Field trip no. 1, Introduction

LATE TERTIARY AND QUATERNARY FAULTING NORTH AND SOUTH OF THE EASTERN SNAKE RIVER PLAIN

Mark H. Anders[1]
David W. Rodgers[2]
James P. McCalpin[3]
Kathleen M. Haller[4]

[1] Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964
[2] Department of Geology, Idaho State University, Pocatello, Idaho 83209
[3] Department of Geology, Utah State University, Logan, Utah 84322
[4] U.S. Geological Survey, Denver, Colorado 80225

Overview

North and south of the Snake River Plain there are a number of northwest trending basins that have been actively subsiding during the late Cenozoic. These basins are mostly half-grabens that result from extension on northwest trending normal faults. Our field trip will examine the structure and stratigraphy of basin-fill deposits in some of these basins in order to interpret the styles and temporal patterns of late Cenozoic normal faulting in the northeastern Basin and Range province. The field trip consists of two traverses along these major fault-bounded basins, one to the south of the Snake River Plain and one to the north. The southern traverse (parts 1 and 2) starts 60 miles (100 km) southeast of the Snake River Plain in Star Valley, Wyoming (**Figure 1**) and continues northeastward into Grand and Swan valleys, Idaho. Each of these three southern basins is formed by extension on a single continuous 85-mile-long (140-km) fault, which is called the Star Valley fault in Star Valley and the Grand Valley fault in Grand and Swan valleys. We will often refer to these two faults together as the Grand Valley/Star Valley fault.

The second day (parts 3 and 4) begins north of the Snake River Plain at the southern end of Birch Creek Valley, stopping at four locations in the valley. Birch Creek Valley is the southernmost of two basins that are formed by late Cenozoic extension along the 90-mile-long (150 km) Beaverhead fault. Birch Creek Valley extends about 36 miles (60 km) northwest from the Snake River Plain and can be divided into two distinct physiographic sub-basins. Birch Creek Valley, like the basins south of the Snake River Plain, is filled with alluvium, colluvium, loess, and lake sediments, all interbedded with Snake River Plain volcanic rocks.

Displacement history of the Grand Valley/Star Valley fault in Star, Swan, and Grand valleys

Seismic reflection data indicates that the Grand Valley/Star Valley fault, as well as other basin-bounding faults south of the Snake River Plain, are listric (Royse and others, 1975; Dixon, 1982). The maximum thickness of Cenozoic sediment in the basin formed by extension on the Grand Valley/Star Valley fault is from 6,500 to 13,000 feet (2-4 km) (Dixon, 1982). The hanging wall of the listric fault is cut by the antithetic Snake River fault, which bounds the southwestern side of Swan and Grand Valley; however, this fault does not extend south into Star Valley. Displacement on the Snake River fault is minor compared to that on the Grand Valley/Star Valley fault.

In Star Valley, the southernmost basin, there are Miocene through Quaternary basin-fill deposits of alluvium and colluvium with a veneer of latest Quaternary loess and recent stream deposits. Star Valley can be divided into two distinct physiographic and geologic sub-basins. The Star Valley fault in southern Star Valley is the most active segment of the entire Grand Valley/Star Valley fault. Fault scarps in some locations on the southern Star Valley fault have over 36 feet (11 m) of offset (Piety and others, 1986; Anders and others, 1989; this field trip, part 1). Piety and others (1986) estimated latest Quaternary displacement rates on this segment to be between 0.02 and 0.04 inches per year (0.6 and 1.1 mm). To the north, only the southernmost part of the Star Valley fault in northern Star Valley has been active in the latest Quaternary. Between this active portion of the Star Valley fault and the Snake River Plain there are no fault scarps on deposits of latest Quaternary age. We will make two stops in Star Valley to examine latest Quaternary fault scarps.

Although latest Quaternary displacement rates in Star Valley can be accurately estimated based on offset deposits of known age, displacement rates over longer intervals cannot presently be estimated for this fault. This is due to the limited exposures of older basin-fill deposits in Star Valley. Northwest of Star Valley, in Grand and Swan valleys, this problem is mitigated by exposures of late Miocene and younger volcanic and sedimentary rocks. In Grand Valley and Swan Valley, the late Miocene and younger basin-fill deposits are moderately tilted to the northeast, suggesting that there has been significant pre-latest Quaternary movement on the Grand Valley fault. Although there must have been significant tectonic activity in these valleys, almost none has occurred during the Quaternary. There has been only minor offset (91 ft/28 m) since deposition of a 1.5 Ma basalt across the Grand Valley fault (Piety and others, 1986). Furthermore, the 2.0 Ma Huckleberry Ridge Tuff in Swan Valley is not tilted (Anders and others, 1989). This field trip provides an opportunity to examine a variety of volcanic rocks used to assess the movement history of the Grand Valley fault.

Displacement history of the Beaverhead fault in Birch Creek Valley

Birch Creek Valley is bounded on the northeast by the Beaverhead fault, a southwest dipping normal fault with several miles (kilometers) of displacement (Garmezy, 1981). Based on range-front and fault-scarp morphology patterns, two segments of the Beaverhead fault are recognized in Birch Creek Valley, the Blue Dome segment in southern Birch Creek Valley and the Nicholia segment in northern Birch Creek Valley (this field trip, part 4). At the southern end of Birch Creek Valley (Howe Point, **Figure 1**), basin fill accumulated and was progressively tilted northeastward from middle Miocene to late Pliocene/early Quaternary time (Rodgers and Zentner, 1988). In central Birch Creek Valley, near Lone Pine (**Figure 1**), middle Miocene to early Quaternary basin fill accumulated without tilting, then was subsequently tilted to the northeast during the Quaternary (this field trip, part 3). Along southern Birch Creek Valley, the Blue Dome segment of the Beaverhead fault does not cut latest Quaternary (< 15 ka) deposits, and pediment surfaces estimated to be about middle to lower (?) Pleistocene (Scott, 1982) are roughly symmetric about the axis of southern Birch Creek Valley. In contrast, the Nicholia fault segment in northern Birch Creek Valley consists of fault scarps cutting latest Quaternary deposits, and pediment surfaces have steeper slopes on the west side of the valley than the east. These data suggest that Quaternary tilting and fault displacement rates increase to the north in Birch Creek Valley. This conclusion is further supported by the surficial geology of both sub-basins: Neogene basin fill is commonly exposed in the southern valley, whereas Quaternary basin fill covers most of the northern valley. A more quantitative evaluation of fault displacement rates through the late Cenozoic will be made in the future.

The southern part of the Nicholia segment in northern Birch Creek Valley is characterized by a discontinuous sequence of prominent fault scarps. Fault scarps on latest Quaternary sediments are 16 to 32 feet (5-10 m) high, yet Holocene alluvium within the canyons are not faulted. This suggests that the most recent rupture on this segment occurred approximately 15 ka. The range-front along the Nicholia segment is also more linear than the range front along the Blue Dome segment, with well-defined facets.

North of the Snake River Plain, there are limited seismic reflection data suitable for interpreting the geometry of the basin-bounding late Cenozoic faults. Despite the lack of reflection data, structural analyses (Scott and others, 1985), aftershock data from the Borah Peak earthquake ($M_s = 7.3$) (Richins and others, 1987), and paleomagnetic data (this field trip, part 3) all suggest late Cenozoic tectonics in the northern circum-Snake River Plain are dominated by large horizontal block rotations on planar normal faults. Birch Creek Valley is located between two of these large blocks, the southern Beaverhead and Lemhi Ranges, both of which have rotated about 10°NE since 6.5 Ma (Anders and others, 1988).

Apart from the difference between "domino" style faulting of the Beaverhead fault and listric faulting of the Grand Valley/Star Valley faults, there are broad similarities in the timing of faulting relative to their distances from the Snake River Plain. Close to the Snake River Plain, neither fault shows latest Quaternary fault scarps. The southern Birch Creek Valley, like the Grand and Swan valleys, has numerous exposures of middle Miocene to Quaternary basin fill. In these basins, most of the deposits are exposed on the southwest margins of the basins and are tectonically tilted to the northeast. Farther from the Snake River Plain, latest Quaternary fault scarps characterize both the Beaverhead and the Star Valley faults. Scarps on both faults exceed 30 feet (10 m) in places, indicating high displacement rates during the latest Quaternary. In the basins adjacent to these active faults, surficial deposits are almost exclusively latest Quaternary, most likely due to latest Quaternary subsidence and burial of older basin fill. Although the subsidence relations are not symmetric about the axis of the Snake River Plain (i.e. northern Birch Creek Valley is closer to the axis than Star Valley), the timing of late Cenozoic faulting is remarkably similar north and south of the Snake River Plain. For a further discussion of this pattern of faulting, we refer the reader to Scott and others (1985) for faults north of the Snake River Plain, and to Anders and others (1989) for faults south of the Snake River Plain.

References cited

Anders, M.H., Geissman, J.W., Piety, L.A., and Sullivan, J.T., 1989, Parabolic distribution of circum-eastern Snake River Plain seismicity and latest Quaternary faulting: migratory pattern and association with the Yellowstone hotspot: Journal of Geophysical Research, v. 94, no. B2, p. 1589-1621.

Anders, M.H., Hagstrum, J.T., and Rodgers, D.W., 1988, Late Cenozoic structural development of the southern Beaverhead and Lemhi Ranges, Idaho: Geological Society of America Abstracts With Programs, v. 20, no. 7, p. A63.

Dixon, J.S., 1982, Regional structural synthesis, Wyoming salient of western Overthrust Belt: American Association of Petroleum Geologists Bulletin, v. 66, n.o 10, p. 1560-1580.

Garmezy, L., 1981, Geology and tectonic evolution of the southern Beaverhead Range, east-central Idaho: M. S. thesis, Pennsylvania State University, 155 p.

Piety, L.A., Wood, C.K., Gilbert, J.D., Sullivan, J.T., and Anders, M.H., 1986, Seismotectonic study for Palisades Dam and Reservoir, Palisades Project, Idaho: U.S. Bureau of Reclamation Pacific and Northwest Regional Office and Engineering and Research Center, Seismotectonic Report 86-3, p. 355.

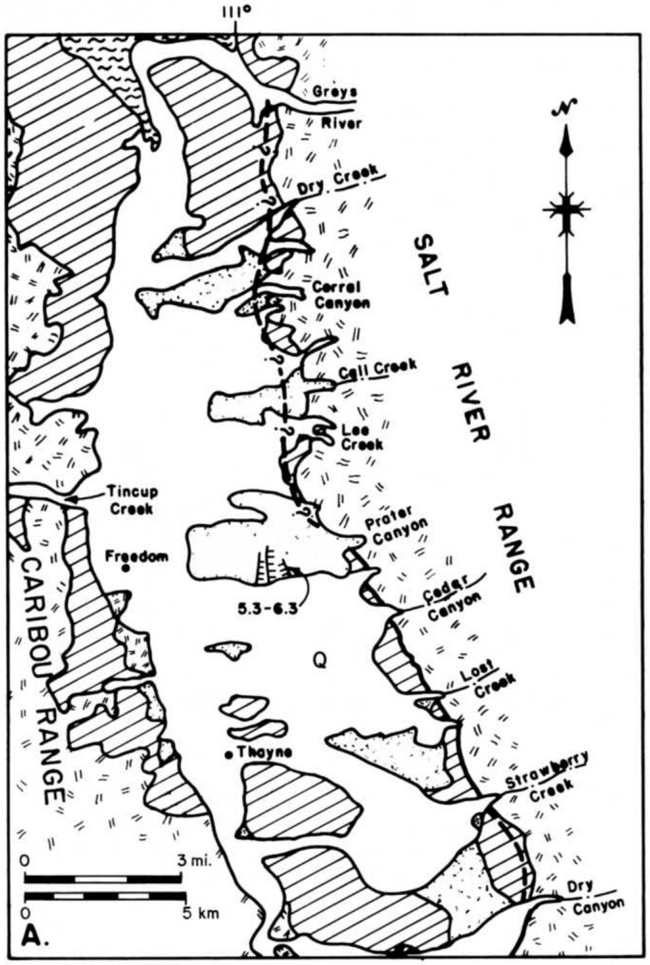
Richins, R.D., Pechmann, J.C., Smith, R.B., Langer, C.J., Goter, S.K., Zwollweg, J.E., and King, J.J., 1987, The 1983 Borah Peak, Idaho earthquake and its aftershocks: Bulletin of the Seismological Society of America, v. 77, no 3, p. 694-723.

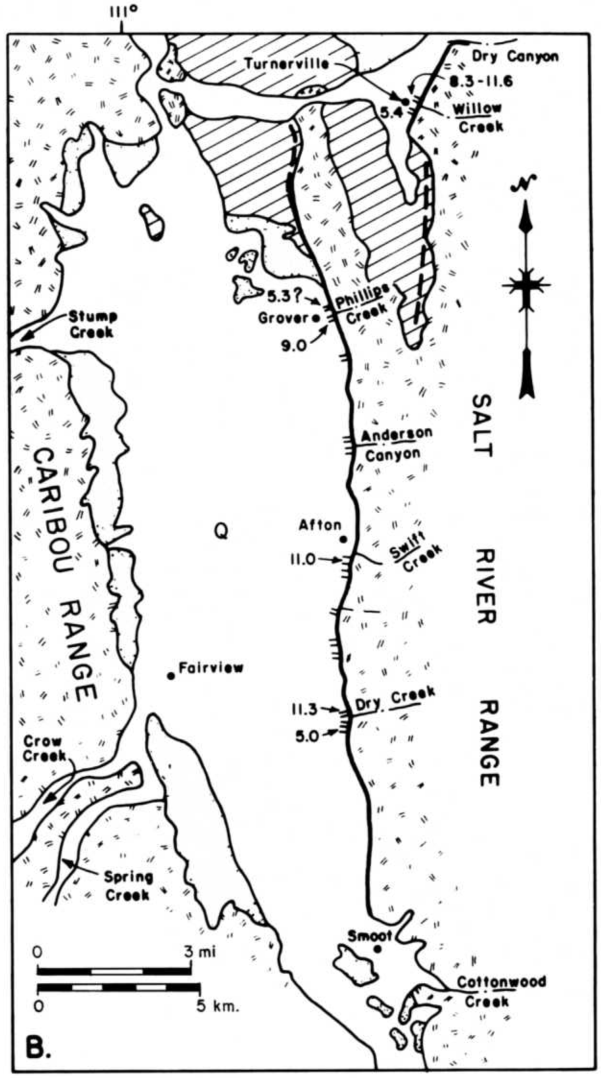
Rodgers, D.W., and Zentner, N.C., 1988, Fault geometries along the northern margin of the eastern Snake River Plain, Idaho: Geological Society of America Abstracts with Programs, v. 20, no. 6, p. 465.

Royse, F., Jr., Warner, M.A., and Reese, D.L., 1975, Thrust belt structural geometry and related stratigraphic problems, Wyoming-Idaho-northern Utah, *in* Boyard, D.W., editor, Deep drilling frontiers of the Central Rocky Mountains: Rocky Mountain Association of Geologists Symposium, p. 41-54.

Scott, W.E., 1982, Surficial geologic map of the eastern Snake River Plain and adjacent areas, 111° to 115° W, Idaho and Wyoming: U.S. Geological Survey Miscellaneous Investigations Map I-1372, scale 1:250,000.

Scott, W.E., Pierce, K.L., and Hait, M.H., Jr., 1985, Quaternary tectonic setting of the 1983 Borah Peak earthquake, central Idaho: Bulletin of the Seismological Society of America, v. 75, no. 4, p. 1053-1066.





EXPLANATION

Star Valley fault; shown as a solid line where the range front is straight and faceted spurs are preserved; shown as dashed where the range front is more sinuous, and queried where the fault is concealed; bars show the locations of scarps in younger upper Quaternary (≤ 15 ka) alluvial fan deposits; numbers show vertical surface displacements (in meters) taken from topographic profiles measured across scarps at the locations indicated.

Scarps in older upper Quaternary (> 15 ka) deposits; numbers show vertical surface displacements (in meters) taken from topographic profiles measured across the scarp near the location indicated.

Upstream end of Palisades Reservoir

Generalized geology:

Q — Younger upper Quaternary alluvium and colluvium.

Older upper Quaternary alluvium and colluvium; usually covered by loess ≥ 1.5 m thick.

Upper Tertiary and (or) lower Quaternary basin-fill deposits; commonly covered by loess ≥ 1.5 m thick.

Paleozoic and Mesozoic rocks, undifferentiated.

Geology generalized from Jobin (1972), Rubey (1973), Albee and Cullins (1975), and Oriel and Platt (1980), or geology inferred from Ravenholt and others (1976).

Figure 1. Generalized geologic maps of (A) northern Star Valley and (B) southern Star Valley, showing locations of the Star Valley fault and the Quaternary fault scarps. The two maps overlap about 1.2 miles (2 km). (From Anders and others, 1989.)