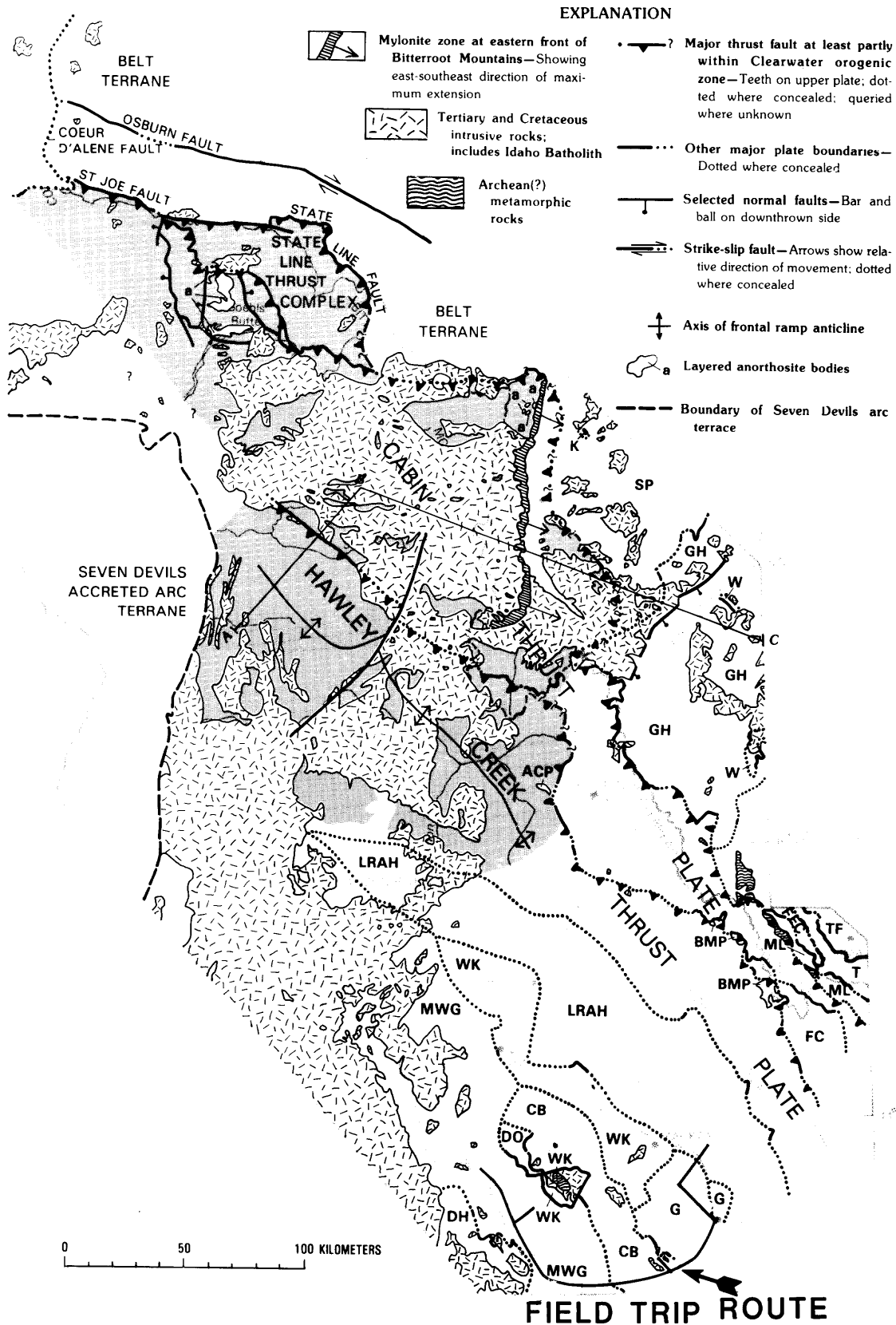


Figure 2.

foreland basin are preserved as Copper Basin Formation on the Copper Basin plate.

Rocks of the Devonian Milligen Formation are thought to have composed part of the the Mississippian Antler highland in Idaho (Skipp and Hall, 1980; Davis, 1984) and to have been the source for some of the coarse-grained sediment that is present in the Mississippian Copper Basin Formation. The Copper Basin Formation contains up to 3500 meters of conglomerate, sandstone, limestone, and argillite (Paull and others, 1972; Paull and Gruber, 1977). The Lower Mississippian portion is inferred to represent an eastward-prograding submarine fan complex (Nielsen, 1977). The Lower Mississippian distal flysch trough is represented in the Lost River-Arco Hills, Grouse, and White Knob plates by fine-grained sandstones and shales of the McGowan Creek Formation (Sandberg, 1975). The Upper Mississippian White Knob Limestone of the White Knob plate contains western-derived cobbles and pebbles of chert and quartzite, thus recording the interaction of the carbonate platform and the western Antler highland source area.

Pennsylvanian and Permian Rocks

In Pennsylvanian time, a second carbonate bank complex, the Bluebird Mountain and Snaky Canyon Formations, developed in central Idaho and is now exposed in the Lost River-Arco Hills, Grouse, and White Knob plates (Skipp, Hoggan, Schleicher and Douglass, 1979). To the west, Mississippian rocks of what is now the Copper Basin plate were uplifted to form the Copper Basin highland, which was flanked on the west by the Middle Pennsylvanian-Early Permian Wood River basin (Skipp and Hall, 1980). Rocks of the Wood River basin are found in the Milligen-Wood River plate, the Dollarhide plate, and the Grand Prize plate (Mahoney and Sengebusch, 1988, this volume). Strata deposited in the Wood River basin include three partly coeval lithostratigraphic units: the Dollarhide, Grand Prize, and Wood River Formations (Fig. 19). The Wood River basin is discussed more fully in the introduction to the second day of this field guide.

TECTONICS OF SOUTH-CENTRAL IDAHO

Mesozoic Thrusting and Intrusion

South-central Idaho is composed of several Cordilleran thrust plates (Skipp and Hait, 1977; Skipp, 1987; Figs. 2 and 4). The thrust plates have distinctive Paleozoic stratigraphic sequences and are recognized primarily on that basis, although segments of the actual thrust faults are locally exposed. Paleozoic strata have been telescoped eastward and their present distribution represents a compressed paleogeography.

The western part of south-central Idaho was intruded by Cretaceous biotite granodiorite of the Idaho batholith, from 100 Ma to 75 Ma (Bennett, 1980; Kiilsgaard and Lewis, 1985; Bennett and Knowles, 1985; Johnson and others, 1988, this volume). Three eastern outliers of the batholith occur on the west side of the Wood River Valley (Stop 2-5). In this area the batholith passively intruded country rocks of the Wood River basin, which are contact-metamorphosed over tens of square kilometers (Wavra, 1985). Hydrothermal fluids associated with Cretaceous magmatism are thought to have remobilized metals in carbonaceous Paleozoic rocks, forming the silver-lead-zinc mineral deposits of the Wood River Valley and Smoky Mountains (Hall, Rye, and Doe, 1978; Hall, 1985; Darling, 1988, this volume).

Paleogene Extension and the Challis Magmatic Episode

Paleogene crustal extension affected much of east-central Idaho and southwest Montana (Hait, 1984) and formed the Wildhorse detachment system between upper and lower plates in the Pioneer Mountains core complex (Wust, 1986a, b; Wust and Link, 1987; Wust and Link, 1988, this volume). Extension related to the Wildhorse detachment may have produced low-angle normal faults and reactivated the Wood River thrust in the Wood River Valley to the west (Skipp and others, 1986; Link and Mahoney, 1987; Turner and Otto, 1988, this volume).

Figure 2. Tectonic sketch map of east- and south-central Idaho, from Skipp (1987). Field trip route is shown in southwest part of map. Map shows interpreted distribution of rocks of the Cabin, Hawley Creek, and State Line thrust sheets. Shaded areas are Clearwater orogenic zone. GH = Grasshopper plate (Ruppel and Lopez, 1984; Skipp, 1985), W = window through Grasshopper plate; ACP = Ordovician Arnett Creek pluton. BMP = Beaverhead Mountains pluton. K = Proterozoic gneiss and schist in interpreted klippe of rocks of Cabin plate. Remaining letters designate thrust plates: MWG = Milligen-Wood River thrust complex. This was labelled as the Milligen-Wood River-Grand Prize thrust complex by Skipp (1987) and (Hall, 1985), but recent work suggests that the Grand Prize Formation is not part of the same thrust complex as the Milligen Formation (see Figure 18 of this paper). DH = Dollarhide thrust complex west of MWG plate (Hall, 1985); DO = Devonian, Silurian, and Ordovician rocks undivided (Dover, 1981); CB = Copper Basin plate (Skipp and Hait, 1977); WK = White Knob plate (Skipp and Hait, 1977); G = Grouse plate; LRAH = Lost River-Arco Hills plate (Skipp and Hait, 1977); FC = Fritz Creek plate (Skipp, 1985); ML = Medicine Lodge plate (Scholten and others, 1955; Skipp, 1985); FEC = Four Eyes Canyon plate (Perry and Sando, 1983); T = Tendoy plate (Scholten and others, 1955); TF = Footwall of Tendoy thrust; SP = Sapphire plate (Hyndman, 1980). A-B-C = line of diagrammatic cross sections shown in Figure 3 of Skipp (1987). Sketch map based on geologic map compiled at 1:1,000,000, then reduced and simplified. Map sources include reports cited in Skipp (1987) and geologic maps of Idaho (Bond, 1978), and Montana (Ross and others, 1955).

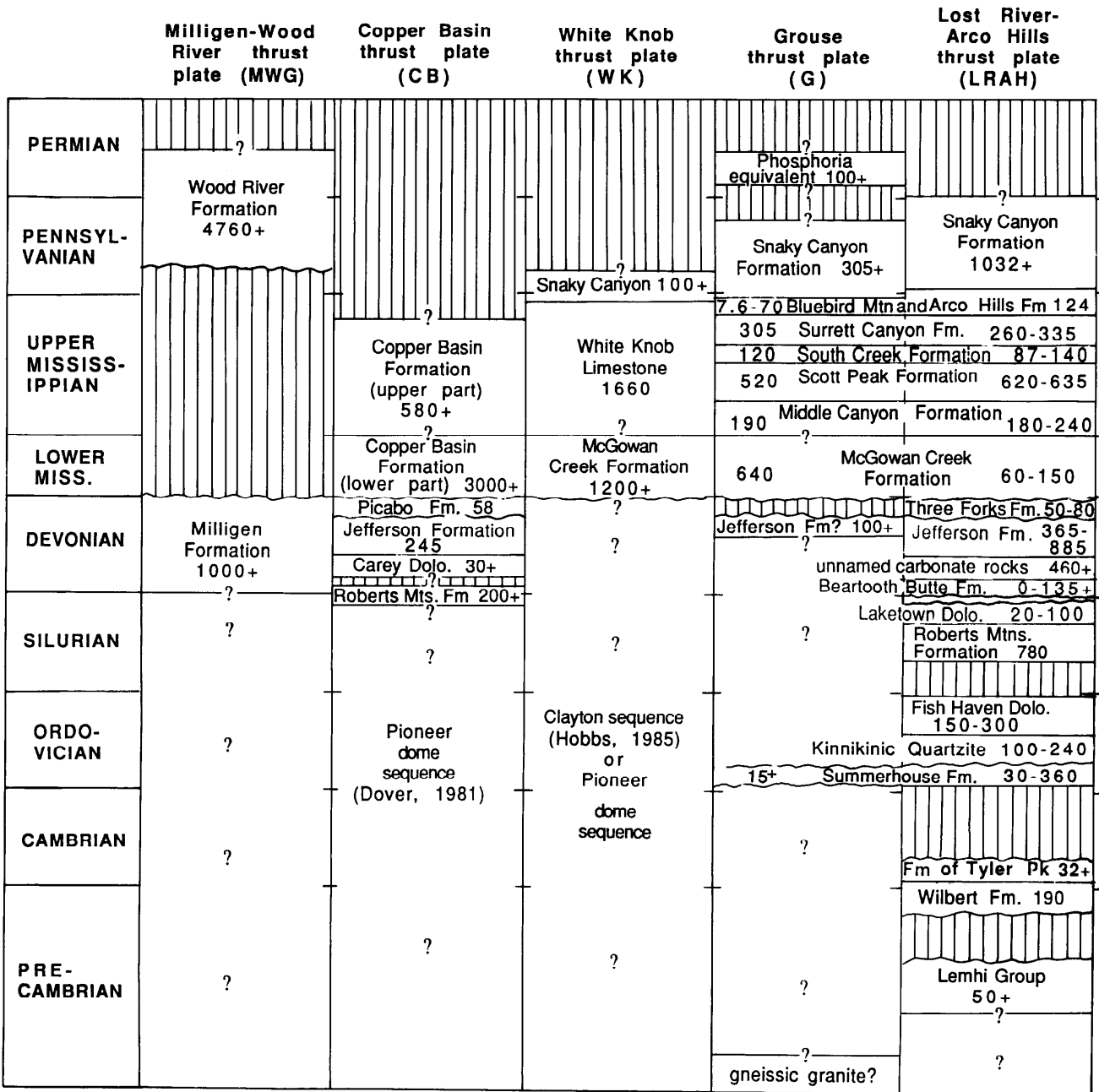


Figure 3. Generalized stratigraphic columns showing Precambrian and Paleozoic formations and their thicknesses (in meters) that make up five Cordilleran thrust plates (Skipp, 1987, Fig. 2, this paper) in south-central Idaho in the area of the field trip. Vertical lines indicate a hiatus caused by either nondeposition, erosion, or faulting. A wavy line indicates a disconformity. Question marks indicate systems that may be present but are outside the field trip area, or are not exposed. Columns are revised from Figure 4 of Skipp and Hait (1977). References used to construct Figure 3 that postdate Skipp and Hait (1977) include Skipp, Hoggan, Schleicher, and Douglass (1979); Skipp, Sando, and Hall (1979); Hays and others (1980); Ingwell (1980); McCandless (1982); Davis (1983); and Hobbs (1985).

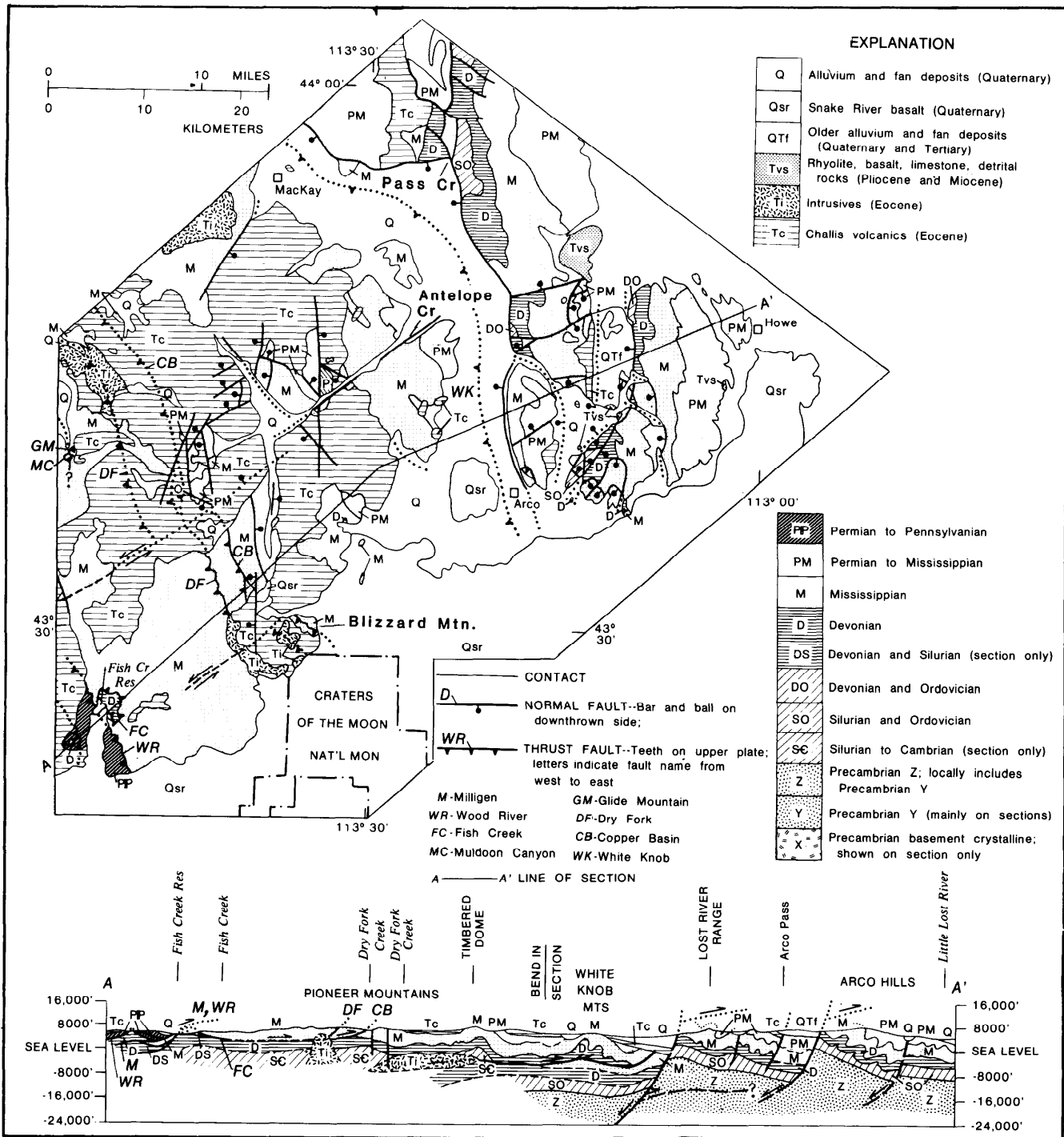


Figure 4. Geologic map and cross section of the southern Lost River, White Knob, and Pioneer Mountains, from Skipp and Hait (1977, plate 1). Three new interpretations of the structural relations are proposed in the present paper, and not shown on the map and cross section, which reflect concepts developed over 10 years ago. These changes are: a) Rocks shown as belonging to the White Knob plate on this map are now thought to comprise the Grouse plate and the White Knob plate. For location of boundaries of thrust plates see Figure 2. b) This map shows rocks of the Arco Hills east of Arco belonging to the Lost River-Arco Hills plate rather than the Grouse plate. The new interpretation is based on conodont alteration index data, and is discussed in text at Stop 1-1. c) This map shows a Fish Creek thrust. This interpretation has been changed as discussed at in the text before Stop 1-7. Also, the cross section shown is not balanced.

Paleogene extension is also manifested in the trans-Challis fault system (Bennett, 1986) in the Challis 1 x 2 degree quadrangle (Fisher and others, 1983). This northeast-trending fault system is thought to have controlled the migration of ore-forming fluids and the locations of calderas in the northern Challis volcanic field. In the southern Challis volcanic field, eruptive centers may have been localized along northwest-trending normal faults (Moye and others, 1988, this volume).

Magmatism and deformation associated with the Challis magmatic episode (51-40 Ma) was probably coeval with some extensional tectonics and produced a large field of extrusive rocks (the Challis Volcanic Group, defined by Fisher and others, 1987) and several generations of plutons in south-central Idaho (McIntyre and others, 1982; Bennett and Knowles, 1985; Moye and others, 1988, this volume).

Eocene tectonism just preceding and coeval with Challis volcanism is documented by the basal Challis conglomerate (Paull, 1974). Recent work demonstrates that this unit represents a conformable transition from proximal alluvial fan sedimentation lacking any volcanic component to volcanic lithic sandstone and heterolithologic tuff breccia. Fine-grained interbeds both above and below the tuff breccia have yielded sparse palynomorphs that probably represent a late Eocene to early Oligocene assemblage (Burton and Blakley, 1988).

Basin and Range and Snake River Plain

Basin and Range faulting and Snake River Plain bimodal volcanism began in Idaho about 15 million years ago (Armstrong and others, 1975; Kuntz and others, 1986). The rhyolitic caldera-forming volcanism and locus of high-angle normal faulting have migrated northeastward toward Yellowstone Park at a rate of about 3 cm per year (Christiansen and McKee, 1978; Allmendinger, 1982). Basin and range extension has been oriented in a dominantly west-southwest to east-northeast direction in response to regional oblique stress, forming the present northwest-trending mountain ranges. As shown in Figure 5, in many places the basin and range faults juxtapose rocks of different Mesozoic thrust plates.

DAY ONE: GEOLOGY OF THE LOST RIVER, WHITE KNOB, AND SOUTHERN PIONEER MOUNTAINS

Roadlog from Arco to Antelope Creek

The field trip route is shown in Figures 1, 2, and 5, and mileage begins in Arco, Idaho, at the intersection of U. S. Highways 20-26 and 93. A geologic map of the area traversed on the first day of the trip is shown in Figure 4. Head north on Highway 93. Regional

compilation geologic maps of the area are available in Rember and Bennett (1979a, b).

The Lost River Range lies to the east of the highway and is bounded by the historically active Lost River range-front fault system (Crone, 1988, this volume; Pierce, 1988, this volume). To the west of the highway are the foothills of Appendicitis Hill and the White Knob Mountains.

At mile 11.1 turn left (west) on Antelope Creek Road and stop on right. In the late 1800s Antelope Creek was part of the route used by miners and cattlemen to get from the Wood River Valley to the Big Lost River Valley on their way to mining areas along the Salmon River.

Stop 1-1: View of Lost River and White Knob Mountains From Mouth of Antelope Creek

Stratigraphy and Thrust Plates

This stop introduces the stratigraphy and structure of the Lost River Range. Stratigraphic differences between Upper Mississippian rocks in the Lost River Range to the east and the White Knob Mountains to the west suggest that they are parts of at least three separate thrust plates (from east to west: the Lost River-Arco Hills, White Knob, and Grouse plates, Figs. 2 and 3) (Skipp and Hait, 1977; Skipp, Sando, and Hall, 1979; Skipp, 1987). The White Knob plate (WK on Fig. 2) is structurally highest, and the Upper Mississippian rocks are White Knob Limestone consisting of limestone and interbedded chert- and quartzite-pebble conglomerate and sandstone. Upper Mississippian rocks of the underlying Grouse (G on Fig. 2) and Lost River-Arco Hills (LRAH on Fig. 2) plates are carbonate bank limestones with no interbedded clastics. Though Upper Mississippian rocks of the Grouse plate are similar to rocks of the Lost River-Arco Hills plate, they are thicker and have lower conodont color alteration index (CAI) values than those of the Lost River-Arco Hills plate. Rocks of the LRAH plate have CAI values of 5 to 5.5 (John Repetski, written communication, 1976), whereas rocks of the Grouse plate have values of 2 to 3.5 (Kirk Denkler, Anita Harris, and Bruce Wardlaw, written communications, 1982).

Extensional Faulting

The Lost River Range has been profoundly affected by Tertiary and Quaternary extension, including low-angle detachment faulting (Hait, 1984) (Stops 1-2 and 1-3) and Neogene to Holocene basin and range faulting. The west flank of the range is bounded by a moderately west-dipping normal fault, which last slipped in October 1983 and produced a magnitude 7.3 earthquake (Crone and Machette, 1984; Crone and others, 1985; Crone, 1988, this volume). Ongoing studies by Janecke at the

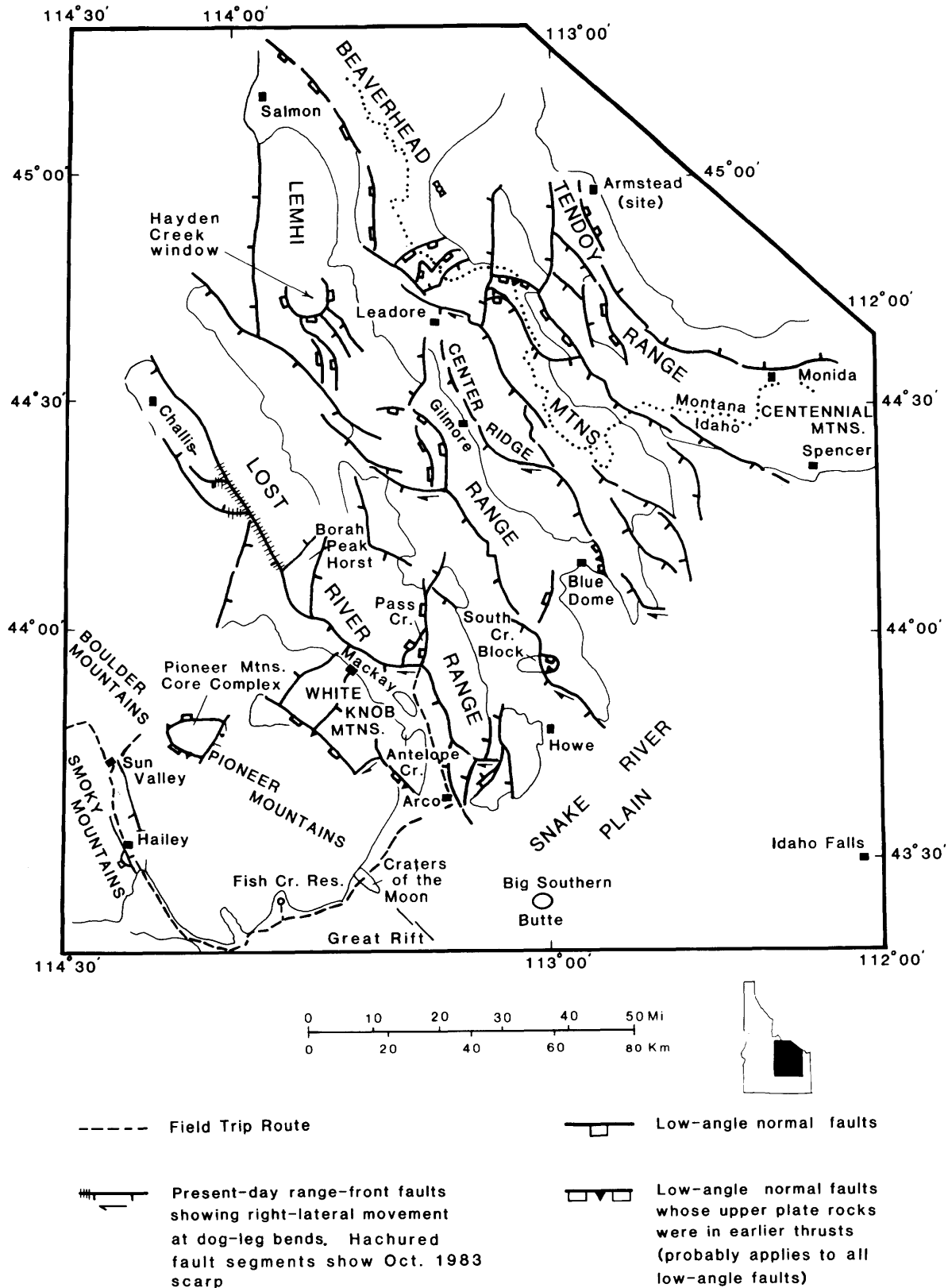


Figure 5. Diagrammatic map of eastern Idaho and adjacent Montana by M. H. Hait, Jr. showing Basin and Range normal faults and segments of normal faults above which are thrust plates.

University of Utah are aimed at defining the timing, kinematics and precise geometry of Tertiary extension in the Lost River Range.

View from the Mouth of Antelope Creek

The topographic low in the Lost River Range directly to the north marks Pass Creek, which runs north-south (Fig. 1). The view will be discussed in a clockwise manner, starting from the northwest. Figure 4 shows the geology of the area. Figure 6 shows Hait's interpretation of the geologic structure from Mt. McCaleb on the northwest to the Pass Creek and Elbow Canyon areas on the southeast. Figure 7 is a photographic panorama of the same area.

To the far northwest in the Lost River Range, the white peak is composed of Ordovician quartzite within the Borah Peak horst (Fig. 5) (Ross, 1947, Baldwin, 1951, Skipp and Harding, 1985). Mississippian rocks are exposed on the crest of the range to the south, with the prominent blocky peak (Mt. McCaleb) underlain by resistant Mississippian Scott Peak Formation (Fig. 6, left side). Below Mt. McCaleb is orange talus of the Middle Canyon Formation, which overlies a smooth slope on the McGowan Creek Formation. Halfway down

the mountain are juniper-covered slopes of the Devonian Three Forks and Jefferson Formations. Southeast (right) of Mt. McCaleb are complex north-northwest-trending folds in Mississippian and Pennsylvanian limestones, such as the tight syncline-anticline pair at Franklin Canyon (Fig. 6).

The dark, blocky cliffs northwest (left) of Pass Creek Canyon are east-dipping Eocene Challis Volcanics. Pass Creek will be the site of field trip **Stops 1-2 and 1-3**. A prominent landslide at the mouth of Crows Nest Canyon (Fig. 6) forms the fan-shaped landform below the volcanic cliffs.

The main structure of the Pass Creek area is the north-trending, west-dipping Pass Creek normal fault system (shown on Fig. 5), which here is composed of two low-angle normal faults cutting Paleozoic strata and Challis Volcanics (Fig. 6). In the Pass Creek canyon area Challis Volcanic Group strata are rotated eastward into these faults. Hait (1984) suggests that the extension structures in the Pass Creek area were originally continuous with even larger extension structures of the central Lemhi Range to the east (Hait, 1987). Those structures are overlapped by lower Miocene vertebrate-bearing beds that provide an upper age limit for the large-scale extension.

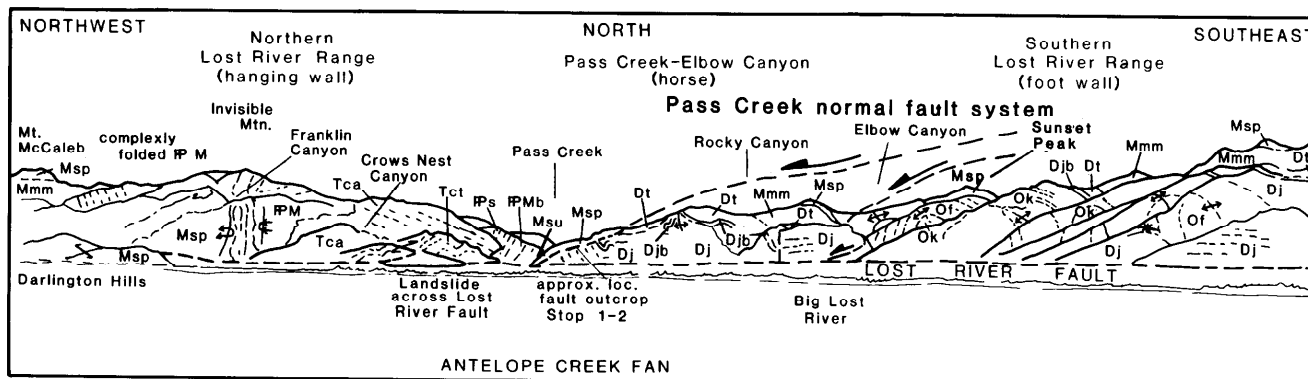


Figure 6. Sketch by M. H. Hait Jr. of panorama looking north and east to the Pass Creek normal fault system from the mouth of Antelope Creek (Stop 1-1). Units are as follows: Q--Quaternary; Tct--Challis tuffaceous units; Tca--Challis andesite (?); Ps--Snaky Canyon Formation (Penn.); PMb--Bluebird Mountain Formation; Msu--Surrett Canyon Formation; Mso--South Creek Formation; Msp--Scott Peak Formation; Mmm--Middle Canyon and McGowan Creek Formations; Dt--Three Forks Formation; Djb--Birdbear Member of Jefferson Formation; Dj--Jefferson Formation; Of--Fish Haven Formation and Laketown Dolomite; Ok--Kinnikinic Quartzite.

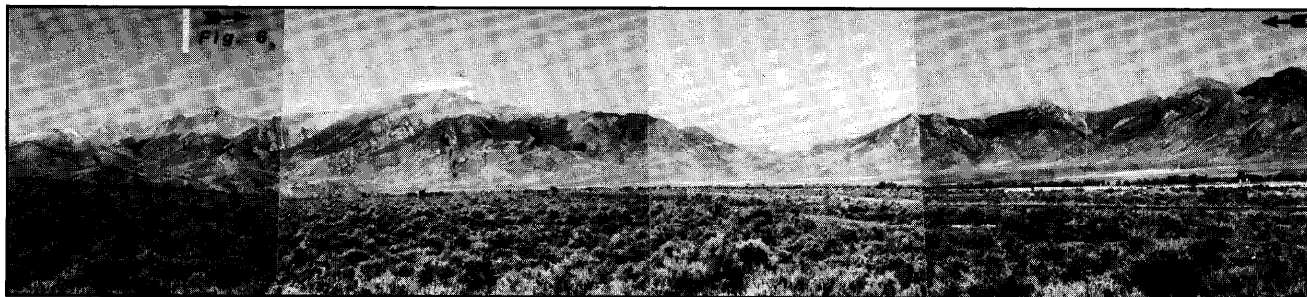


Figure 7. Panorama of the Pass Creek area from the mouth of Antelope Creek (Stop 1-1). Photo shows nearly the same area as diagrammed in Figure 6.

The upper fault of the Pass Creek system is exposed in Pass Creek Canyon (Stop 1-2). On this fault, the rocks west of the canyon have been moved westward from on top of the rocks to the southeast (right) of the canyon. The hanging wall of the upper normal fault contains upper Paleozoic, mostly Mississippian strata as well as Eocene Challis Volcanic Group and, perhaps, Tertiary gravels near Wet Creek (Mapel and Shropshire, 1973). The footwall of the lower fault contains Ordovician through Mississippian strata (Fig. 6). To the north, the footwall extends into Precambrian strata (Mapel and Shropshire, 1973). The structurally complex horse between the two faults is made up of Devonian through Mississippian strata.

King Mountain (Fig. 8) to the southeast of the mouth of Antelope Creek is composed of gently dipping Devonian Jefferson Formation (dolomite) at the base, overlain by thin Devonian Three Forks Formation, Lower Mississippian McGowan Creek Formation, orange talus of the sandy Upper Mississippian Middle Canyon Formation, and thick-bedded pure limestones of the Upper Mississippian Scott Peak Formation at the top.

On the south flank of King Mountain is Beaverland Pass (Fig. 8) which occupies a fault valley separating King Mountain (part of the Lost River-Arco Hills plate) from the Arco Hills block (part of the Grouse plate) to the south (Fig. 1). The part of the Arco Hills that lies south-southeast of Beaverland Pass is underlain by limestone and sandstone beds ranging in age from Late Mississippian to Late Pennsylvanian. These rocks have a cooler thermal overprint (CAI of 3 to 3.5) than rocks of the remainder of the Arco Hills farther south and east (CAI of 5 to 5.5). Skipp thus believes that this block has affinities with rocks of the Grouse thrust sheet to the west, which have similar low CAI values, rather than with the remainder of the Arco Hills (Fig. 2).

View to Southwest

To the southwest are the foothills of Appendicitis Hill. To the west and north are the White Knob Mountains, bisected by northeast-flowing Antelope Creek (Figs. 1 and 4). Appendicitis Hill belongs to the Grouse plate, and contains Upper Mississippian and Pennsylvanian carbonate bank facies rocks similar to those found in the Arco Hills (Skipp, Hoggan, Schleicher and Douglass, 1979; Davis, 1983). On the east margin of Appendicitis Hill the limestones are folded to tight east-vergent folds with several-hundred-meter wavelengths (Fig. 9). Lavas of the Challis Volcanic Group overlie the limestones and dip east about 30 degrees to form the brown flatirons on the east face of the hills. Hait believes that the eastward dip of the volcanic rocks suggests that they have been rotated to the east on the west-dipping Lost River range-front fault system.

Sheep Mountain, north of Antelope Creek, is com-

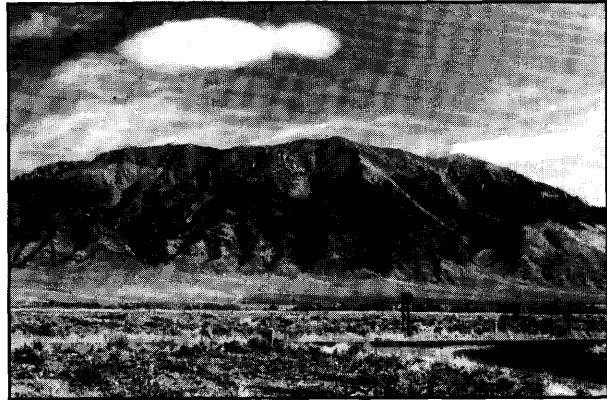


Figure 8. King Mountain, looking east from Stop 1-1. King Mountain is made up of gently dipping Devonian Jefferson Formation (dolomite) at the base, overlain by thin Devonian Three Forks Formation, Lower Mississippian McGowan Creek Formation (bulk of tree-covered slope), orange talus of the sandy Upper Mississippian Middle Canyon Formation, and thick-bedded pure limestones of the Scott Peak Formation at the top. Beaverland Pass is on the right side of the photo.

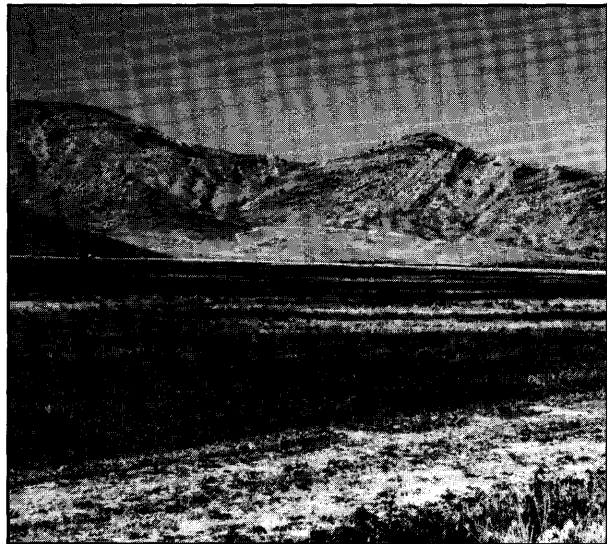


Figure 9. Folded Pennsylvanian limestones of the Grouse plate on the east side of Appendicitis Hill, just southwest of the mouth of Antelope Creek. View is from Highway 93 about a mile south of Stop 1-1.

posed of a thick, nearly flat-lying section of Challis Volcanic Group including silicic ash-flow tuffs, and dacitic and andesitic lavas (Moye and others, 1988, this volume).

In the distant northwest are peaks of the White Knob Mountains, underlain by Upper Mississippian White Knob Limestone which is intruded and bleached by the Eocene Mackay stock (Nelson and Ross, 1968, 1969).

Continue north on Highway 93. Pass through

Darlington and Leslie and at mile 18.9, turn north (right) on a gravel road to Pass Creek. The turnoff is not obvious, but it is marked by a white trailer house southwest (left) of the road and a small brown sign to Pass Creek about 50 meters north of the highway.

Proceed north toward the Lost River Range. At mile 20.1 take the middle fork of three gravel roads, continuing northeast toward Pass Creek. Rocks to the northwest (left) are folded Upper Mississippian limestones overlain unconformably by east-dipping Challis Volcanic Group. A prominent landslide deposit, cut by a strand of the Lost River fault system, empties from Crows Nest Canyon in the Challis Volcanic Group north of the road (mile 22.0) (Fig. 6).

Preliminary results of work by Janecke suggest that angular unconformities may be present in the Challis Volcanic Group between Crows Nest Canyon and Pass Creek. If these unconformities are caused by syn-eruptive faulting, their dating may bracket the timing of Eocene extension.

Stop 1-2: Exposure of Upper Strand of Pass Creek Detachment Fault System in Pass Creek

Park on the right in small turnout at mile 23.9 just past the sign for entering the Challis National Forest. This location is on the Methodist Creek 7.5-minute quadrangle. Walk east across the diversion dam and up the slope to the southeast.

In a small gully just east of the limestone knob at elevation 6320 is an exposure (discovered by Janecke in 1987) of the upper strand of the Pass Creek normal fault system seen from Stop 1-1. Here the fault dips 35 degrees to the southwest. The fault has sections of shallow dip (15 degrees), separated by segments with steep dip (45 to 50 degrees). The normal fault here separates medium gray limestone of the Upper

Mississippian Surret Canyon (?) Formation above from darker, banded dolomites of the Devonian Jefferson Formation below. The fault is iron-stained and has two prominent sets of striae (trending 290° and 225° azimuth) on a slickenside surface (150, 35W.), demonstrating two episodes of westward transport. Upper plate rocks are locally brecciated but not disrupted on a large scale. Map-scale folds in the upper plate are truncated by the fault. The low-angle normal fault can be seen by climbing to the saddle at elevation 6440 and looking at the cliff to the north.

Return to the cars and proceed northward up the Pass Creek canyon road. The narrow canyon is cut in folded Mississippian limestones of the Surret Canyon, South Creek, and Scott Peak Formations. The cliff-forming unit is the Scott Peak Formation. North of Bluejay Canyon (mile 25.3), a prominent upright crest of an anticline can be seen straight ahead in the cliff.

Stop at corral on right at mile 26.2, just after leaving narrow canyon.

Stop 1-3: View of Syncline in Challis Volcanic Group Strata

As shown in Figure 10, east-dipping white tuffs of the Challis Volcanic Group are present on the west side of the basin. Challis beds in the sage-covered hills to the north (prominent tan-colored cliff) dip west. This suggests to Hait a syncline which formed over a ramp in an underlying detachment fault. To the east are cliffs of folded Mississippian limestone that comprise a "gravity glide" block overlying Tertiary strata (Mapel and Shropshire, 1973). Tertiary gravels near Wet Creek, exposed several kilometers to the northeast of this locality, dip eastward. Hait believes that these tuffs and younger gravels were rotated above a low-angle normal fault in the subsurface. An alternate interpretation of the map relations, proposed after preliminary work by

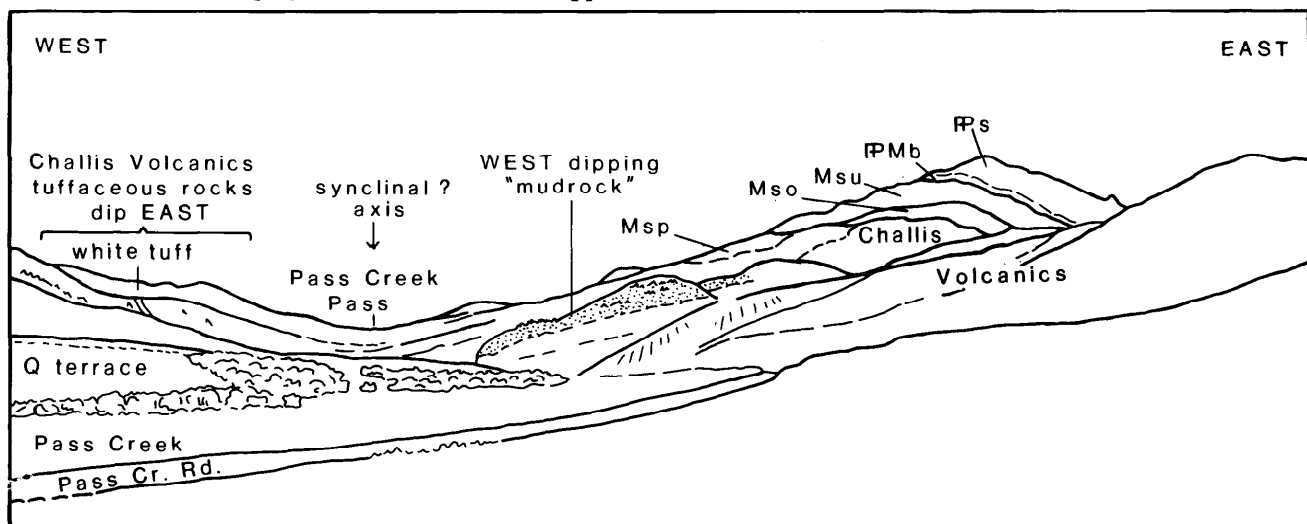


Figure 10. Sketch by M. H. Hait, Jr. of view looking north from Stop 1-3, Pass Creek narrows, Methodist Creek quadrangle. Unit designations are given in caption for Figure 6.

Janecke, is that the tilt may have been produced by north-trending high-angle normal faults.

The area to the north was mapped by Mapel and Shropshire (1973), who defined a general stratigraphic succession in the Challis Volcanic Group. Basal andesite and basalt are overlain by a middle interval of sediments and tuffs, with an upper unit of basalts.

Return to cars, turn around, and proceed back to Arco. Reset odometers at intersection of Highways 93 and 20-26 in Arco, and proceed west. Stop for lunch at Atoms for Peace Park on the left at mile 0.4.

Stop 1-4: View of Upper Mississippian Carbonate Bank of the Arco Hills

On warm spring evenings, juniors from Arco High School steal up the steep cliffs of the Surret Canyon Formation at the south end of the Arco Hills (visible directly to the east) and paint their graduation year on the Upper Mississippian bioclastic grainstones of the Surret Canyon Formation (Fig. 11).

All of the units present in the Arco Hills (from oldest to youngest: Middle Canyon, Scott Peak, South Creek, Surret Canyon, Arco Hills and Bluebird Mountain Formations) (Fig. 3) are of the Upper Mississippian carbonate bank facies (Skipp, Sando, and Hall, 1979). In the Arco Hills, the Upper Mississippian Surret Canyon Formation is overlain by the Arco Hills Formation (type section at south end of outcrop east of town) and the Mississippian/Pennsylvanian Bluebird Mountain Formation (Skipp, Sando, and Hall, 1979). The letter "B" for Butte County is in the sandstones of the Bluebird Mountain Formation.

Roadlog from Arco to Blizzard Mountain Road

Proceed west on Highway 26 from Arco.

At mile 2.3 the road climbs onto a terrace of the Big Lost River. The Arco airport is on the left, and to the north is Appendicitis Hill. To the south is Big Southern Butte, a compound rhyolite dome that intruded and tilted basalt lavas along the axis of the Snake River Plain about 300,000 years ago. The Butte stands about 600 meters above the surrounding basalts.

At mile 7.6, by an irrigation storage pond on the north side of the road, is a view to the northwest of treetopped Timbered Dome. The dome is capped by locally metalliferous jasperoid, but the flanks are made up of a complete section of Upper Devonian through Upper Pennsylvanian rocks, totalling more than 2960 meters in thickness. A reference section for the international mid-Carboniferous stratotype boundary is located there (Skipp and others, 1985).

Appendicitis Hill is east of Timbered Dome; both are on the Grouse plate. Between them on the skyline ridge of the White Knob Mountains is the craggy tree-covered summit of Sheep Mountain, composed of the Challis

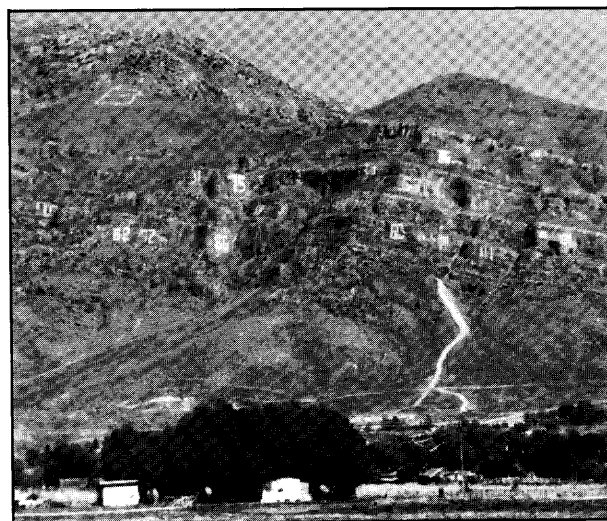


Figure 11. Photo of the Arco Hills showing the formations that make up the Upper Mississippian carbonate bank. The South Creek Formation forms the slopes at the base of the hill. Graduating class years are painted on the Surret Canyon Formation. Slopes with ledges above the Surret Canyon Formation are in the Arco Hills Formation. The letter "B" is painted on the Bluebird Mountain Formation.

Volcanic Group. The sharp, bare ridge west of Sheep Mountain is underlain by Mississippian McGowan Creek Formation and White Knob Limestone of the White Knob plate. The sharp peak with broad shoulders to the west of the White Knob Mountains is Smiley Peak in the Pioneer Mountains, underlain by Challis Volcanics. The Pioneer Mountains lie to the west and are underlain dominantly by folded Mississippian Copper Basin Formation of the Copper Basin plate.

Rocks of the Grouse thrust plate make up the mountains between Arco and this stop (Figs. 2 and 3) (Skipp, 1987). The Grouse plate contains the Upper Mississippian carbonate bank and overlying Pennsylvanian/Permian carbonate bank. Within the Grouse plate, the Mississippian-Pennsylvanian carbonate rocks stratigraphically overlie the Lower Mississippian McGowan Creek Formation, an eastern, finer-grained facies of the Antler flysch.

At mile 12.2 the road crests a hill just beyond an abandoned log cabin on the north. Straight ahead to the southwest are the basaltic cones of Craters of the Moon lava field (Stephens, 1988, this volume). To the north is an outcrop of folded Ordovician quartzites and dolomites (Summerhouse (?) Formation) surrounded by basalt. This possibly is a block along the down-dropped margin of the Snake River Plain. Pull off at mile 16.6 at the Blizzard Mountain Road to the north.

Stop 1-5: View of Copper Basin Thrust at Blizzard Mountain

Blizzard Mountain is the prominent peak to the

northwest (left) (Fig. 4). Figure 12 is a geologic map of the area. Directly north just below the old ski lift tower is the nearly vertical Copper Basin thrust that separates the upper part of the Copper Basin Formation (Copper Basin plate) on the west from the underlying folded Middle Canyon and McGowan Creek Formations (Grouse plate). Thus, at this locality, coarse-grained Antler-derived clastics were thrust to the east over finer-grained Antler clastics and overlying limestones of the Upper Mississippian carbonate bank (Skipp, 1987).

Above the Copper Basin thrust is the Copper Basin plate, which forms the mountains north of the highway from here west to Fish Creek Reservoir, and which contains the main part of the Antler flysch. The Copper Basin thrust plate is divided into two subplates: an upper Glide Mountain subplate and a lower Copper Basin subplate (Dover, 1981). Nilsen (1977) referred to these subplates as the Brockie and Scorpion subplates, respectively. The Copper Basin plate contains thick Mississippian strata of the Copper Basin Formation underlain by thin Devonian outer shelf facies rocks (Fig. 3, Stop 1-8). The lower part of the Copper Basin Formation is a coarse-grained detrital sequence of turbidite deposits that constitute proximal and distal submarine fan deposits derived from a western Antler highland (Nilsen, 1977; Paull and others, 1972).

Just north of here is Lava Creek, where basaltic vents breach the Paleozoic rocks (Fig. 12). These vents lie on a northwest continuation of the Great Rift, a northwest-trending 85-km-long volcanic rift zone in the Snake River Plain which extends south to Craters of the Moon National Monument and the Kings Bowl area west of American Falls (Fig. 1) (Kuntz and others, 1982; 1986; Skipp and Kuntz, unpublished mapping in the SE 1/4 Grouse 15-minute quadrangle). Radiocarbon dates of organic material between basalt flows along Lava Creek provide the following ages: basalt flow of Lava Creek (Qb1) 12.7 ± 0.15 Ka, and basalt flow of Sunset crater (Qbs) 12.0 ± 0.15 Ka (Kuntz and others, 1986).

Just north of Lava Creek, the Copper Basin thrust is offset to the northeast along a tear fault or lateral ramp.

Return to Highway 26, heading west. The entrance to Craters of the Moon National Monument (mile 19.0) is on the left. Volcanism at Craters of the Moon occurred along the Great Rift. The youngest flows in the monument are 2 Ka (Kuntz and others, 1982; 1986; Stephens, 1988, this volume).

Continue west to mile 26.5; pull off on right, and disembark carefully on right side. *WARNING: this is a blind curve; watch carefully for vehicles.*

Stop 1-6: Turbidites of the Mississippian Copper Basin Formation

Rocks exposed in this roadcut are part of the Glide Mountain subplate of Dover (1981) (Fig. 4). The Glide Mountain subplate contains coarse-grained turbidites, deposited in the Antler flysch trough proximal to the

western Antler highland. Bedding in the Copper Basin Formation here dips steeply eastward. Rocks are siltstone, fine to coarse sandstone, and both matrix-supported and clast-supported conglomerate displaying complete and partial Bouma sequences (Fig. 13). This outcrop contains most of the structures of the ideal Bouma turbidite sequence shown in the inset of Figure 13. Sedimentary structures visible here include normal and reverse graded bedding (on far western end), load casts, cross beds, cross and parallel laminations, ripple marks, soft-sediment folds, and floating mudstone clasts in matrix-supported conglomerate. *Nereites*-ichnofacies trace fossils or bedding trails are found in some of the mudstones. Their presence indicates a deep water, nonturbulent environment between episodes of coarse turbidite sedimentation.

The basal 10 meters of outcrop displays a coarsening- and thickening-upward cycle interpreted to represent a depositional lobe of a submarine fan. Two fining- and thinning-upward cycles are present in the upper 30 meters of outcrop. These contain matrix-supported conglomerates with soft-sediment clasts and are interpreted to represent submarine fan channel deposits.

Continue west on Highway 26. At mile 34.3, the fault between the overlying Milligen-Wood River plate and underlying Copper Basin plate (WR on Fig. 4) is exposed in the saddle just off the road to the north. Here the Pennsylvanian-Permian Wood River Formation and underlying Devonian Milligen Formation are juxtaposed against Mississippian turbidites of the Copper Basin Formation. Mississippian rocks are not present in the Milligen-Wood River thrust plate, and Devonian rocks of the thrust plate are thought to have been part of the Antler highland during Early Mississippian time.

Reset odometers at the Fish Creek Reservoir Road (mile 36.3). Turn right (north) to Fish Creek Reservoir. The road crosses a Pleistocene basalt flow erupted from a vent just south of Fish Creek Reservoir.

Geologic Setting of Fish Creek Reservoir

The Fish Creek Reservoir area is geologically important because it exposes the stratigraphically lowest rocks of the Copper Basin plate, several thrust faults, and may contain Carlin-type silver and gold mineralization. In the sagebrush-covered hills to the east, the Pennsylvanian-Permian Wood River Formation is thrust over the Copper Basin Formation. The hills to the west contain the Wood River Formation faulted over the Devonian Milligen Formation.

The Fish Creek area was formerly thought to contain a structural window to rocks below the Copper Basin plate (Skipp and Hall, 1975); the map of Figure 4 shows this interpretation. A new interpretation of the geology is presented in Fig. 14, a geologic sketch map and cross sections of the Fish Creek Reservoir area, revised from Skipp and Hall (1975) by Betty Skipp using modern

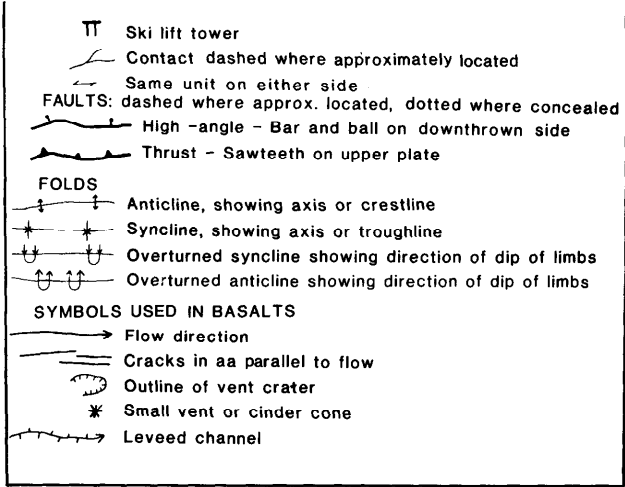
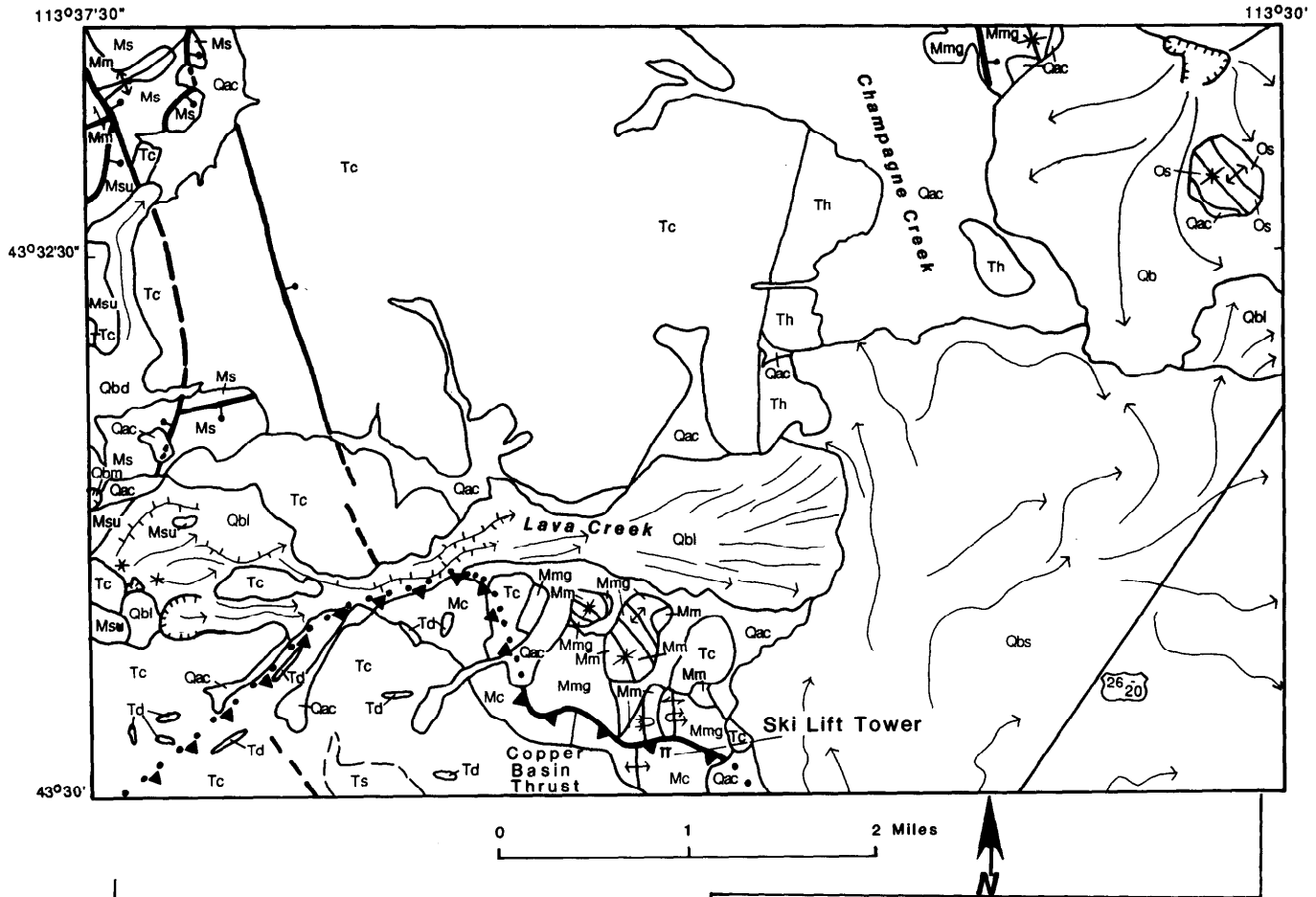


Figure 12. Geologic sketch map of southeastern part of the Grouse 15-minute quadrangle showing the Copper Basin thrust in relation to Blizzard Mountain ski lift tower and locations of vent craters and cinder cones in Lava Creek at the northern end of the Great Rift volcanic rift zone. Geology is by Betty Skipp, M.A. Kuntz, and L.A. Morgan. Map units: Qac--Alluvium, colluvium, landslide deposits, some basaltic ash (Holocene to Pleistocene); Qbs--Basalt flow of Sunset crater (latest Pleistocene); Qbm--Basalt cone (Pleistocene); Qbd--Basalt flow of Dry Creek (Pleistocene); Qbl--Basalt flow of Lava Creek (Pleistocene); Qb--Unnamed basalt flow (Pleistocene); Th--Rhyolitic ash-flow tuffs of Heise Group (Pliocene and Miocene); Td--Rhyolite dike (Eocene); Ts--Quartz monzonite stock (Eocene); Tc--Challis Volcanic Group (Eocene); Msu--Surrett Canyon Formation (Upper Mississippian); Ms--Scott Peak Formation (Upper Mississippian); Mm--Middle Canyon Formation (Upper Mississippian); Mmg--McGowan Creek Formation (Lower Mississippian); Mc--Copper Basin Formation (Mississippian); Os--Summerhouse(?) Formation (Ordovician).

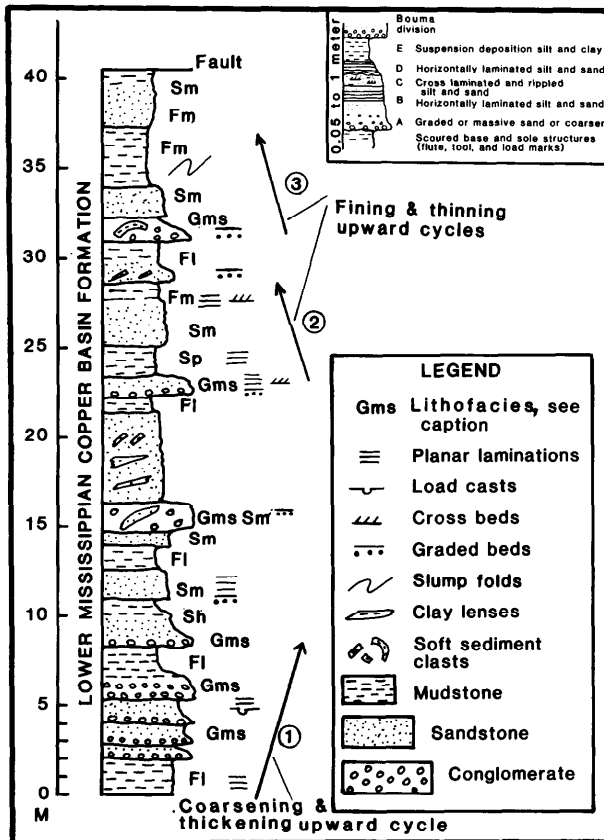


Figure 13. Measured stratigraphic column of part of the Mississippian Copper Basin Formation at Stop 1-5 along Highway 26, 26.5 miles west of Arco, Idaho. Column was measured by the Idaho State University Sedimentary Petrology class, Sept. 1987. Lithofacies codes are: Gms--matrix-supported gravel; Sm--massive sand; Sp--planar cross-bedded sand; Sh--horizontally bedded sand; Fi--laminated mud; Fm--massive mud. Inset in upper right is a schematic diagram showing complete Bouma sequence for turbidite sands (from Tucker, 1981, p. 73).

thrust belt structural concepts (Dahlstrom, 1970; Royse and others, 1975).

In the new map interpretation (Fig. 14), the concept of the Fish Creek thrust (FC on Fig. 4), which placed Mississippian Copper Basin Formation on older rocks (Skipp and Hall, 1975), is abandoned; faults formerly attributed to the Fish Creek thrust are reinterpreted to be normal faults. The contact between the uppermost Devonian Picabo Formation and the Mississippian Copper Basin Formation, formerly thought to be part of the Fish Creek thrust, is redefined as a disconformable sedimentary contact within the Copper Basin plate. New mapping southeast of the reservoir suggests that large segments of the Wood River thrust that place Wood River Formation against the Copper Basin Formation (Fig. 4 of Skipp and Hall, 1975) are also normal faults. In addition, siltstone, argillite, and quartzite formerly

assigned to the uppermost Wood River Formation on the west side of Fish Creek are now thought to correlate with the Milligen Formation, although no age has yet been established for these beds.

At mile 3.0 from the highway cross Fish Creek. At mile 3.8 take a dirt road on the right for 0.2 mile to Stop 1-7.

Stop 1-7: Lower Part of the Wood River Formation

This stop involves a short climb through an unusually coarse eastern facies of the lower part of the Wood River Formation which was deposited proximal to the Copper Basin highland source area (Skipp and Hall, 1975) (Fig. 15). The rocks are sandy, chert pebble-bearing, conglomeratic limestone and purple siltstone. In exposures of the Wood River Formation in the Wood River Valley to the west, such conglomerate-bearing strata are confined mainly to the basal Hailey Conglomerate Member (Fig. 19). Here, however, they are present through the entire exposed section. The bulk of the clasts in the Wood River Formation here were derived from the Mississippian Copper Basin Formation of the Copper Basin plate, which now forms the hills to the east.

Return to main Fish Creek Road (mile 4.2) and continue north. The basalt vent and road to Fish Creek Dam are on the left at mile 4.4. Continue to mile 5.0, turn left on road to the reservoir and park.

Stop 1-8: Silurian-Devonian Roberts Mountains Formation Thrust Over Devonian Carey Dolomite

This stop affords discussion of the structural setting and mineral deposits of the Fish Creek Reservoir area and illustrates outer carbonate platform sedimentary facies of the Silurian-Devonian Roberts Mountains Formation. Hike east from the parking spot, across a thrust fault within the Copper Basin plate that places Upper Silurian and Lower Devonian Roberts Mountains Formation over Middle Devonian Carey Dolomite (Fig. 14).

The Roberts Mountains Formation here (Fig. 16) was first studied by Skipp and Sandberg (1975). It contains stromatoporoid boundstone, laminated siltstone and rip-up clast conglomerate deposited in proximal and marginal carbonate buildup environments.

Figure 17 is an annotated photograph of the hill west of Fish Creek Reservoir, modified from Figure 3 of Skipp and Hall (1975) and taken near this locality. The photograph shows the Milligen-Wood River plate thrust onto the Copper Basin plate which contains the Copper Basin Formation and underlying Devonian strata.

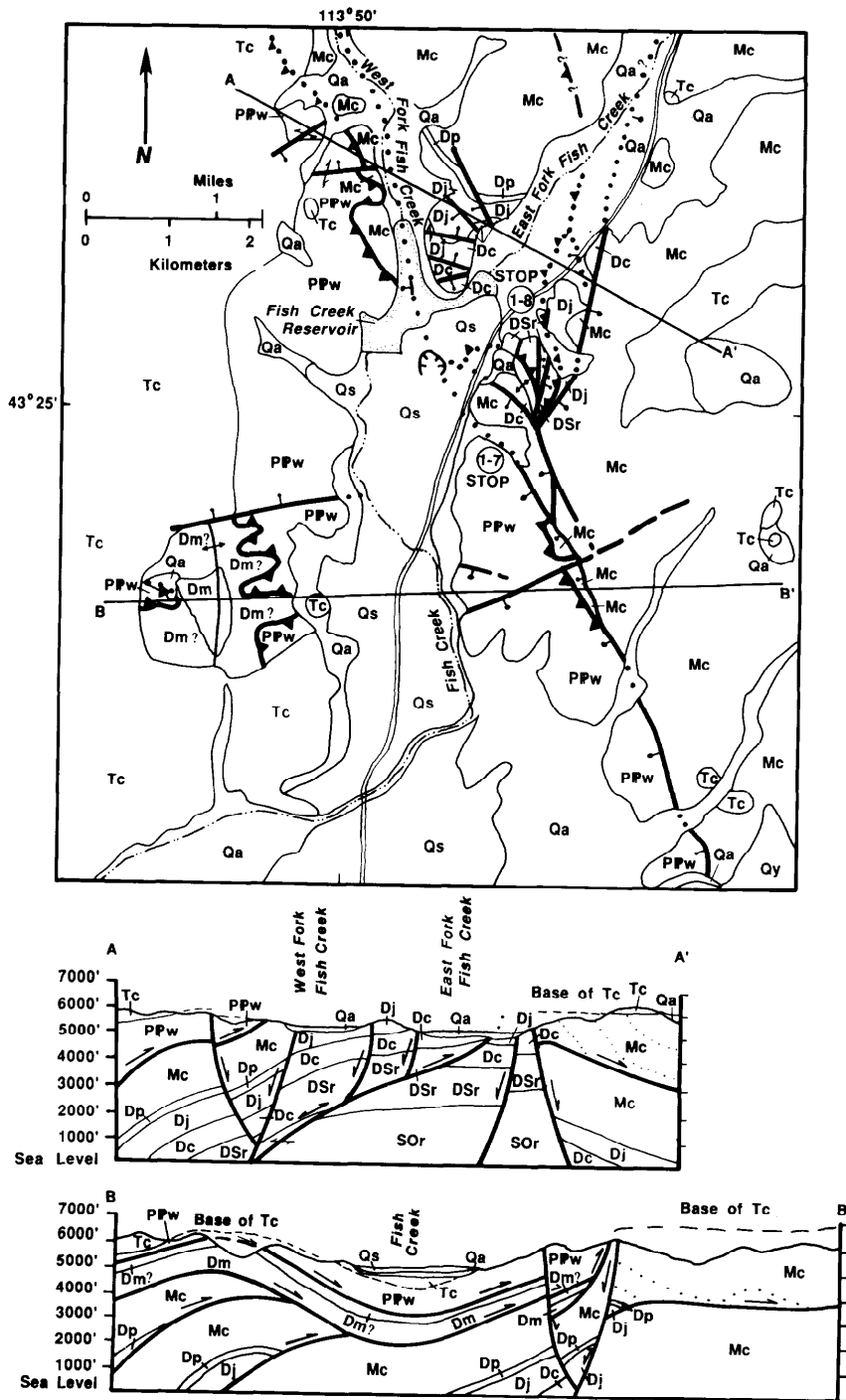


Figure 14. Geologic sketch map and cross sections (no vertical exaggeration) of the Fish Creek Reservoir area revised from Skipp and Hall (1975, Fig. 4). Locations of field trip Stops 1-7 and 1-8 are shown. Map units: QTa--Alluvium, landslide deposits, colluvium, terrace deposits, and jasperoid undifferentiated (Quaternary and Tertiary); Qy--Younger basalt (Quaternary); Qs--Snake River Group (Quaternary); Tc--Challis Volcanic Group (Eocene); P/Pw--Wood River Formation (Permian and Pennsylvanian); Mc--Copper Basin Formation (Mississippian); Dp--Picabo Formation (Upper Devonian); Dj--Jefferson Formation (Upper and Middle Devonian); Dc--Carey Dolomite (Middle and Lower Devonian); Dm--Milligen Formation (Upper and Middle Devonian); Dm?--Milligen(?) Formation (Upper and Middle Devonian?); DSr--Roberts Mountains Formation (Lower Devonian and Upper Silurian); SOr--Silurian and Ordovician rocks undivided-unit used only on cross section A-A'.

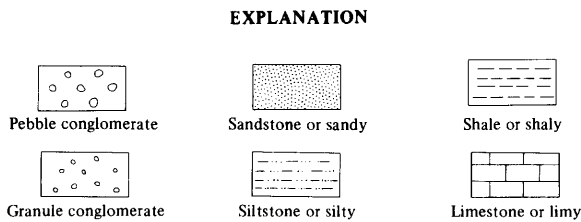
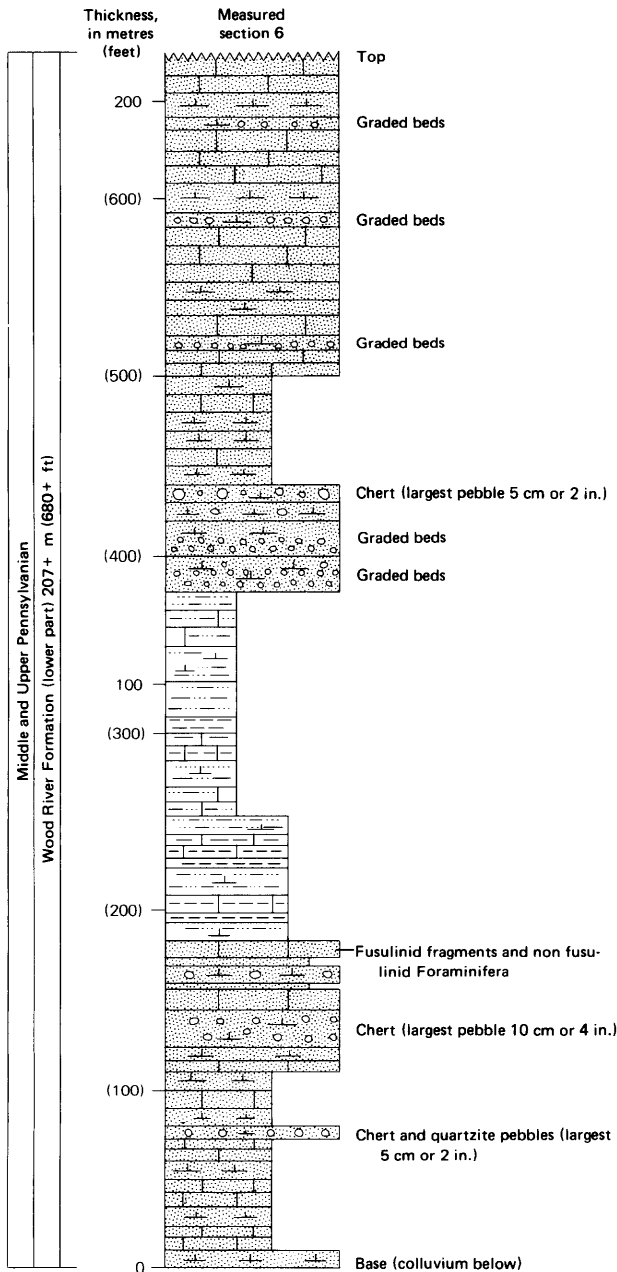


Figure 15. Measured section of lower part of Wood River Formation in NW 1/4 sec. 23 and NE 1/4 sec. 15 (approx.), T. 1 N., R. 22 E., Blaine County, Idaho. From Skipp and Hall (1975, Fig. 8).

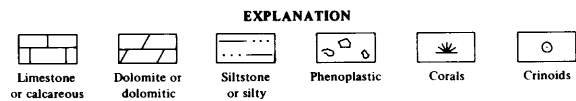
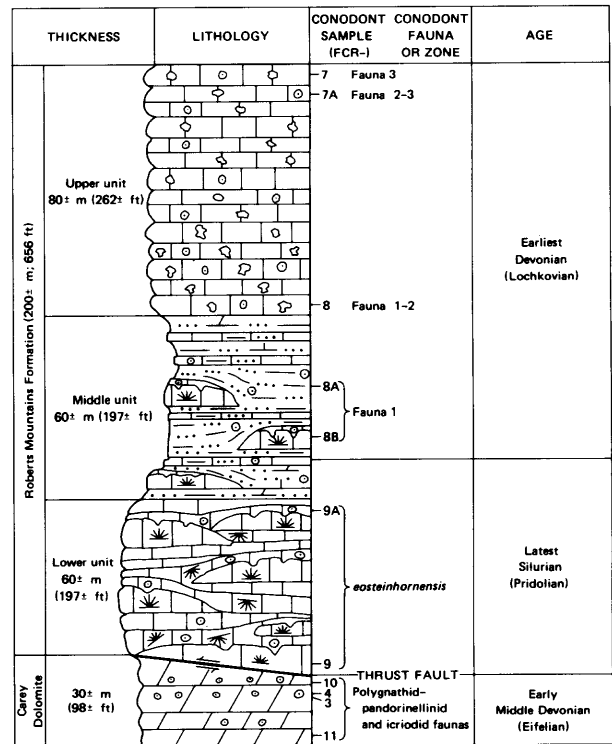


Figure 16. Diagrammatic (partly restored) section of the Roberts Mountains Formation showing conodont zonation of faulted sequence along ridge on east side of Fish Creek Reservoir in NW 1/4 sec. 14 (unsurveyed), T. 1 N., R. 22 E. From Skipp and Sandberg (1975, Fig. 3).

Mineral Deposits at Fish Creek Reservoir

The major normal fault that drops Copper Basin Formation down against the thrust-faulted Silurian and Devonian rocks (Fig. 14) can be observed on the ridge to the southeast. The normal fault recently has been prospected for metal deposits.

Mineral exploration in the Fish Creek area was initiated in 1977 as a result of publications by Skipp and Hall (1975) and Skipp and Sandberg (1975). Wayne Hall and Betty Skipp recognized the similarity of the structural and stratigraphic setting of the Fish Creek area to that of the Carlin gold deposit in Nevada. Cordex, founded by John Livermore, a co-discoverer of the Carlin ore body, was the first company to test the prospect in the Fish Creek area. Samples from three rotary holes drilled just east of the fault that drops Copper Basin Formation down against Silurian-Devonian carbonate rocks yielded as much as 0.61 ppm gold and 11 ppm silver. More exploratory drilling for deeper targets has

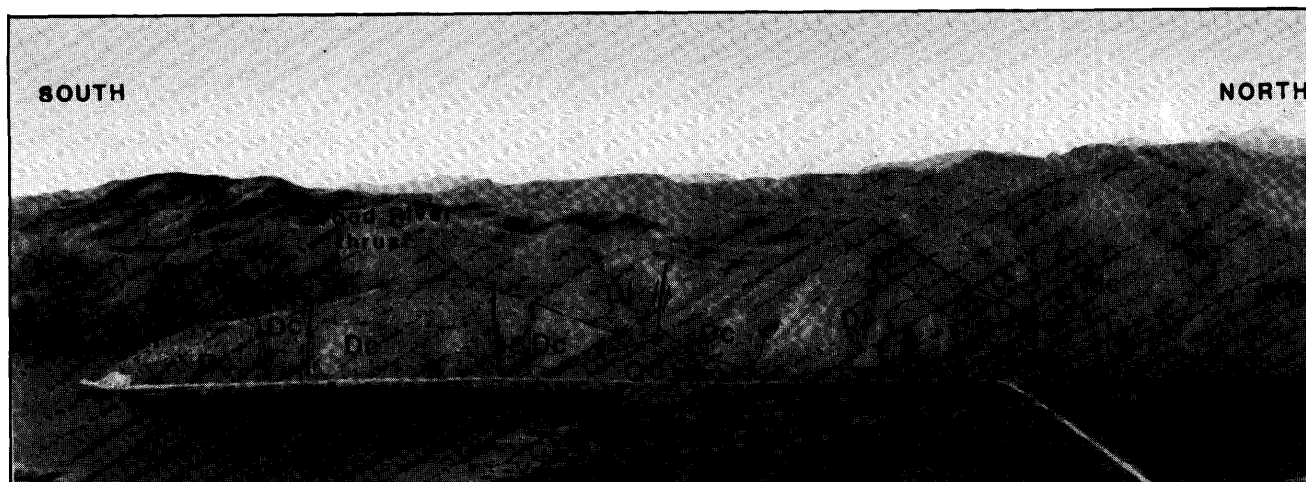


Figure 17. View to west of promontory at north end of Fish Creek Reservoir showing distribution of some map units and a segment of the trace of the Wood River thrust between the Wood River and Copper Basin Formations. Compare with Figure 14. Map units: Dc, Carey Dolomite; Dj, Jefferson Formation; Dp, Picabo Formation; Mc, Copper Basin Formation; P/Pwu, upper part of Wood River Formation; Tc, Challis Volcanic Group; Qd, colluvial, alluvial, and lake deposits. Modified from Skipp and Sandberg (1975).

been proposed for the area by James D. Loghry, a consultant from Tucson, Arizona, who kindly furnished the historical and sample information on the prospect.

Return to the intersection of Fish Creek Road and Highway 26-93. Reset odometers to zero. Continue west toward Carey.

Roadlog from Fish Creek Road to Hailey

Between the Fish Creek Reservoir Road and Carey, Quaternary Snake River Group basalts are south of the road. North of the road, the lower hills are composed of Eocene Challis Volcanic Group. The conspicuous southward-dipping slope that caps these hills is formed on Miocene rhyolite ash-flows of the Idavada Volcanics. These silicic pyroclastic rocks were erupted from multiple vents on the Snake River Plain (F. J. Moyer and W. P. Leeman, unpublished mapping, 1987). The term Idavada Volcanics (Malde and Powers, 1962) is used loosely for Miocene rhyolitic and basaltic units on the central Snake River Plain (Bonnichsen, 1982). For more discussion of these rocks see Bonnichsen and others (1988, this volume).

At mile 3.6, the view to the northwest is of the Little Wood River Valley. The mountains on the skyline to the northwest are underlain by Pennsylvanian-Permian Wood River Formation and Devonian Milligen Formation. Eocene Challis Volcanic Group and Miocene Idavada Volcanics underlie much of the middle ground. To the west is the Queen's Crown, capped by a rhyolite ash-flow tuff of the Idavada Volcanics. This ash flow dips southward, toward the Snake River Plain, and is truncated on the north by a normal fault.

The road to Little Wood River Reservoir intersects the

highway at mile 6.8. Pass through Carey and at mile 7.8 turn right (west) on U. S. Highways 20 and 26 toward Fairfield and Sun Valley.

The highway bends to the southwest at mile 9.0 and ascends the Queen's Crown. The Idavada Volcanics in this area are being studied by W. P. Leeman (Rice University), F. J. Moyer and W. R. Hackett (Idaho State University) and include several composite sheets from several vents.

The summit is reached at mile 9.9. From here the road descends through more volcanic rocks, including white tuff of the Idavada Volcanics and Pleistocene olivine basalt of the Bellevue Formation of Schmidt (1961).

At mile 12.4 cross Silver Creek; this spring-fed creek is an internationally famous trout stream. At mile 14.3 enter Picabo. The Challis Volcanic Group forms the main part of the hills to the north (right). To the south, the Timmerman Hills are composed of Wood River Formation intruded by Cretaceous rocks of the Idaho batholith and overlain by Idavada Volcanics. To the west of the valley of the Wood River are the Smoky Mountains, which are composed of Pennsylvanian-Permian strata of the Wood River and Dollarhide Formations intruded by Cretaceous and Tertiary granodiorites, and overlain in places by the Challis Volcanic Group.

At mile 16.6 cross Silver Creek again. At mile 17.7 turn right (north) on county road toward Gannett. The hills to the north are composed of Wood River Formation overlain by andesite and tuff of the Challis Volcanic Group and Idavada Volcanics.

Pass through the town of Gannett (mile 21.6). At mile 25.2, a black-colored tailings pile marks the mine dump of a silver prospect pit in Devonian Milligen Formation. The Wood River thrust, separating the Milligen from overlying Wood River Formation, is about 100 m above the valley floor in the hills to the north.

At mile 28.9 cross an irrigation ditch. The valley of the Wood River is to the west (left). The trace of the Wood River thrust is near the base of the hill to the east.

Turn right (north) at the intersection of County Road and State Highway 75 at the south end of Bellevue (mile 29.6). In the hills east of Bellevue, the Wood River thrust is present near valley level, at the base of the more resistant outcrops; it dips gently east.

Broadford Street intersects Highway 75 on the left, north of downtown Bellevue (mile 30.3). It leads to the Minnie Moore mine west of town. This mine was the second largest silver producer in the Wood River Valley. The largest producer was the Triumph mine, located on the East Fork of the Wood River, southeast of Ketchum.

The south end of the runway for the Hailey-Sun Valley airport is west of the road at mile 33.0. The view to the west (Fig. 22) is of Colorado Gulch. The prominent break in slope on the ridge north of Colorado Gulch occurs at the outcrop of a low-angle normal fault, and will be examined at **Stop 2-2**. The roadlog ends at mile 34.5, at the intersection of South Main Street and Highway 75 in Hailey.

DAY TWO: GEOLOGY OF THE WOOD RIVER VALLEY

Introduction

Figure 18 is a geologic map and tectonostratigraphic diagram of the Wood River Valley area. Field trip stops follow on three geologic problems:

(1) Distinguishing the carbonaceous siltstones and limestones of the Devonian Milligen Formation (**Stops 2-2 and 2-4**) from similar strata of the Permian Dollarhide Formation (**Stop 2-5**) is important for two reasons. The black mudrocks in question are host to silver-lead mineralization near Bellevue and Hailey, and the distinction is vital toward reconstructing late Paleozoic facies of the Wood River basin and the geometry of Mesozoic and Paleogene faults.

(2) Reconstruction of basin geometry and stratigraphy of the late Paleozoic Wood River basin, its relation to the continental margin, and other coeval basins to the south and east (**Stops 2-3, 2-4, 2-7**): Figure 19 shows the stratigraphy of the three tectonostratigraphic units containing rocks of the Wood River basin.

(3) Faults that place upper Paleozoic rocks of the Wood River basin on older strata have been called the Wood River thrust by previous workers (Hall, Batchelder and Tschanz, 1978; Dover, 1983). In places they retain what is thought to be their Mesozoic geometry (**Stop 2-3**), but elsewhere they have the geometry of Tertiary normal faults (**Stops 2-2, 2-4, 2-7, 2-8**).

The normal faulting may have been related to movement on the Wildhorse detachment system of the Pioneer Mountains core complex (**Stop 2-6**), denuda-

tion above the rising Boulder Mountains magmatic center (**Stop 2-9**), or Basin and Range extension.

Dollarhide-Milligen Problem

Black, carbonaceous and metalliferous limestones and mudstones of the Wood River Valley area have traditionally been mapped as Devonian Milligen Formation (Umpleby and others, 1930; Anderson and others, 1950). Sandberg and others (1975) determined that the type Milligen Formation southeast of Ketchum was Devonian in age, and restricted the name Milligen to Devonian age rocks. However, much of the exposed carbonaceous strata near Hailey and Bellevue are sparsely fossiliferous and despite several efforts have not yielded definitive fossil assemblages.

Dark-colored mudrocks west of the Wood River were all mapped as Milligen Formation until 1983, when Wayne Hall and co-workers discovered Permian fusulinids in carbonaceous limestones near the headwaters of Deer Creek, about 6 km west of **Stop 2-5** (Hall, 1985; Wavra, 1985). Most dark mudstones west of the Wood River were redesignated as Permian Dollarhide Formation (Hall, 1985).

As seen at **Stop 2-2**, rocks of the Milligen Formation commonly show penetrative cleavage (Turner and Otto, 1988, this volume), while rocks of the Dollarhide Formation (**Stop 2-5**) lack a penetrative fabric. However, this criterion for distinguishing the formations has not proven applicable at all locations.

The geologic compilation map of Hall (1985) shows an east-dipping thrust fault with Milligen Formation over Dollarhide Formation, west of the Wood River between Hailey and Bellevue. However, detailed mapping of this contact by M. E. Ratchford reveals the relations shown in Figures 18 and 26, with a west-dipping fault placing Dollarhide above Milligen. The interpretation shown in Figures 26 and 27 implies that this contact is a folded Mesozoic thrust. North of Colorado Gulch (**Stop 2-2**, Fig. 26), a low-angle normal fault cuts both the Wood River thrust and the Milligen-Dollarhide thrust, and it locally places Dollarhide Formation topographically above the Milligen Formation. Major questions remain about the extent of the Dollarhide Formation and its structural relationship to both the Wood River and Milligen Formations.

Wood River Basin

The Wood River basin developed on the site of the former Antler highland (Devonian Milligen Formation) and was filled with several thousand meters of mixed siliciclastic-carbonate sediment. The Wood River basin was coeval with similar depocenters to the south (Oquirrh, Sublett, and Cassia basins). These epicratonic basins are thought to have formed during transtensional faulting of the Ancestral Rockies orogeny (Kluth, 1986). Wavra and others (1988) propose that the Wood River

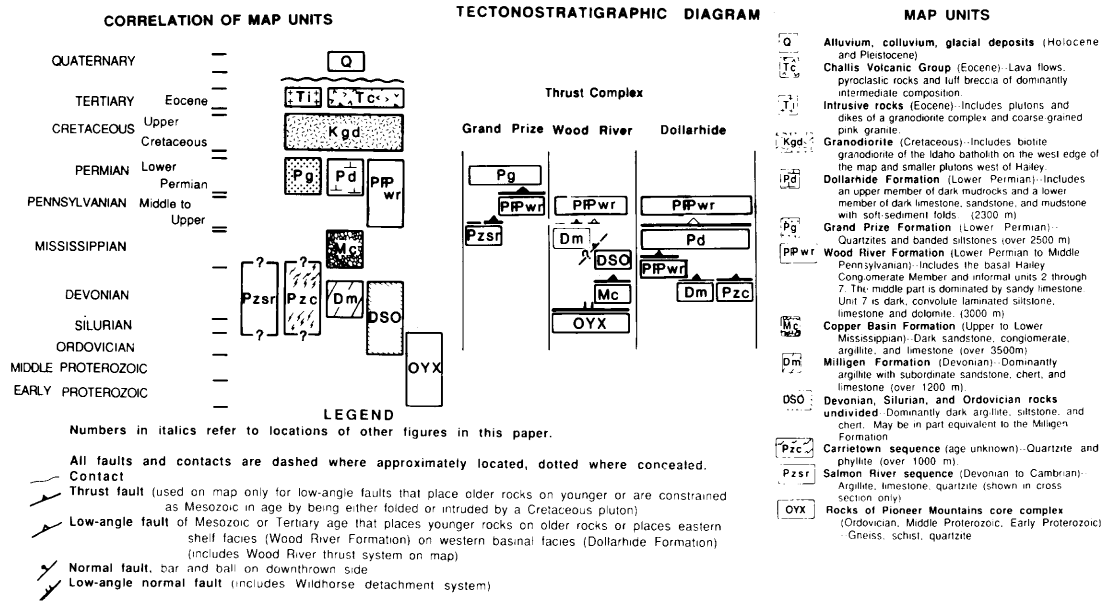
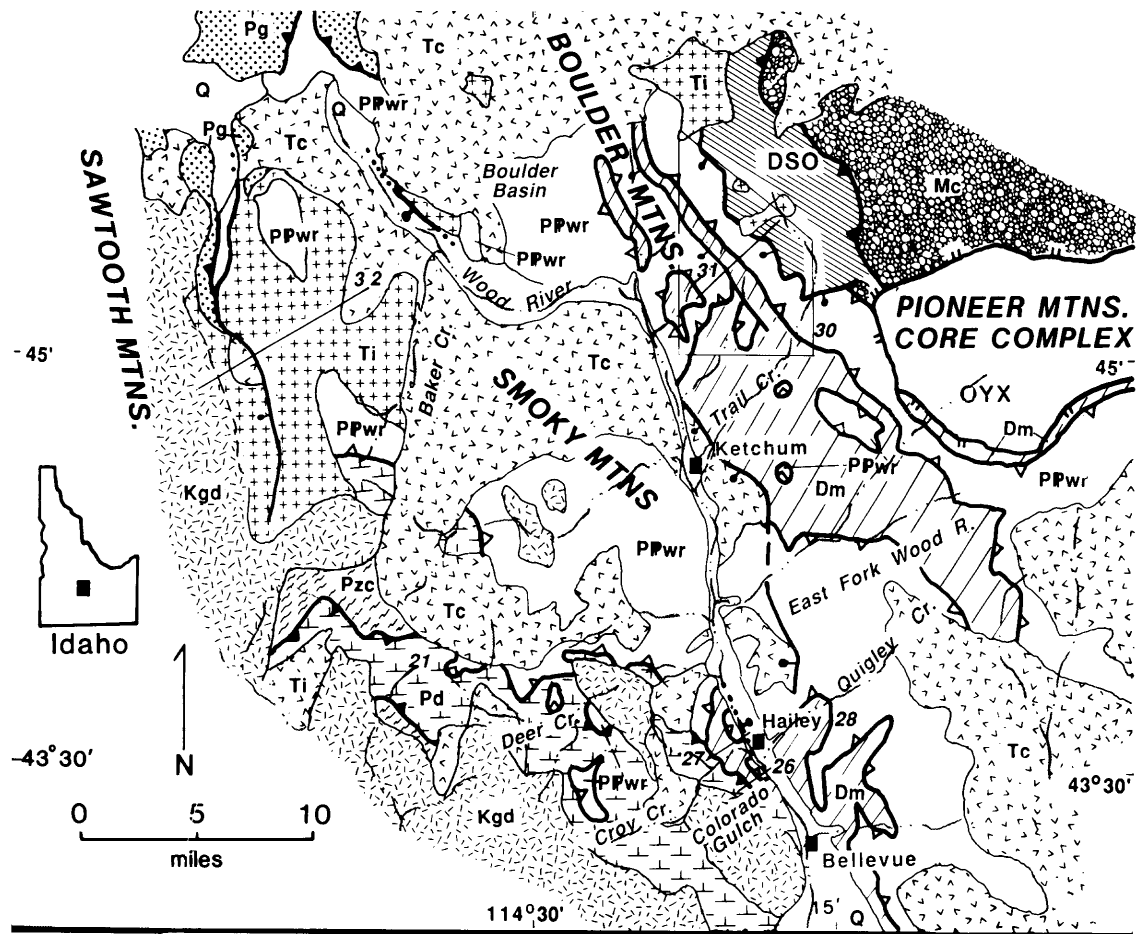


Figure 18. Simplified geologic map, correlation chart, and tectonostratigraphic diagram of the central Idaho black shale mineral belt, modified from Hall (1985) based on new mapping by P. K. Link, B. R. Burton, and M. E. Ratchford. Locations of photograph (Fig. 21), cross sections (Figs. 26, 27, 31, 32), and geologic maps (Figs. 28 and 30) are shown in *italic numbers*.

“basin” was instead a west-facing continental margin. An alternate interpretation, that the Wood River basin had complex paleoslopes, is advocated in this paper.

Strata deposited in the Wood River basin now compose three thrust-bounded tectonostratigraphic units: the Wood River, Dollarhide and Grand Prize Formations (Hall, 1985; Link and others, 1987) (Fig. 19).

The Wood River basin received sediment from three sources: (1) The basal Hailey Conglomerate Member of the Wood River Formation had a nearby northeastern source area consisting of uplifted rocks of the Antler flysch trough (Mississippian Copper Basin Formation) and locally, rocks of the underlying Milligen Formation. (2) The bulk of the quartzose sand was derived from the North American craton, probably from uplifts of the Ancestral Rockies system. 3) The carbonate mud found in the Wood River and Dollarhide Formations may have been derived from the carbonate bank now represented by the Pennsylvanian Snaky Canyon Formation of the Lost River-Arco Hills, White Knob, and Grouse plates.

Wood River Formation

The Wood River Formation in the type area east of Bellevue contains at least 3000 meters of strata (Fig. 19), with a formally defined basal member (the Hailey Conglomerate Member) and overlying informal units 2 through 7 (Hall and others, 1974, Goodman, 1983). Siltstones at the top of the formation were proposed to belong to unit 8 (Hall, Rye, and Doe, 1978; Hall, Batchelder, and Tschanz, 1978), but recent work by Burton has demonstrated that unit 8 is unmappable because it cannot be distinguished from unit 7.

The contact between the Hailey Conglomerate Member and underlying Devonian Milligen Formation has been mapped as the Wood River thrust. Our work shows that this contact is both a Mesozoic thrust and a Tertiary normal fault (Fig. 18). In places (Fig. 30) the Hailey Conglomerate Member contains lithoclasts of the subjacent Devonian Milligen Formation, and the contact is interpreted as an unconformity.

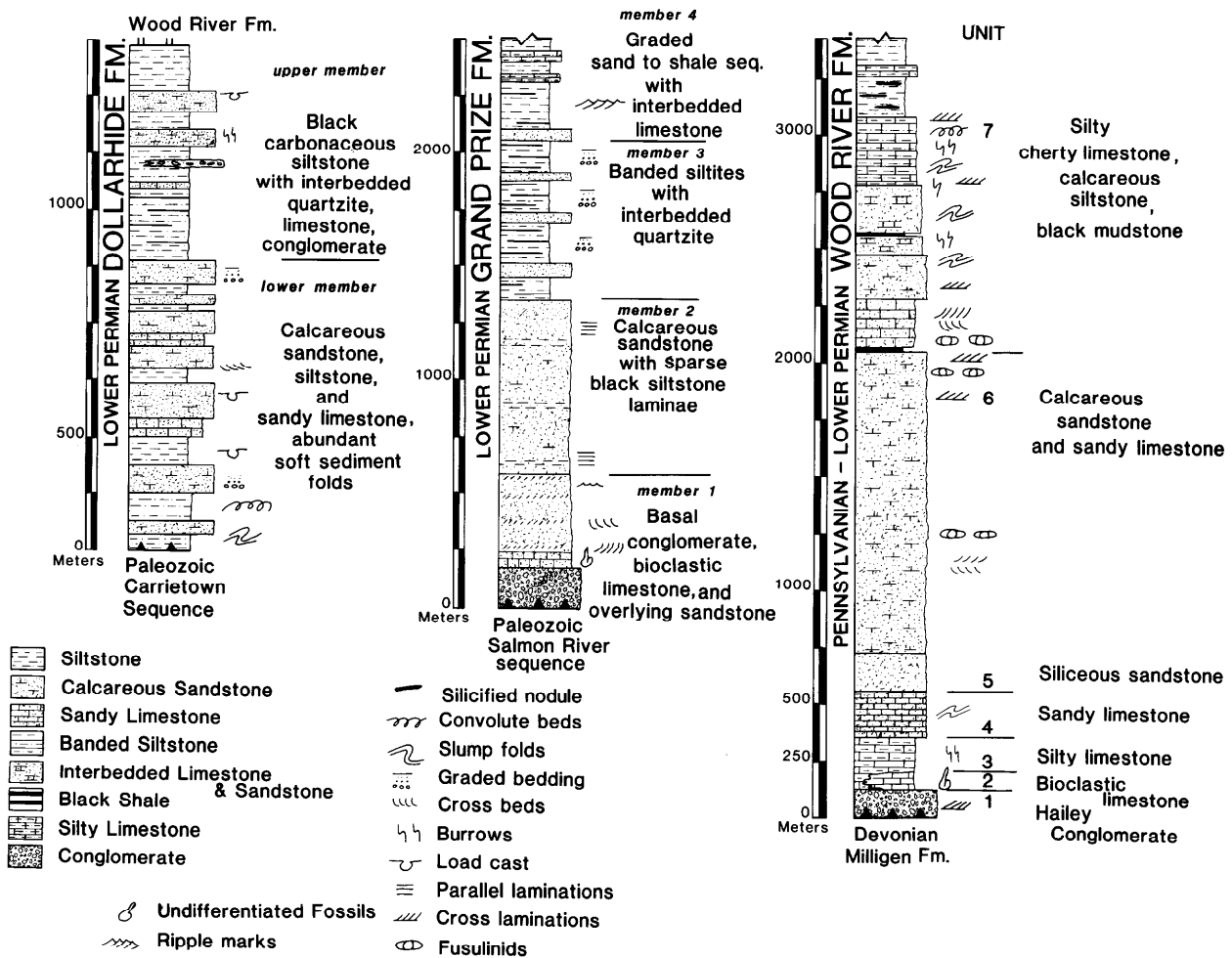


Figure 19. Stratigraphic columns for tectonostratigraphic units of the Wood River basin. Sources of stratigraphic information include: Hall and others (1974), Sengebusch (1984), Wavra and others (1986), Geslin (1986), Mahoney (1987) and B. R. Burton (unpublished). Figure is modified from Link and others (1987).

The Hailey Conglomerate Member is thought to be deposits of a braid- or fan-delta complex that carried clasts from the uplifted and lithified Copper Basin Formation to the northeast (Winsor, 1981). The Hailey Conglomerate Member coarsens and thickens northeastward toward its source area and contains southwest-directed paleocurrents. In the type area of the Hailey Conglomerate Member (Stop 2-3), conglomerate is only present in the basal few tens of meters. In easternmost exposures of the lower Wood River Formation (Stop 1-7 at Fish Creek Reservoir), conglomeratic debris is present through 200 m of section (Fig. 15).

The Hailey Conglomerate Member contains thin interbeds of coralline limestone and is overlain by fossiliferous Wood River Formation unit 2 (Fig. 19), which contains Middle Pennsylvanian macrofossils that lived on a substrate of conglomerate debris. The Hailey Member and unit 2 are mapped as the lower part of the Wood River Formation on the geologic map of the eastern Boulder Mountains (Fig. 30).

The middle part of the Wood River Formation (units 3 through 6, Late Pennsylvanian to Early Permian) consists of light brown to gray, calcareous (locally siliceous) sandstone and sandy limestone deposited on a carbonate ramp, but dominantly above storm wave base. Unit 3, a sub-wave-base siltstone, abruptly overlies shallow-water bioclastic unit 2, suggesting a rapid deepening of the basin.

Where brittle siliceous sandstone of unit 5 is not present, units 4 and 6 cannot be separated and all rocks above unit 2 and below dark siltstone of unit 7 are mapped as middle part, Wood River Formation (Fig. 30).

The upper part of the Wood River Formation (unit 7) contains distinctive thin-bedded, parallel and convolute laminated, silty and sandy limestone and dolomite, plus black shale containing abundant trace fossils. These lithologies suggest deposition from periodic silty turbidity currents (Burton, 1988).

Dollarhide Formation

The Dollarhide Formation was defined by Hall (1985) for carbonaceous limestone, siltite, quartzite and mudstone near Dollarhide Summit in the Smoky Mountains (Fig. 18). More detailed studies by Wavra (1985), Wavra and others (1986), and Geslin (1986) show the Dollarhide to be about 2300 m thick.

Two members (Fig. 19) are mappable: a lower member of sandy limestones and sandstones and an upper member containing black mudstone and argillite with varying amounts of sandy limestone, calcareous sandstone, and conglomerate. The lower member contains abundant soft-sediment folds and was deposited on a slope. The upper member is thought to be a basinal mudstone (Wavra and others, 1986; Geslin, 1986). The upper member contains much carbonaceous matter and strongly resembles rocks mapped as Devonian Milligen Formation east of the Wood River (Link and others,

1987). The upper member hosts silver-lead mineralization west of the Wood River at the Silver Star Queen and Minnie Moore mines near Bellevue (Hall, 1985) and in the Carrietown mining district west of Ketchum (Darling, 1988, this volume).

Grand Prize Formation

The Grand Prize Formation was named by Hall (1985) for a thick sequence of quartzites and banded siltites exposed along Pole Creek, north of Galena Summit (Fig. 18). The Grand Prize Formation includes much of what was mapped as upper Wood River Formation by Tschanz and others (1986) and all of the Pole Creek formation of Fisher and others (1983). The age of the Grand Prize Formation is poorly constrained as Early Permian (Leonardian) but the rocks could be as old as Pennsylvanian (Wolfcampian). These age assignments are based on stretched and corroded conodonts from the base of the section (Hall, 1985).

The Grand Prize Formation is faulted above the early Paleozoic Salmon River assemblage, and also lies in low-angle thrust contact above the Wood River Formation (Hall, 1985). The Grand Prize Formation is nowhere in contact with the Devonian Milligen Formation.

Mahoney and Sengebusch (1988, this volume) argue that the Grand Prize Formation contains deposits of subaqueous mass-gravity flows, and suggest that parts of the unit were deposited in a submarine fan setting. The Grand Prize Formation contains less carbonate mud than the Wood River and Dollarhide Formations and must have accumulated in a part of the basin that was isolated from carbonate input.

Correlation Within Wood River Basin Strata

Each formation of the Wood River basin is defined as a tectonostratigraphic unit, bounded above and below by faults (Fig. 18) (Hall, 1985). There are several striking lithologic similarities among the units. The basal conglomerate of the Grand Prize Formation strongly resembles the Hailey Conglomerate Member of the Wood River Formation. The Lower Permian portions of all three formations indicate deepening sedimentary environments. The upper member of the Grand Prize Formation is similar to both the upper member of the Dollarhide Formation and to unit 7 of the Wood River Formation.

Southwestward paleocurrents and northeastward-coarsening of clasts in the Hailey Conglomerate Member suggest that during Middle Pennsylvanian time the Wood River basin lay southwest of a highland that contained rocks of the Copper Basin Formation. Shelf-facies deposits of the lower and middle Wood River Formation may have passed southwestward to deeper water deposits now represented by the Dollarhide Formation (Wavra and others, 1986; Mahoney and Link, 1987a, b; Mahoney and others, 1987; Link and others, 1987).

Wood River Formation unit 7 (Lower Permian) in the Boulder Mountains contains abundant soft-sediment folds that verge southeast (Burton, 1988; Burton and Link, 1988), indicating a southeast paleoslope in Early Permian time. Unit 7 in the southwestern allochthon of the Boulder Mountains may represent the western edge of an epicratonic Wood River basin. The documentation of a southeastward paleoslope in unit 7 suggests that the upper Wood River Formation was deposited in a basin with complex and multidirectional paleoslope.

Time correlations and a rigorous basin analysis for these rocks await biostratigraphic resolution.

Wood River Thrust

In the central Idaho black shale mineral belt of the Pioneer, Boulder and Smoky Mountains, faults of regional extent place upper Paleozoic rocks of the Wood River basin over older, metamorphosed, lower Paleozoic strata (Milligen Formation and Salmon River assemblage). These faults have been grouped under the term "Wood River thrust" (Hall, Batchelder, and Tschanz, 1978; Dover, 1983). In places this fault system is folded into eastward-overtained folds and is intruded by Cretaceous rocks. These localities include the area west of Hailey (Stops 2-1 to 2-3) (Figs. 26 and 27) and the White Cloud Mountains north of the map of Figure 18 (Tschanz and others, 1986; Sengebush, 1984). Other characteristics thought to represent parts of the thrust preserving Mesozoic geometry include the development of a gouge zone (Stop 2-8 and Fig. 20) and the presence of a full section of Wood River Formation above the fault, as in the type area east of Bellevue.

In large areas of the Wood River Valley the Wood River thrust can be recognized only as pre-Challis Volcanic Group in age. In many places the thrust appears to have been cut by later normal faults (Figs. 27 and 31) (Stops 2-2, 2-8) (Skipp and others, 1986; Otto and Turner, 1987; Turner and Otto, 1988, this volume). Among the criteria used to infer Tertiary normal faults are: attenuation and boudinage of the basal Hailey Conglomerate Member and overlying units 2 and 3 of the Wood River Formation above the fault (Fig. 21) (Stops 2-2, 2-4, 2-8), and the presence of breccia zones and smooth slickensided surfaces along the fault (Stop 2-4).

Roadlog from Ketchum to Hailey

Mileage starts at the intersection of Sun Valley Road and State Highway 75 at the stoplight in downtown Ketchum. Figure 18 is a geologic map of the Wood River Valley. Proceeding south on Highway 75 from Ketchum, we travel through the southward-widening Wood River graben filled with Quaternary and Holocene alluvial deposits of the Wood River. To the west is Bald Mountain (Fig. 24) with the main Sun Valley ski area.

Bald Mountain is underlain by folded rocks of the upper part of the Wood River Formation. To the east are dacite lavas of the Eocene Challis Volcanic Group (Fig. 23). This area has been mapped by Hall, Batchelder and Tschanz (1978) and Batchelder and Hall (1978).

At the bridge over the Wood River (mile 2.3) rocks to the east are mapped as rhyodacite of the Challis Volcanic Group. Thick-bedded sandstone of Wood River Formation unit 6 lies to the west. At Cold Springs Road (mile 3.6) the unconformable contact of the Challis Volcanic Group over Wood River Formation is visible in the gully directly to the east.

Proceed south to Hailey (main intersection is at mile 12.1). Where the road bends to the east (mile 12.6), remain on South Main Street by bearing right across from the Blaine County Hospital. Pull off at mile 13.2 for a view of the Hailey area.

Stop 2-1: View of Hailey Area and Discussion of Wood River Thrust

To the west lie the tree-lined course of the Wood River and steep-sided hills on the west side of the Wood River graben (Figs. 22 and 25). To the southwest is Colorado Gulch, which contains the critical contact between the Devonian Milligen and Permian Dollarhide Formations. The hill directly west is Della Mountain (Fig. 26). The lower slopes of Della Mountain are underlain by siltstone, sandstone, and phyllite of the Milligen Formation, and the blocky outcrops along the summit ridge are the basal Hailey Conglomerate Member of the Wood River Formation. The Hailey Conglomerate Member overlies the Milligen Formation on the Wood River thrust, which is flat-lying on the summit of Della Mountain and is offset down to the south at the prominent bench on the south flank of the mountain. This bench is thought by Link to be the topographic expression of a low-angle normal fault which cuts the Wood River thrust and which will be visited at Stop 2-2.

To the northwest is the valley of Croy Creek and Carbonate Mountain north of the creek. As shown in the cross section of Carbonate Mountain (Fig. 27), the Wood River thrust has been folded into an eastward-overtained antiform, and the Hailey Member dips steeply westward, overturned. The type area for the Hailey Conglomerate Member is at the base of Carbonate Mountain and will be visited at Stop 2-3. The Milligen Formation underlies the main part of the hills to the west.

Hills to the east across the Wood River Valley are underlain by the Wood River Formation, with Milligen Formation below the Wood River thrust. The Wood River thrust will be visited in Quigley Creek, directly to the east of Hailey, at Stop 2-4.

Return to the cars and proceed south 0.2 mile (mile 13.4) to a small road to the right (west). Cross a canal and bear left on dirt road. Cross the Wood River and proceed to the mouth of the second gulch on the north (right) side of the road (mile 14.2).



Figure 20. The Wood River thrust in Boulder Basin, Boulder Mountains. Here, the thrust appears to preserve its Mesozoic fabric, with conglomerate of the basal Wood River Formation lying above a gouge zone and phyllite of the Devonian Milligen Formation. The same geologic relation is mapped at the Hailey Conglomerate Member type area (Stop 2-3).



Figure 21. View of a klippe of Pennsylvanian-Permian Wood River Formation unit 6 (sandy limestone) (rounded hill on the skyline) above Permian Dollarhide Formation (upper member, dark mudstone) on Buttercup ridge at the head of Willow Creek, Smoky Mountains. Location of photograph is shown on Figure 18. View is to the southeast. This area was mapped by Geslin (1986). This klippe is thought to overlie a flat, top-to-the-west low-angle normal fault which cuts bedding in both the Wood River and Dollarhide Formations, and which attenuates the Wood River Formation, eliminating at least 1500 meters of strata.

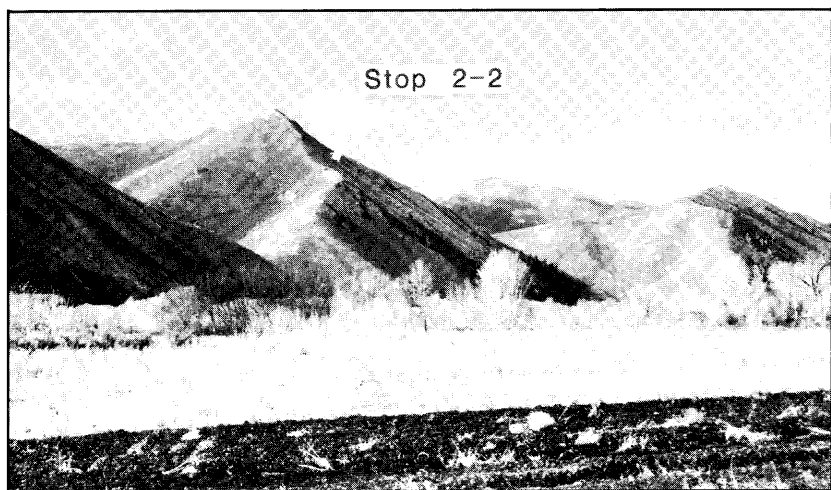


Figure 22. The mouth of Colorado Gulch and site of Stop 2-2, taken looking westward from Highway 75. The prominent jog in the south ridge of Della Mountain marks a low-angle normal fault that cuts the folded Wood River thrust and places boudins of Hailey Conglomerate Member on folded Milligen Formation. Figure 26 is a cross section through this ridge.

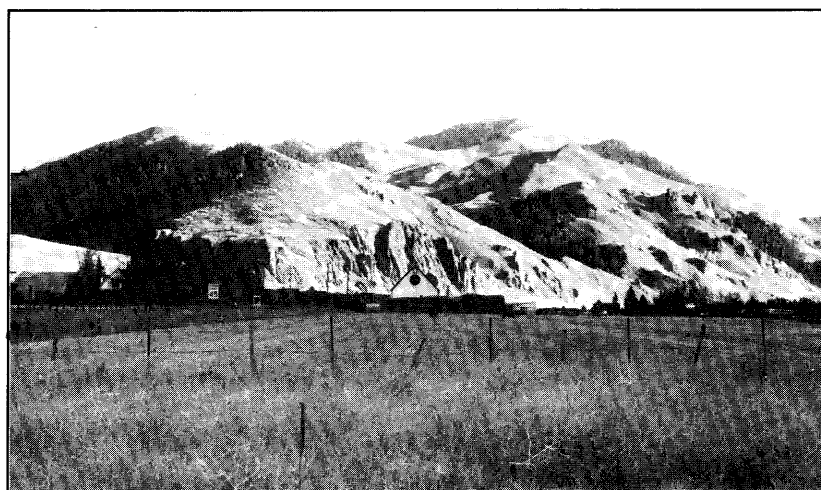


Figure 23. Eocene lavas of the Challis Volcanic Group on the east side of the Wood River graben, just southeast of Ketchum.

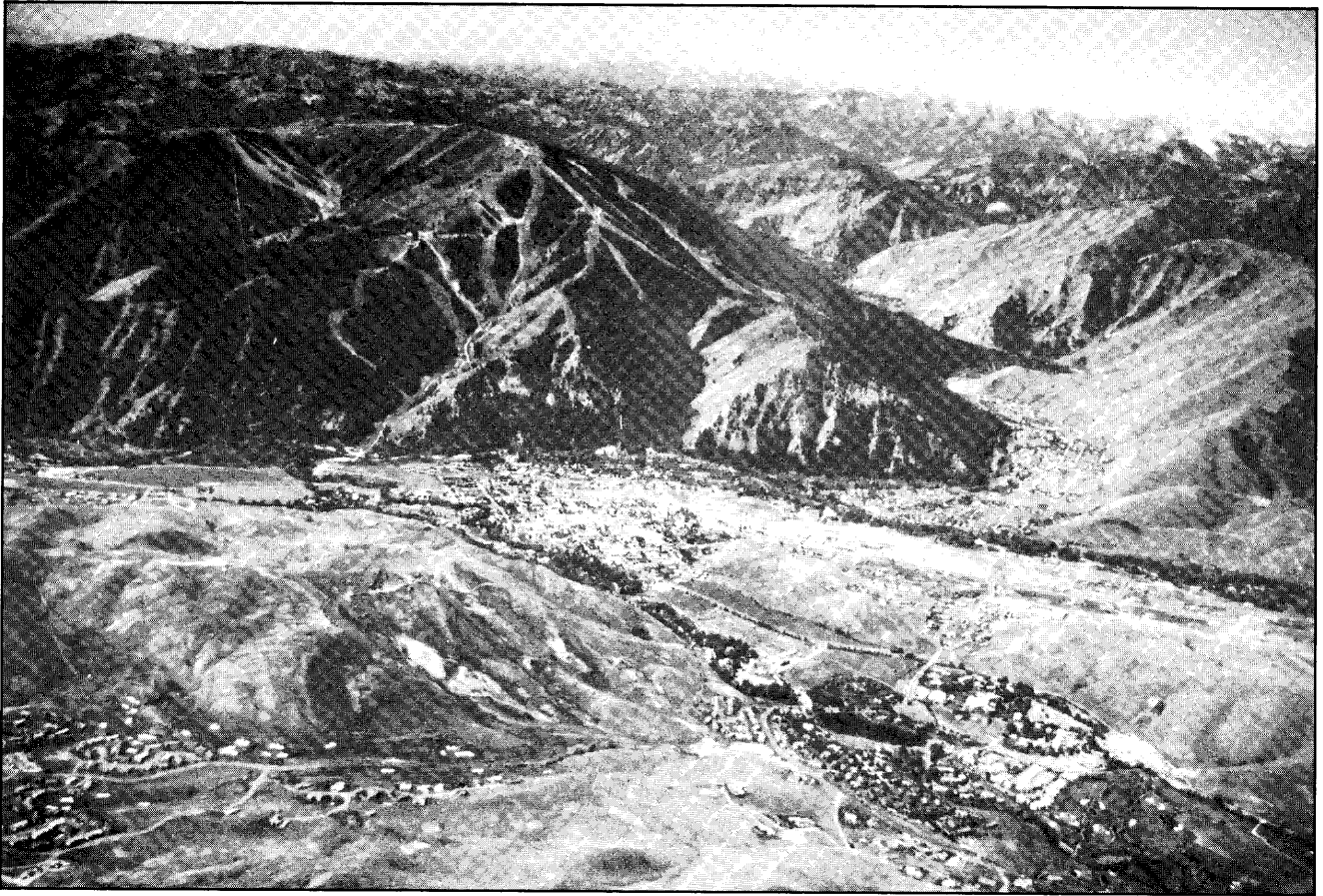


Figure 24. Aerial view looking southwest at Bald Mountain (with prominent ski trails) underlain by folded upper part of the Wood River Formation and with the Smoky Mountains in the distance, made up of Paleozoic strata of the Wood River basin intruded by Cretaceous and Tertiary rocks and overlain by Eocene Challis Volcanic Group. The town of Ketchum is directly below Bald Mountain; Sun Valley is in the right foreground. Warm Springs Creek lies in the valley north (right) of Bald Mountain.

Stop 2-2: Milligen Formation and Low-Angle Normal Fault in Colorado Gulch

This stop involves a walk of about 1.5 miles and a climb of 600 feet. We will walk up the gulch on the south side of Della Mountain and observe isoclinally folded Devonian Milligen Formation with Pennsylvanian Hailey Conglomerate Member in low-angle normal fault contact above it (Fig. 22). Figure 26 is a cross section of the ridge here, north of Colorado Gulch.

The first outcrop on the west side of the gulch exposes isoclinally folded phyllite of the Devonian Milligen Formation. The phyllite has a cleavage (S1), which is axial planar to isoclinal folds, and a later spaced cleavage (S2). Walk up the gulch and around to the right (east) through platy limestone, pink siltite, and gray phyllite of the Devonian Milligen Formation. The Milligen Formation is thought to have made up part of the Antler highland in Mississippian time (Turner and

Otto, 1988, this volume).

Bold outcrops of the Hailey Conglomerate Member occur above a prominent bench where there are several prospect trenches. Here the Hailey Conglomerate Member is exposed as boudins along a shallowly dipping normal fault that cuts bedding in both upper and lower plates. The fault extends to the west, up Colorado Gulch. About 2 km to the west, it places brown-weathering Milligen Formation above black-weathering Dollarhide Formation (Fig. 26). This fault is one of several low-angle normal faults that occur on the flanks of the Wood River Valley.

The view from the bench at the top of the jeep road overlooks the Wood River graben, Bald Mountain west of the Wood River, and the high ridges of the Boulder Mountains to the north.

Return to the cars and proceed back to Hailey. Reset odometers at the major intersection at the corner of Main Street (Highway 75) and Bullion Street. Turn west on Bullion Street. Cross the Wood River, and stop at the west side of the bridge (0.4 mile).

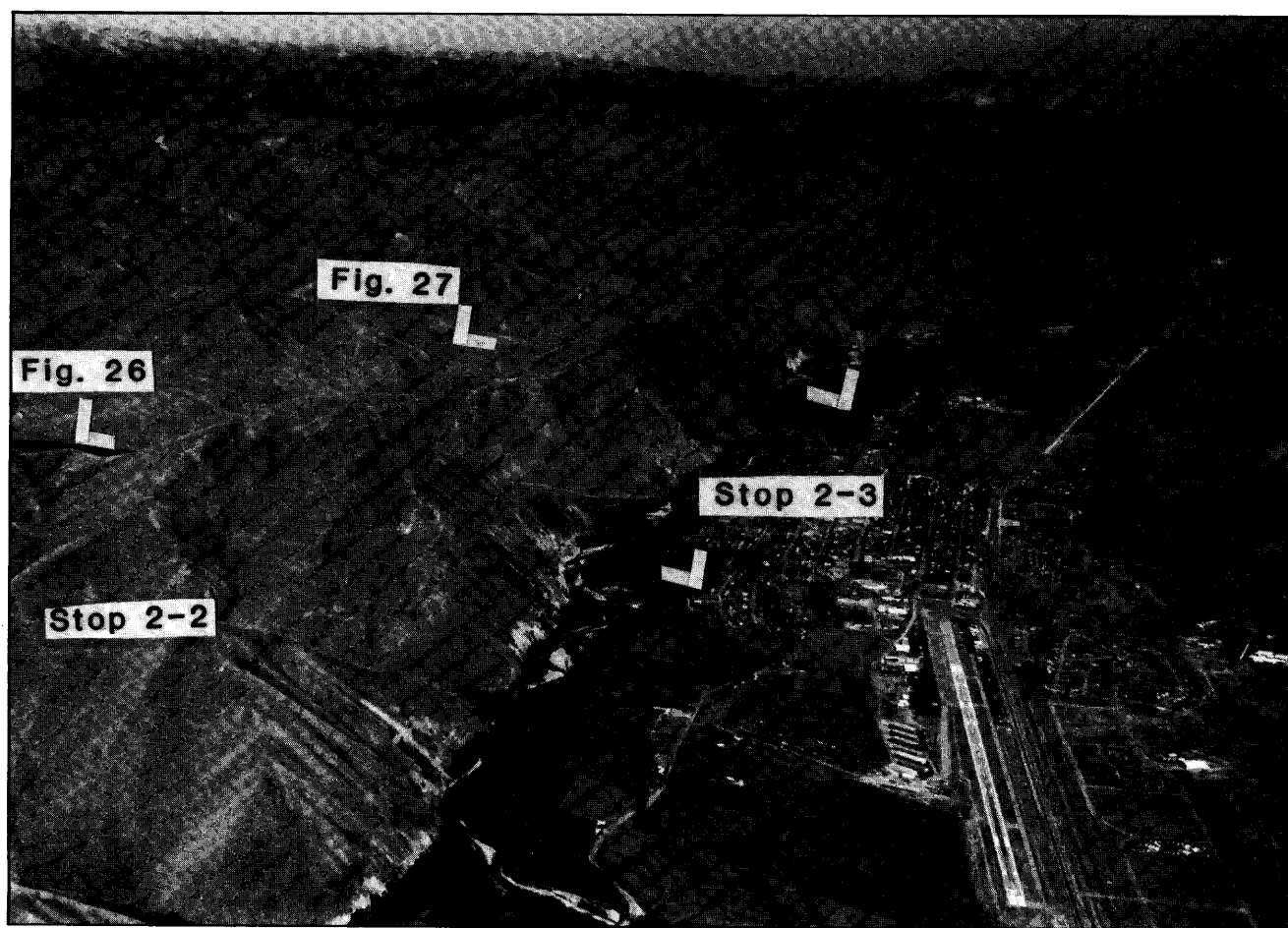


Figure 25. Aerial view looking north at the town of Hailey and the west side of the Wood River graben. Locations of Stops 2-2 and 2-3 are shown, as well as lines of cross sections of Figures 26 and 27.

Stop 2-3: Type Area of the Hailey Conglomerate Member

Walk upstream along the river for a short distance to view the type area of the basal Hailey Conglomerate Member of the Wood River Formation (Bostwick, 1955; Thomasson, 1959; Winsor, 1981). The rocks dip steeply west and are overturned (Fig. 27). The Hailey Member here consists of sheared pebble to cobble conglomerate and coarse sandstone containing clasts of gray mudstone or argillite, black quartzite, and chert-pebble conglomerate. Sedimentary structures include graded bedding, planar cross bedding, and ripple marks. The Hailey Member lies structurally above the Devonian Milligen Formation here along the folded Wood River thrust. The Wood River thrust here preserves its Mesozoic relations and has not been reactivated as a Tertiary normal fault.

Return to cars and go back to Main Street in Hailey. Reset odometers, head south for one block to Croy Street and proceed east. Croy Street becomes Quigley Gulch Road. In the valley of Quigley Creek (mile 1.0), Wood River Formation underlies the hills to the north, with

Milligen Formation at the base of the hills to the south. The Wood River thrust crops out in the steep hills south of the creek about 300 feet above creek level. Bold outcrops of the Wood River Formation lie just above the thrust. Stop at the mouth of Deadman Creek (mile 2.7) to examine the Wood River thrust.

Stop 2-4: Wood River Thrust in Quigley Creek

Tightly folded and silicified, thinly laminated sandy dolomite, siltstone, and purple phyllite make up the Milligen Formation just below the Wood River thrust. Figure 28 is a geologic map of the area. Mesoscopic folds in the Milligen Formation verge east. The Wood River thrust is located at a prominent bench marked by fault breccia and quartz veins and stringers. The overlying Wood River Formation unit 4 is tan- to red-weathering, calcareous sandstone and medium-gray limestone.

This outcrop illustrates the perplexing nature of the Wood River thrust. Here the Hailey Conglomerate Member and overlying units 2 and 3 are missing below

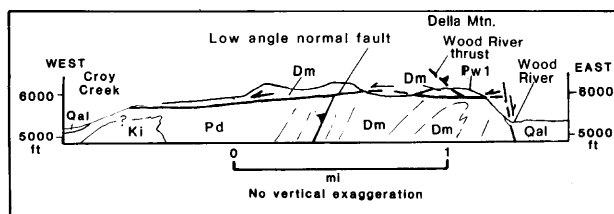


Figure 26. East-west cross section through Della Mountain on the north side of Colorado Gulch, extreme northwestern Bellevue 7 1/2 minute quadrangle. Stop 2-2 is a foot traverse to the low angle normal fault on the east shoulder of Della Mountain. Cross section is by P.K. Link after geologic mapping by M.E. Ratchford. Dm--Milligen Formation (Devonian); Pw1--Hailey Conglomerate Member (Wood River Formation unit 1--Middle Pennsylvanian); Pd--Dollarhide Formation (Permian); Ki--Cretaceous Croesus diorite stock; Qal--Quaternary alluvium. Symbols are shown on Figure 18.

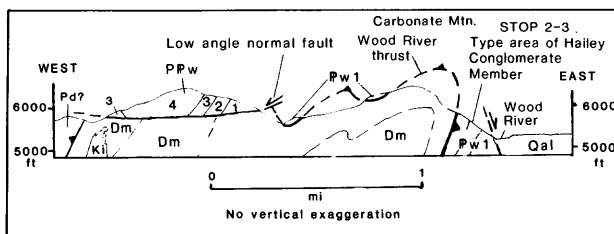


Figure 27. East-west cross section through Carbonate Mountain, on the north side of Croy Creek, Hailey 7 1/2' quadrangle. Cross section shows location of Stop 2-3 at the type area of the Hailey Conglomerate Member of the Wood River Formation. Cross section is by M.E. Ratchford and P. K. Link from geologic map of Batchelder and Hall (1978). Dm--Milligen Formation; P/Pw--Wood River Formation (including units 1, 2, 3, and 4--Middle Pennsylvanian to Early Permian); Pw1--Hailey Conglomerate Member (Wood River Formation unit 1--Middle Pennsylvanian); Pd--Dollarhide Formation (Permian); Ki--Cretaceous Croesus diorite stock; Qal--Quaternary alluvium. Symbols are shown on Figure 18.

the fault, yet only one km to the east, boudins of Hailey Conglomerate Member are present along the fault. These boudins and the omission of units 2 and 3 suggest that the thrust here was reactivated as a Tertiary normal fault, attenuating the lower part of the Wood River Formation.

Return to the vehicles and drive back to Hailey. Reset odometers at Main Street (Highway 75). Proceed 2.5 miles north to Deer Creek Road and turn west (left).

Mileage for the Deer Creek side trip begins at the intersection of Deer Creek Road and Highway 75. Cross the Wood River at mile 0.5. Prominent outcrops on the south side of Deer Creek are the northward continuation of the overturned Wood River thrust relation seen at Croy Creek (Stop 2-3) (Figure 27). Overturned, west-dipping Wood River Formation makes up the face of the hill, with overturned Milligen Formation farther to the

west. Challis Volcanic Group rocks form the craggy summit south of the road at mile 1.2. The faulted contact of Wood River Formation and Dollarhide Formation is crossed at mile 3.9. There are several prospect pits in the Dollarhide Formation north of the road.

Clarendon Hot Springs is to the left of the road at mile 4.5. It is one of several hot springs located on the western margin of the Wood River Valley (Foley and Street, 1988, this volume). Stop in pullout at crest of hill (mile 4.7) to examine intrusive rocks of the Cretaceous Deer Creek stock and beds of the Permian Dollarhide Formation.

Stop 2-5: Deer Creek Stock and Dollarhide Formation near Clarendon Hot Springs

This stop illustrates lithologies of the lower member of the Permian Dollarhide Formation that are in fault contact with biotite granodiorite of the Deer Creek stock. The Deer Creek stock is one of three outliers of the Idaho batholith that intrude strata of the Wood River basin 10 km east of the main batholith (Johnson and others, 1988, this volume). It has been dated at 91 Ma by K-Ar (Hall, cited in Wavra, 1985). The rock is an equigranular biotite granodiorite with trace amounts of hornblende.

The Dollarhide Formation at this locality is folded white quartzite interbedded with calcareous, laminated and banded, gray and black siltite. It is thus "typical Dollarhide Formation", lacking the penetrative cleavage observed in the Devonian Milligen Formation at Stop 2-2.

Return to vehicles and return to Highway 75. Head north for 3.5 miles to East Fork Road. Turn right (east) and proceed up the East Fork of the Wood River for 2.1 miles to an intersection on the right with Canyon Road. Pull out in the clearing on right for a view of the Pioneer Mountains.

Stop 2-6: Pioneer Mountain View

Glacially sculpted peaks of the Pioneer Mountains (including Hyndman Peak on the right) are visible at the head of the East Fork of the Wood River. The peaks are underlain by Proterozoic(?) schist and quartzite and intruded by Cretaceous and Tertiary plutons (Dover, 1981; Wust and Link, 1988, this volume). The peaks are in the lower plate of the Wildhorse detachment system which separates unmetamorphosed upper plate rocks (including the Wood River and Milligen Formations) from high-grade metamorphic and plutonic rocks of the lower plate. The Wildhorse detachment crops out just below the line of sight in front of the peaks. Movement on the detachment was toward the northwest, and it most probably occurred in Eocene time during and after eruptions of the Challis Volcanic Group (Wust and Link, 1988, this volume). It is probable that some of the low-angle normal faults in the Wood River Valley are related

to movement on the Wildhorse detachment system.

Return to Highway 75 and north to the stoplight at the intersection of Highway 75 and Sun Valley Road in Ketchum. Set odometers to zero.

Proceed northeast on Sun Valley Road. The road follows the valley of Trail Creek through the stack of thrust plates on the west flank of the Pioneer Mountains. The Boulder Mountains lie northwest of Trail Creek Road (Fig. 18). The Devonian Milligen Formation underlies the hills between Ketchum and Wilson Creek (Fig. 30). The Wood River Formation is complexly folded and imbricated between Wilson Creek and the upper part of the canyon.

Stop at mile 8.2 to discuss Wood River Formation stratigraphy.

Stop 2-7: Wood River Formation in the Eastern Boulder Mountains

The ridge northwest of Trail Creek rises from the Wood River Valley to peak 10,458 at the head of Rock Roll Canyon, directly to the west (see geologic map of this area, Fig. 30).

Mapping by Burton and Link northwest of Trail Creek (Fig. 30) shows that here the Wood River Formation is made up of two separate allochthons (Fig. 29). The northeastern allochthon (3000 m thick) contains all the informal units of the stratotype near Bellevue. Sandy limestones of units 4 and 6 are separated by brittle siliceous sandstones of unit 5. In the southwestern allochthon, unit 5 is missing, and the section is only two-thirds as thick (1800 m).

Similar to Stop 2-4, the Wood River thrust here displays complex and variable relations between rocks in the hangingwall and footwall. In the high saddle south of peak 10,458, the upper part of the northeastern allochthon (unit 6) is in fault contact with black argillite of the Devonian Milligen Formation. One kilometer farther west, the entire section of the northeastern allochthon is present above the fault, implying that a lateral ramp is present here. Several kilometers farther west, the Hailey Conglomerate in the northeastern allochthon contains clasts of silicified limestone identical to the subjacent Milligen Formation. Here the contact is mapped as a disconformable sedimentary contact.

The ridge to the south of the high saddle contains facies of the southwestern allochthon (Fig. 29). The stratigraphic differences between the two allochthons require that tens of kilometers of telescoping have occurred between them. A Mesozoic thrust fault is therefore interpreted to be present between the allochthons (Fig. 31). The contact between the Hailey Conglomerate Member and the Milligen Formation in the southwestern allochthon is similar to the depositional contact in the northeastern allochthon, but exhibits some brecciation and slickensided surfaces. It is not clear if this contact is a sheared unconformity or another example of the younger-on-older Wood River thrust.

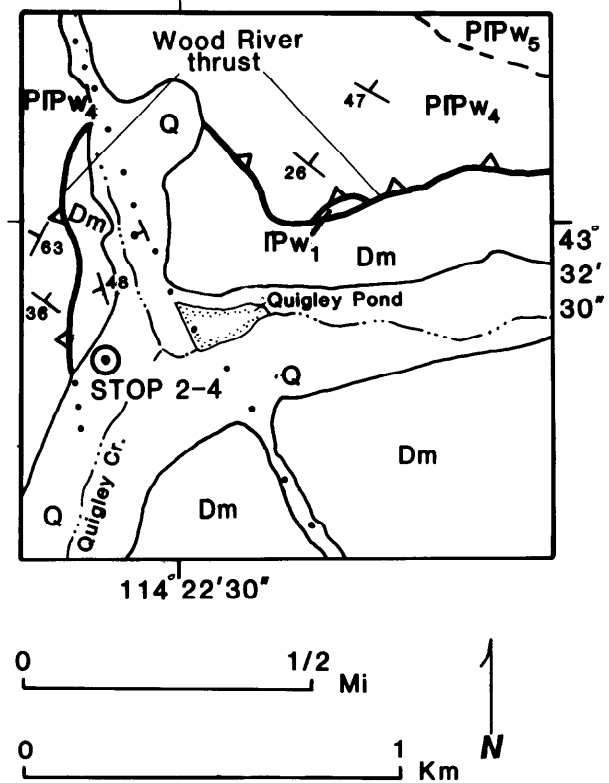


Figure 28. Geologic map of Wood River thrust on Quigley Creek, east of Hailey, showing location of field trip Stop 2-4. Dm--Milligen Formation (Devonian), IPw1--Hailey Conglomerate Member, Wood River Formation (Middle Pennsylvanian), PIPw4--unit 4 of Wood River Formation (Upper Pennsylvanian or Lower Permian), PIPw5--unit 5 of Wood River Formation (Upper Pennsylvanian or Lower Permian), Q--Quaternary units. Map from Batchelder and Hall (1978). Map symbols are shown in Figure 18.

An admissible cross section that obeys thrust belt rules (Boyer and Elliott, 1982; Woodward and others, 1985) can only be drawn across this area if two stages of deformation are involved: northeast-vergent folding of the Wood River and Milligen Formations, followed by thrusting (Fig. 31). The thrusts are cut by high-angle faults that are pinned by Paleogene dikes. Figure 31 shows an admissible cross section through the eastern Boulder Mountains that reflects the observed position of the Wood River thrust in this area, and accommodates the required displacement between allochthons.

Continue northwest up the Trail Creek road. Stop at mile 10.3 to view a strand of the Wood River thrust system.

Stop 2-8: Wood River Thrust in Trail Creek

Here a mineralized and iron-stained gouge zone several meters thick marks the contact between the Wood River

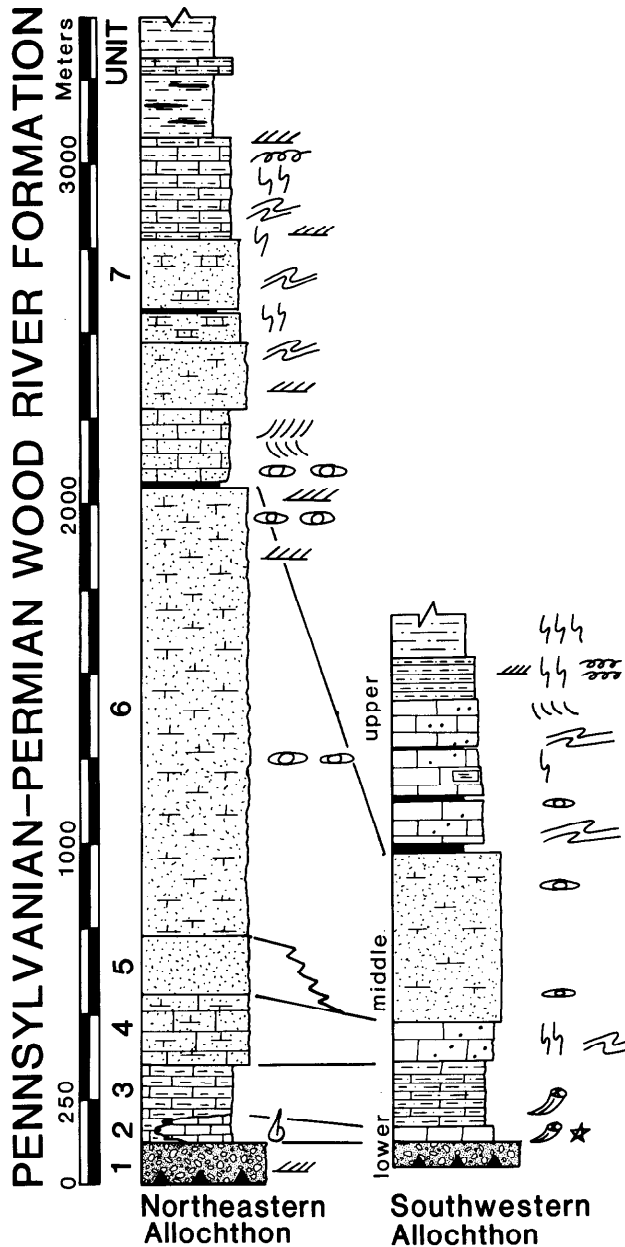


Figure 29. Correlation diagram of the two allochthons of Wood River Formation in the eastern Boulder Mountains. The northeastern allochthon, measured on the ridge east of Stop 2-7, displays a stratigraphic sequence similar to the stratotype of Hall and others (1974), while the southwestern allochthon, measured 2 km to the west, west of Trail Creek, contains a much thinner sequence of rocks in which Unit 5 is missing, and the upper units are thickened at the expense of the middle units. Symbols are shown on Figure 19.

Formation and a fault sliver of the underlying Devonian-Silurian-Ordovician plate. The Wood River Formation is brecciated, thick-bedded, light gray limestone (probably unit 6). The rocks in the footwall are olive-green to maroon argillite and siltite. The underlying plate contains dark graptolitic shales of the Ordovician and Silurian Phi Kappa Formation and Silurian Trail Creek Formation (Dover, 1983).

The fault geometry is again ambiguous, with the gouge zone suggesting ductile Mesozoic thrusting, but the lower part of the Wood River Formation is missing above the fault, suggesting a normal fault relation.

This contact is mapped as a thrust fault by Dover (1983). In the cross-sections of Dover (1983), the Devonian Milligen Formation of the Milligen-Wood River plate lies structurally above the Devonian-Silurian-Ordovician plate of the footwall to the north. This contact is mapped as a normal fault by Burton (Fig. 30) in the area northwest of here because it exhibits a high angle (58 degrees) younger-on-older relationship. Burton interprets the Wood River thrust to be cut by this normal fault at depth.

Turn around and drive back to the stoplight at Highway 75 in Ketchum.

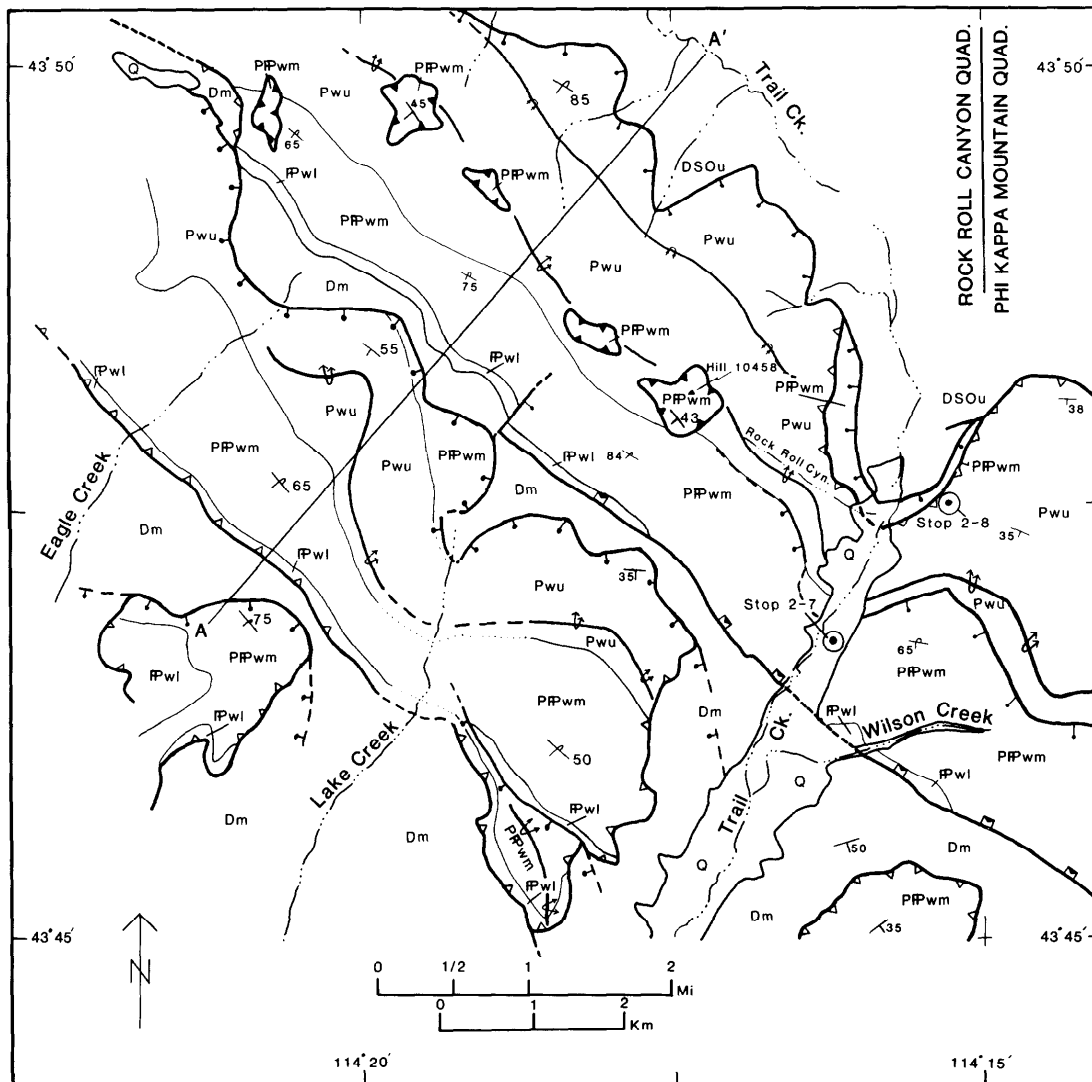
Road Log from Ketchum to the Baker Creek Road

At the intersection of Sun Valley Road and Highway 75 in Ketchum, reset odometers, turn right, and proceed north on Highway 75. At mile 0.3 the view opens up to the north; high peaks of the Boulder Mountains underlain by the Wood River Formation and the Challis Volcanic Group form the skyline. The lower hills are underlain by Challis Volcanic Group, part of a cauldron hypothesized by Hall and McIntyre (1985). Cross the Wood River at mile 6.7. The highway bends to head westward. The terraced slopes to the east are Challis Volcanic Group, with the Wood River Formation underlying the hills to the north. Challis Volcanic Group rocks crop out to the west. Quaternary glacial moraines crop out north of the road at mile 8.8 (Pearce and others, 1988, this volume).

Turn west on the Baker Creek road at mile 15.1 and stop. Climb about 100 feet up the hill northwest of the road for a view of the Boulder Mountains.

Stop 2-9: View of Boulder Mountains

The spectacular cliff exposure to the north is uplifted along the southwest-dipping Boulder front fault, and displays pink granite of the Eocene Boulder Mountains stock intruding dark Eocene dacite porphyry and light-colored limestone and quartzite of the Wood River Formation. Figure 32 is a cross section of the Smoky Mountains northwest of here, which show identical relations to the west side of the Boulder Mountains, with



MAP UNITS		MAP SYMBOLS	
Q	Quaternary, undifferentiated	All contact and fault symbols are dashed where approximately located, dotted where concealed.	
Pwu	Wood River Formation, upper part (Lower Permian); equivalent to unit 7 of Hall and others (1974) and includes unit 8 of Hall, Rye, and Doe (1978).		CONTACT
PPwm	Wood River Formation, middle part; (Lower Permian and Upper Pennsylvanian) equivalent to units 3 - 6 of Hall and others (1974).		NORMAL FAULT - bar and ball on downthrown block
Pwl	Pennsylvanian Wood River Formation, lower part (Middle Pennsylvanian); equivalent to informal unit 2 and the Hailey Conglomerate Member of Hall and others (1974).		THRUST FAULT - older strata juxtaposed on younger strata
Dm	Devonian Milligen Formation		OVERTURNED THRUST FAULT - box and barb symbol on structurally higher plate
DSOu	Ordovician, Silurian, and Devonian, undifferentiated; may include Devonian Milligen Formation.		LOW ANGLE FAULT - younger strata juxtaposed on older
			TRACE OF AXIAL SURFACE OF OVERTURNED ANTICLINE
			TRACE OF AXIAL SURFACE OF OVERTURNED SYNCLINE
			STRIKE AND DIP OF BEDS
			STRIKE AND DIP OF OVERTURNED BEDS
			LINE OF CROSS SECTION

Figure 30. Simplified geologic map of the southern half of the Rock Roll Canyon 7.5 minute quadrangle showing location of Stop 2-7 and 2-8. Note the variable nature of the Devonian Milligen Formation (Dm) contact with Pennsylvanian - Permian Wood River Formation. This contact occurs as an unconformity, a locally overturned Mesozoic younger on older low angle fault (the Wood River thrust), and a high angle normal fault. Cross section A-A' is shown on Figure 31. Mapping by Burton and Link, modified in part from Dover (1983) and Hall, unpublished.

Formation (eastern shelf facies of the Wood River basin) over Dollarhide Formation (western basinal facies) (Skipp and others, 1986). The fault could be a top-to-the-west low-angle normal fault similar to that seen in Colorado Gulch (Stop 2-2). Such a structural relation may have formed during doming of the Boulder Mountains intrusive center to the northeast, with rocks of higher structural levels (Wood River Formation) displaced southwestward along a normal fault.

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