UNITED STATES DEPARTMENT OF INTERIOR

GEOLOGICAL SURVEY

FIELD GUIDE AND ROAD LOG - PENNSYLVANIAN AND PERMIAN DEPOSITIONAL SYSTEMS AND CYCLES IN THE EAGLE BASIN, NORTHWESTERN COLORADO

by

Christopher J. Schenk
Samuel Y. Johnson
John A. Karachewski
U.S. Geological Survey
Box 25046, Denver Federal Center,
Denver, CO 80225

Open-File Report 87-430

1987

INTRODUCTION

This trip will focus on Pennsylvanian and Permian depositional systems and cycles in the Eagle Basin and northern Aspen sub-basin, northwest Colorado. Strata to be examined include the Belden Formation, Minturn Formation, Eagle Valley Evaporite, Maroon Formation (including the Fryingpan Member), and the Schoolhouse Tongue of the Weber Sandstone. These units were deposited in a broad spectrum of environments that produced subaqueous evaporites, carbonate bioherms, clastics representing turbidite to shoreline deposits, fan deltas, terminal fluvial fans, eolian sand sheets, loess fields, and dune fields. Principal emphasis will be placed on 1) recognition of the distinctive sedimentologic characteristics of each facies, 2) recognition of eustatic, climatic, and tectonically controlled cycles, and 3) reconstruction of basin paleogeography.

GEOLOGIC SETTING

Pennsylvanian and Permian tectonism in the western United States resulted in development of the ancestral Rocky Mountains (Curtis, 1958; Mallory, 1972; Tweto, 1977; Kluth and Coney, 1981; Kluth, 1986). Orogenic highlands in Colorado included the ancestral Uncompaghre and Front Range uplifts, which bounded the northwest-trending central Colorado trough, and the ancestral Sawatch uplift (DeVoto, 1972), which subdivided this trough into several sub-basins (Fig. 1). The Eagle Basin, generally regarded as the area in the central Colorado trough north of the northern margin of the Sawatch uplift, is one of these sub-basins. The Aspen sub-basin forms the area west of the Sawatch uplift and is a southern extension of the Eagle Basin. Deposition in the Eagle Basin and associated sub-basins was strongly controlled by local tectonics, relative sea-level changes, and climate (Mallory, 1971, 1972; Bartleson, 1972; Walker, 1972; DeVoto and others, 1986; Dodge and Bartleson, 1986; Johnson, 1987a, b).

The Belden Formation, mainly a dark gray or black shale of deltaic and marine origin, comprises the Early Pennsylvanian fill of the Eagle Basin (Fig. 2; Brill, 1958; Mallory, 1972). The thickness of the Belden Formation ranges from approximately 70 m on the eastern side of the basin to approximately 300 m in the central part of the basin. This variation in thickness is due in part to the choice of upper boundary; along the eastern side of the basin the first buff-colored sandstones mark the top of the Belden and the base of the Minturn Formation, whereas the first gypsum separates the top of the Belden from the overlying Eagle Valley Evaporite in the central part of the basin (Bass and Northrup, 1963). The first gypsum in the central part of the basin may be stratigraphically higher than the first Minturn sandstones.

Recently, Waechter and Johnson (1985; 1986) have suggested that the Belden was a likely source for hydrocarbons. Rock-Eval pyrolysis data summarized by Nuccio and Schenk (1986) indicated that the Belden contains the proper types of organic matter to have been a source for both oil and gas. Vitrinite reflectance data combined with burial history models suggest that the Belden near Gilman, Colorado may have generated hydrocarbons in the Early Permian. However, this was not the general case for the Belden across the Eagle basin because of differences in burial history (Nuccio and Schenk, in press).

In the Middle Pennsylvanian, the effects of local tectonism were more

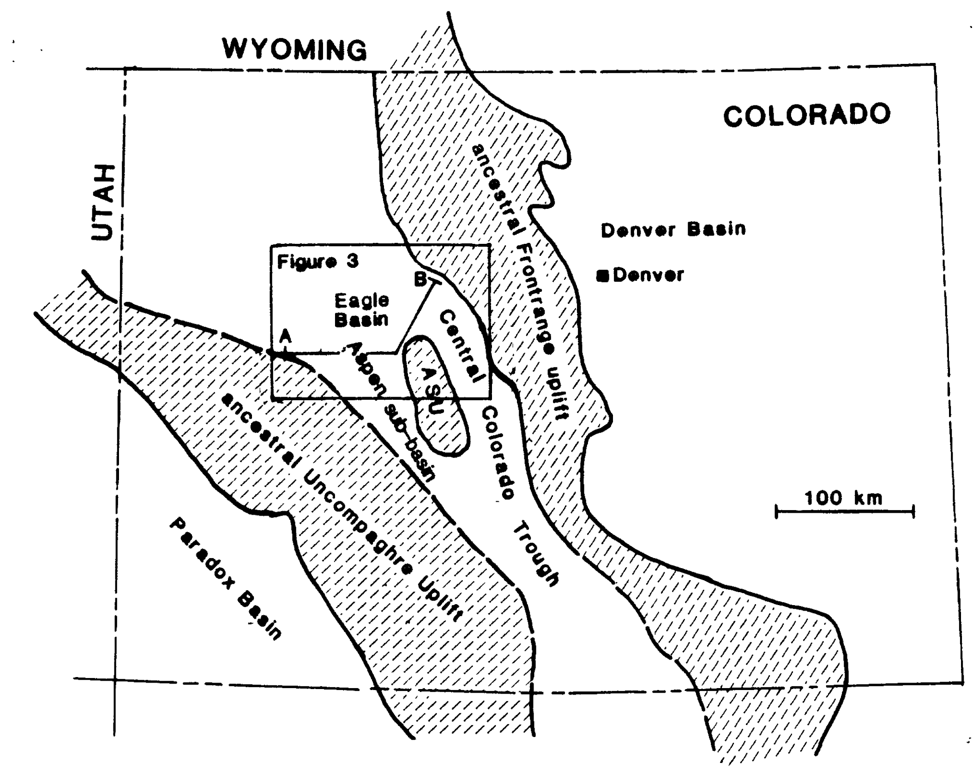

Figure 1. Schematic map showing the location of the ancestral Rocky Mountain highlands and basins in Colorado. ASU = ancestral Sawatch uplift; A-B is line of section for Figure 2. Adopted from Mallory (1972).

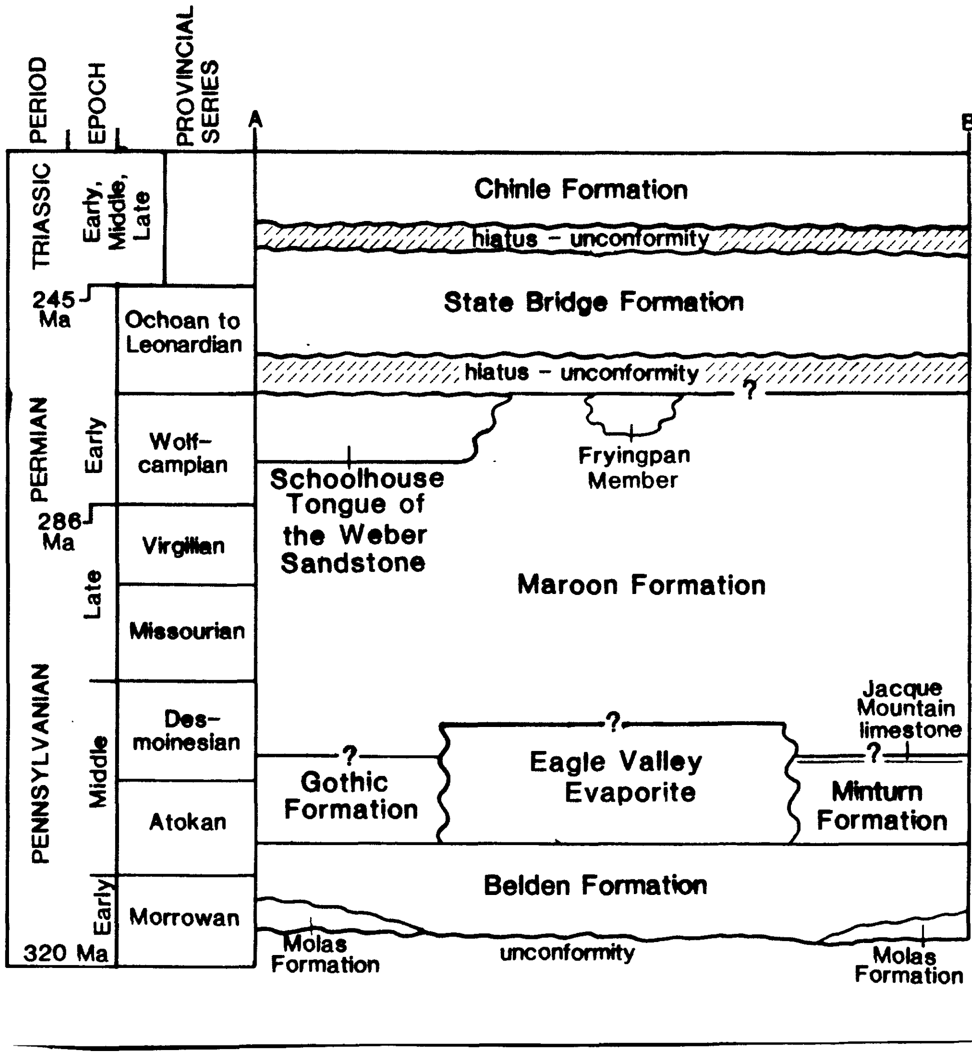

Figure 2. Schematic diagram showing stratigraphy of Pennsylvanian to early Mesozoic strata in the Eagle Basin. Line of section A-B is shown in Figure 1.

pronounced and alluvial-fan and fan-delta deposits of the Minturn, Gothic, and Maroon (lower part) formations accumulated adjacent to basin margins (Boggs, 1966; Bartleson, 1972). These basin-margin facies include interbedded nonmarine coarse-grained clastics and marginal-marine clastics and carbonates (Tillman, 1971) that pass laterally into evaporite and clastic deposits of the Eagle Valley Evaporite (Mallory, 1971; Schenk, in press, a). The Eagle Valley Evaporite comprises a series of sedimentary cycles that generally begin with marine limestone, followed by laminated gypsum, and end with a sequence of mudstones and sandstones. The clastic sequences generally begin with turbiditic sandstones and interbedded mudstones (Schenk, 1986), grade to nearshore marine sandstones, and finally to fluvial and eolian sandstones at the top of some cycles (Schenk, in press, b). Some of the cycles do not contain gypsum, and are composed almost entirely of clastics. The clastics generally thin towards the center of the basin where the evaporites are thickest. Several of the limestones in the lower part of the Eagle Valley cycles have been correlated with thin limestones in the coeval Minturn Formation (Schenk, in press, a).

Nonmarine rocks of the upper part of the Maroon Formation, largely a sequence of nonmarine red beds, comprise the Late Pennsylvanian and Early Permian part of the basin fill. The Maroon may be as thick as 4600 m in the Aspen sub-basin (Fig. 1; Freeman and Bryant, 1977), whereas to the north in the Eagle Basin, the thickness of the Maroon is considerably less, about 300 to 1000 m. The contact between the Maroon Formation and underlying strata is markedly transgressive, which in part explains the major thickness variations (Johnson, 1987a). In the area around Vail, Colorado, Tweto and Lovering (1977) placed the lower Maroon contact at the top of a prominent marker horizon, the Jacque Mountain Limestone; however, elsewhere in the basin the contact is generally placed at a color change between underlying brown and gray rocks and overlying red beds. The Maroon consists of interbedded fluvial and eolian deposits (Johnson, 1987a, b, in press). Maroon fluvial systems decreased in flow strength, flow depth, and discharge in the downstream directions, characteristics of "terminal fan" fluvial systems in arid basins (Friend, 1978). Facies and paleocurrent patterns indicate that the basin axis was strongly skewed to the northeast in Maroon time. Maroon eolianites are sand-sheet deposits throughout most of Eagle Basin and Aspen sub-basin. Loessites and dune deposits form local basin-margin eolian facies that occur adjacent to the Sawatch uplift. These basin-margin facies are best exposed in the Ruedi Reservoir area (Fig. 3), where they will be examined on this trip.

The nonmarine Schoolhouse Tongue of the Weber Sandstone (Brill, 1952) overlies the Maroon Formation over much of the Eagle Basin, and consists mainly of yellowish-gray sandstone that is extensively oil stained. The Schoolhouse Tongue has a maximum exposed thickness of about 70 m, but is locally much thinner and is absent in the eastern portion of the Eagle Basin and the Aspen sub-basin. The contact between the Maroon Formation and the Schoolhouse Tongue is generally gradational and placed at the upper limit of red beds. Over much of the Eagle basin, this contact is primarily of diagenetic origin; the reddish sandstones pass laterally into bleached, white to buff-colored sandstones. The Maroon Formation and the Schoolhouse Tongue of the Weber Sandstone are overlain, locally with an angular unconformity (Freeman, 1971a, b) by redbeds of the the Permian to lower Triassic State Bridge Formation.

The precise configuration of the Eagle Basin is not known because many Pennsylvanian fault zones in western Colorado, including the Gore fault on the eastern margin of Eagle Basin, were reactivated in the Laramide orogeny

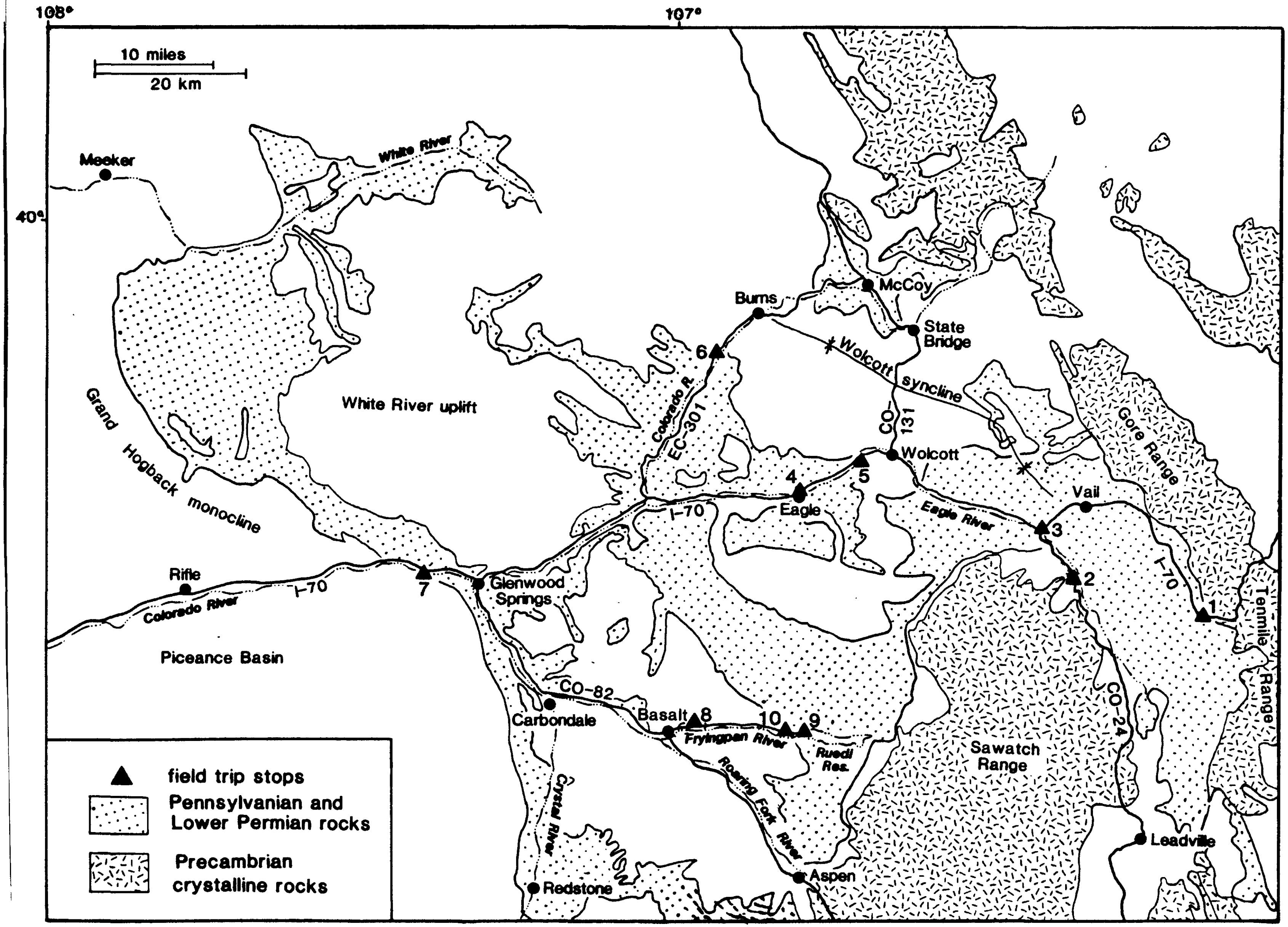

Figure 3. Schematic map showing field trip stops and outcrop patterns of Pennsylvanian strata and Precambrian crystalline rocks in the Eagle Basin.

(Tweto, 1977) and in the Neogene. Pennsylvanian deposits of the Eagle Basin now crop out mainly in structurally low areas and on the margins of the Laramide White River Uplift. These strata dip off the Grand Hogback monocline into the subsurface of the Piceance Basin.

ROAD LOG

DAY 1

Mileage

0.0	Road log begins on U.S. I-70 at the Copper Mountain turnoff, approximately 81 miles west of Denver.
2.2	Crossing the approximate trace of the Gore fault. To the south is a view of Jacque Peak.
3.1	Beginning of discontinuous outcrops of Minturn Formation nonmarine redbeds.
4.8	Turn off of I-70 to Vail Pass rest area.
5.1	Turn left from offramp and drive to rest area.
5.4	STOP 1. Vail Pass rest area. Vista and courtesy stop. To the north is a view of the Gore fault zone, which juxtaposes Precambrian crystalline rocks of the Gore Range on the east and Pennsylvanian and younger rocks on the west. The fault zone generally dips vertically or to the east. Considerable offset is Laramide or younger (Tweto, 1977). The common presence of Pennsylvanian fine-grained rocks and limestones adjacent to this fault zone suggests that the Late Paleozoic margin of Eagle Basin was located farther east. To the south is a view of Jacque Peak, capped by the Jacque Mountain Limestone, the uppermost bed in the Minturn Formation. Return to I-70.
5.6	Turn left on westbound onramp.
6.4	Summit of Vail Pass, elevation of 3250 m (10,662 ft)
11.7	View in foreground of the Gore Range.
14.4	Outskirts of East Vail. Note that in the next few miles, the colors of the discontinuous outcrops of the Minturn Formation on both sides of I-70 are changing from reds and reddish browns to grays, pinks, and buffs. At least in part, this color change reflects a facies change from nonmarine to marginal marine and marine deposits. Also note the large foresets of probable fan-delta origin in the prominent, resistant outcrops on the slope north of I-70.
19.7	Vail. In the foreground, the contact between the Minturn and Maroon Formations is exposed about 40 percent up the prominent slopes north of I-70 highway (on the west side of Red Sandstone Creek).

23.3 West Vail. Beginning of prominent roadcut outcrops of the Minturn Formation on the north side of I-70.

24.8 Leave I-70 on Exit 171 to Minturn.

25.0 Yield sign from exit ramp. Turn right onto Colorado Highway 24 and proceed up the Eagle River Valley to the south towards Minturn.

25.5 Sandstone, mudstone, and limestone of the Minturn Formation are exposed in cliffs to the east for the next few miles. In this part of the Eagle River valley, the Minturn Formation dips less than 10° to the northeast off the Laramide Sawatch Range anticline. The hummocky topography on the west side of the road was produced by dip-slope landsliding, resulting from interbedding of incompetent mudstone and more competent, thickly bedded sandstone.

26.8 Outcrop of Mississippian Leadville Limestone on the west side of the road. Karstification is common in the upper part of the Leadville (DeVoto, 1980). At Gilman, the Leadville is host to silver, lead, and zinc mineralization.

27.3 U.S. Forest Service, Holy Cross Ranger Station.

28.2 Cliffy exposures of the Minturn Formation. Noel Waechter (personal commun., 1986) noted oil-stained sandstone in the Minturn from this area.

29.0 View in the right foreground of the glaciated valley of Cross Creek. The cities of Aurora and Colorado Springs have filed applications with the state for water diversion projects in this valley.

30.3 Bridge over Eagle River. Mississippian Leadville Limestone is exposed near road level. Outcrops of the Belden Formation occur higher up the slope.

31.3 STOP 2. Pull off road in turnout on west side of road. Belden Formation roadcut (Fig. 4). The Belden Formation in this area consists of dark-gray to black mudstone and limestone, and less common fine-grained sandstone (Tweto and Lowering, 1977). The Pando porphyry is present as a sill in the lower part of the Belden; note the columnar jointing in the sill. Vitrinite reflectance values greater than 3.0% have been reported from the Belden in this locality by Nuccio and Schenk (1986). These relatively high values, combined with burial history models, suggest that the Belden in this area may have generated hydrocarbons in the Early Permian. Elsewhere in Eagle Basin, however, the Belden may have remained a viable source rock until much later due to differing burial histories.
Turn around and drive north on Highway 24 toward Minturn.

31.8 OPTIONAL STOP. Roadcut with exposures of the channelized contact between thin-bedded sandstone of the Belden Formation and overlying,

Figure 4. Photograph of the Belden Formation roadcut near Gilman, Colorado at Stop 2. Note the columnar jointing in the Pando porphyry (arrow), with the black shales of the Belden exposed above the porphyry. Photograph taken from the top of the Leadville Limestone.

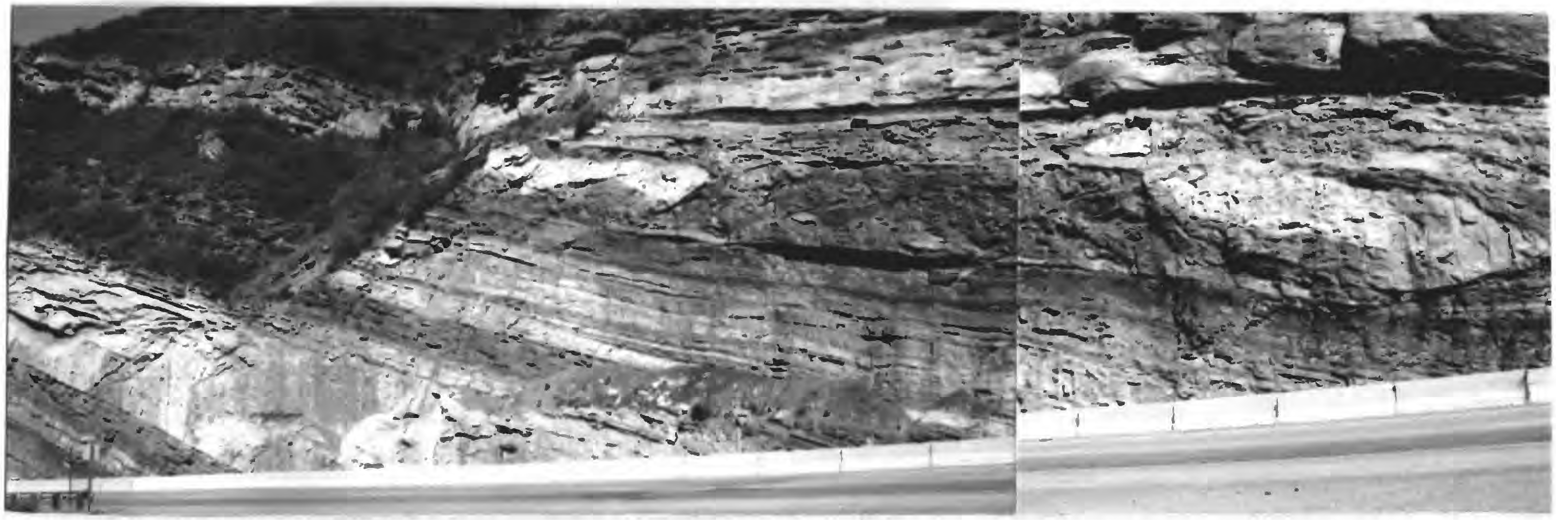

Figure 5. Photomosaic of interbedded sandstone and mudstone of the Minturn Formation at Stop 3A. Note large-scale soft-sediment deformation and detached block of sandstone in bed near the top of the outcrop.

thick-bedded sandstone of the Minturn Formation. View to the north shows the dipslope off the Sawatch Range on the west side of the Eagle river. Note prominent cliff exposures of the lower part of the Minturn Formation on the east side of the valley, including the Lionshead dolomite bioherm. Although algal bioherms more than 30 m thick are present in this area, carbonate biostromes less than 3 m thick are more common. Walker (1972) provides a synthesis of bioherm distribution and development in the Minturn Formation. Continue north on Highway 24.

37.4 Turn right on eastbound I-70 onramp.

38.2 STOP 3A. Pull off into broad, unpaved turnout on south side of turnoff. View of roadcuts on north side of I-70. THIS IS A VISTA STOP. YOU WILL BE ABLE TO EXAMINE THE ROCKS AT STOP 3B. DO NOT CROSS THE FREEWAY. These spectacular outcrops (Fig. 5) consist mainly of marginal marine sandstone and mudstone with less common limestone and conglomeratic sandstone. Larger-scale soft-sediment deformation features include detached blocks of sandstone and thick contorted and chaotically folded horizons of interbedded mudstone to fine-grained sandstone. Smaller-scale features include pocket structures, pillar structures, clastic dikes, and other features suggesting liquefaction and fluidization. This evidence of abundant soft-sediment deformation is almost certainly related to rapid deposition on unstable slopes in a seismically active region. Martin Lockley (personal commun., 1987) has found an ammonoid fauna in these rocks.
Re-enter I-70 carefully and continue east.

40.6 Exit I-70 at West Vail (Exit 173)

40.7 Turn left at offramp stop sign and drive under I-70.

40.8 Turn left on I-70 westbound onramp.

43.1 Exit freeway at the Minturn exit (Exit 171).

43.3 Turn left at offramp stop sign and proceed west on U.S. 6.

43.5 STOP 3B. Pull off in large turnout on right side of the road and walk west to roadcuts. THE ROAD IS NARROW AND CAUTION IS ADVISED. This stop provides the opportunity to closely examine the facies of the Minturn Formation viewed at stop 3A.
Continue west on U.S. 6.

47.0 Gypsum of the Eagle Valley Evaporite forms slopes on the south side of the highway.

47.6 Turn right at intersection, drive through the town of Avon and under I-70. Outcrops of gypsum of the Eagle Valley Evaporite are visible on the slopes north of I-70.

48.0 Turn left on westbound I-70 onramp and drive west.

48.5 View in the foreground of the eastern limb of the Wolcott syncline (Fig. 3). The visible section extends upward from the Pennsylvanian rocks on the syncline flanks to Cretaceous rocks in the center of the syncline.

52.5 The thick gypsum bed on the slopes south of I-70 is the highest gypsum in the Eagle Valley Evaporite. Note that the uppermost gypsum is some distance below the lower boundary of the Maroon Formation.

54.1 Outcrops on the south side of I-70 contain redbeds of the Triassic Chinle Formation overlain by buff-colored, cliff-forming beds of the Jurassic Entrada Sandstone.

56.1 Outcrops of the Cretaceous Mancos Shale on the south side of I-70.

57.7 Outcrops of the Dakota Sandstone on both sides of I-70.

59.9 Cross the Eagle River. Outcrops at road level on north side of I-70 show (from bottom to top) redbeds of the Permian to lower Triassic State Bridge Formation, buff-colored beds of the Sloane Peak Member of the State Bridge, purplish-gray beds of the Gartra Member of the Chinle Formation, and Chinle redbeds.

60.7 Bold outcrops of the Maroon Formation, the Schoolhouse Tongue of the Weber Sandstone, and the State Bridge Formation on both sides of I-70. Beds are dipping gently to the northeast into the Wolcott syncline (Fig. 3).

63.2 The thick, uppermost gypsum bed in the Eagle Valley Evaporite is visible on the south side of I-70.

66.9 Exit I-70 to Eagle (Exit 147).

67.1 Turn right at offramp stop sign.

67.2 STOP 4. Pull off and park in open area on east side of road, and walk north approximately 500 m to upturned outcrop of boulder conglomerate (Fig. 6). Although this outcrop of conglomerate is isolated from the adjacent outcrop, similar conglomerates are interbedded with the evaporitic portion of the Eagle Valley Evaporite at several localities. Several lines of evidence indicate that this rock is not cemented alluvium. Paleogeographic constraints suggest that the clasts were derived from the ancestral Sawatch uplift to the south. This facies is important in that it supports periodic subaerial exposure of the central part of the basin during the Middle Pennsylvanian, indicating that tectonic controls on sedimentation were important. When finished examining the conglomerate, walk south to examine the laminated gypsum and associated clastics of the Eagle Valley Evaporite (Fig. 7). Note the fine lamination of the gypsum, the thin beds of black to gray carbonate, and the thickness of the gypsum unit. These features suggest a subaqueous origin for the gypsum, rather than an origin as a sabkha deposit. As you proceed up the south-facing slope, note

Figure 6. Photograph of the boulder conglomerate in the Eagle Valley Evaporite, on the east side of Eiby Creek, immediately north of Eagle at Stop 4. Conglomerates such as this are rare in the Eagle Valley Evaporite, but are found at several localities. Person is 2 m tall.

Figure 7. Photograph of the gypsum and associated clastics of the Eagle Valley Evaporite above the boulder conglomerate on the east side of Eiby Creek, at Stop 4.

the change from laminated to more massive gypsum, and the gradational contact with the clastic sequence above. At least two cycles are exposed in this area; the second cycle does not contain gypsum.
Return to vehicles, turn around, and drive south over I-70 toward Eagle.

68.4 Turn left on U.S. 6 and drive east up the Eagle Valley.

73.1 STOP 5. Pull off into turnout on right. This is a brief vista stop. To the north is a good view of the Maroon Formation, the Schoolhouse Tongue of the Weber Sandstone, and the State Bridge Formation (Fig. 8). To the south is a good view of the dominantly clastic upper portion of the Eagle Valley Evaporite, the Maroon Formation, and the Schoolhouse Tongue.
Proceed east on U.S. 6 to Wolcott. Note that in the cliffs on the north side of the road, the bleached beds of the Schoolhouse Tongue pass laterally into redbeds (Freeman, 1971a). The contact between the Maroon Formation and the Schoolhouse Tongue at this locality is diagenetic and not depositional in origin (Freeman, 1971b).

77.9 Turn left at Wolcott onto Colorado 131 to State Bridge, Bond, and McCoy.

80.5 Legend has it that the flat-topped area on the west side of the road is an Indian burial ground.

80.8 Driving along the contact between the Cretaceous Dakota Sandstone and Mancos Shale.

83.1 Note the resistant "offshore sandstone" beds in the outcrops of Mancos Shale in the foreground.

88.5 Outcrop of Miocene or Pliocene basaltic dike. Clayton and Bostick (1986) have recently studied the thermal effects of the dikes in this area on adjacent fine-grained Cretaceous strata.

93.4 Cross the Colorado River at State Bridge. The type locality of the State Bridge Formation is exposed on the slopes north of the river. This section of southeast-dipping Late Paleozoic and Mesozic rocks is overlain with marked angular unconformity by nearly flat-lying Pliocene and Miocene volcanic rocks.

95.6 Beginning of sporadic exposures of the Minturn Formation on both sides of the Colorado River.

96.4 Town of Bond

99.9 Town of McCoy

101.3 OPTIONAL STOP. Pull off on the west side of the road and examine roadcut outcrop of the Maroon Formation. This is one of several fluvial sandstone bodies in the Maroon Formation described in detail by Johnson (in press, a). The body consists predominantly of

Figure 8. View of the Maroon Formation, the Schoolhouse Tongue of the Weber Sandstone (arrow), and the State Bridge Formation at Stop 5, north of I-70.

intersecting, sheet-like channel architectural elements (Allen, 1983; Miall, 1985) of sandstone and conglomeratic sandstone. The body is oriented at a high oblique angle (63°) to paleoflow, so that channel outlines are accentuated. The architecture and texture of this sandstone body suggest deposition in a mobile-channel, bedload-dominated fluvial system.
Continue north on Colorado Route 131.

101.4 Turn left on gravel road, Eagle County Route 301, and proceed down the valley of Colorado River. Stevens (1956) correlated the limestone bed visible on the west side of the road with the Jacque Mountain Limestone of the Minturn area.

102.9 Note the large west-dipping foresets in Minturn Formation sandstone outcrops on the south side of the Colorado River. These beds have been interpreted by Walker and Harms (unpublished field guide) as part of a fan-delta system.

103.4 More large foresets of a fan-delta system in Minturn Formation sandstones on the slopes north of the Colorado River and in the outcrops on the south bank of the river.

106.0 More large foresets in Minturn Formation sandstone outcrops on the south side of the river.

107.0 For the next 0.6 miles, there is a very good view of the Late Paleozoic and Mesozoic section on the south bank of the river. Note the relatively thin section of the Maroon Formation, the bleached Schoolhouse Tongue of the Weber Sandstone, and the overlying State Bridge Formation. The purplish-gray beds in the lower part of the State Bridge Formation are bedded and chicken-wire gypsum. The purplish-gray bed that overlies the State Bridge Formation is the Gartra Member of the Chinle Formation. Chinle redbeds are overlain by the buff-colored Entrada Sandstone.

108.8 Cross the Colorado River. The cliffs on the east are capped by the Dakota Sandstone.

109.8 Driving over the Mancos Shale. Note rolling, hummocky topography.

113.0 Cross the Colorado River at the town of Burns.

113.4 Turn left at junction, continuing along the Colorado River toward Dotsero.

114.3 Derby Junction.

115.8 Good view of the Chinle Formation and Entrada Formation in the foreground.

117.8 STOP 6. Pull off into large open area on south side of road. Walk north up the slopes to view the upper part of the Maroon Formation and the Schoolhouse Tongue of the Weber Sandstone. These outcrops provide an excellent example of the mixed fluvial-eolian

depositional style of the Maroon (Fig. 9). Fluvial deposits mainly form beds of purplish-gray, fine- to medium-grained sandstone. Paleocurrent directions obtained from the crossbeds in the fluvial sandstones indicate sediment transport to the east, suggesting that the Eagle Basin was markedly asymmetric during Maroon time (Johnson, 1987a, in press,a). Eolianites are sand-sheet deposits and form beds of reddish-orange very fine to fine-grained sandstone. Coarse sand grains and granules are common and occur as thin, discrete laminations and as scattered grains interpreted mainly as deflation lags (Fig. 10). The difference in color between the fluvial channel deposits and the eolianites probably reflects differential early diagenesis associated with the relative position of the depositional environment and the water table. The Schoolhouse Tongue of the Weber Sandstone at this locality is about 6 m thick and consists primarily of sand-sheet deposits similar to those viewed in the underlying section of the Maroon Formation. The contact between the Maroon and the Schoolhouse Tongue again appears to be diagenetic. Johnson (1987a) interpreted the 165-cm-thick bed of coarse and very coarse grained sandstone near the top of the Schoolhouse Tongue as a concentrated deflation-lag horizon. The significance of this and other similar beds will be addressed in more detail on the second day of this trip.
Continue along Eagle County Route 301, down the valley of the Colorado River.

118.7 The contact between the Minturn Formation and the Maroon Formation is approximated by the color change from gray- and tan-colored beds to redbeds, visible in the outcrops on the south side of the river.

119.8 Cross the Colorado River.

122.3 OPTIONAL STOP. Pull off on the north side of the road in order to view exposures of interbedded gypsum and clastics of the Eagle Valley Evaporite in the slopes on the north bank of the Colorado River (Fig. 11). These outcrops continue sporadically on both sides of the river for the next several miles.

127.0 Cross the Colorado River.

128.0 Outcrops of the Belden Formation on slopes on the south side of the Colorado River.

128.3 Sweetwater Creek. Excellent exposures of the Belden Formation are present up the Sweetwater Creek road.

129.3 The contact between the Belden Formation and the Eagle Valley Evaporite is present at road level in outcrops on the north side of the road.

129.9 The contact between the Eagle Valley Evaporite and the overlying Maroon Formation is visible high on the bold cliffs on the southeast side of the Colorado River.

132.0 Sporadic exposures of the Belden Formation occur for the next few

Figure 9. Mixed eolian sand-sheet deposits (light-colored beds in the lower part of the photo) and fluvial channel deposits (darker beds at the top of the photo) in the Maroon Formation at Stop 6. Figure 10 shows details of the eolian stratification.

Figure 10. Stratification in eolian sand-sheet deposits in the Maroon Formation, Stop 6. Coarse sand grains and granules are common and occur as thin, discrete laminations and scattered coarse grains interpreted mainly as deflation lags. Granule ripples are uncommon.

Figure 11. Photograph of the upper part of the Eagle Valley Evaporite along the west side of the Colorado River.

Figure 12. Photograph of the upper part of the Belden Formation and the lower part of the Eagle Valley Evaporite between Sweetwater and Deep Creeks, along the east side of the Colorado River. Note the sandstones in the upper part of the Belden Formation, and the first gypsum of the Eagle Valley Evaporite (arrow).

miles (Fig. 12). Note the sandstones in the upper part of the Belden; the first gypsum marks the lower boundary of the Eagle Valley Evaporite.

135.4 Turn right onto westbound I-70 onramp and drive through Glenwood Canyon to Glenwood Springs. Glenwood Canyon cuts down through the Paleozoic section to Precambrian crystalline basement rocks. The Mississippian Leadville Limestone forms the prominent outcrops at the head of the canyon on the eastern fringe of Glenwood Springs.

153.0 Turn off of I-70 on Exit 116 to Glenwood Springs.

153.1 Turn right at end of offramp.

153.2 Turn right at intersection onto 6th street. Drive straight through the next intersection (crossing Pine Street)

153.3 Park in front of the Hotel Colorado. END LOG, DAY 1

DAY 2

0.0 Leave the Hotel Colorado and drive to westbound I-70 onramp (Exit 116)

0.3 Enter I-70 and drive west.

5.2 Turn off of I-70 on Exit 111 to South Canyon Creek.

5.3 Turn left at stop sign and cross the Colorado River. Follow the road to the east and then to the south, up the valley of South Canyon Creek.

5.8 STOP 7. Pull off in turnout on west side of road. The section visible in outcrops on the west side of the creek includes the upper part of the Maroon Formation, the Schoolhouse Tongue of the Weber Sandstone, the State Bridge Formation, the Chinle Formation, and the Entrada Sandstone. Walk west across South Canyon Creek to examine the the upper Maroon and the Schoolhouse Tongue. These outcrops are steeper than they look and we recommend caution and restraint for trip participants who are not in good physical shape. The Maroon at this locality also consists of interbedded fluvial channel (purplish-gray) and eolian (reddish-orange) deposits. Fluvial channel deposits (Fig. 13) are relatively resistant and consist of intersecting, sheet-like channel architectural elements (Allen, 1983; Miall, 1985) of conglomeratic sandstone (Johnson, 1987a, in press,a). These channel deposits are oriented nearly perpendicular to the north-northeast paleoflow direction, so that channel outlines are accentuated. The architecture and texture of these channel deposits suggest deposition in a mobile-channel, bedload-dominated fluvial system. Eolianites are mainly low-angle, sand-sheet deposits similar to those observed at stop 6 along the Colorado River. Rare eolian crossbed sets at this locality are as thick as 2 m. The Schoolhouse Tongue of the Weber Sandstone is 42 m thick at

Figure 13. View looking east at fluvial channel sandstone body in the Maroon Formation, Stop 7. Note pebble-filled channel in the middle of the bed. Hammer (handle is barely visible in the center of the photograph) for scale.

this locality and consists mainly of yellowish-gray to gray, very fine to fine grained sandstone of eolian sand-sheet origin. Facies and sedimentary structures are similar to those found in the Maroon sand-sheet deposits, again suggesting that the contact between the Maroon and the Schoolhouse Tongue is diagenetic (Johnson, 1987a). The Schoolhouse Tongue at this locality includes a 330-cm-thick interval of interbedded fluvial channel deposits (Fig. 14) and low-angle bedded eolianites, and a 125-cm-thick interval of deformed eolian cross beds (Fig. 15).
Turn around and return to I-70.

6.3 Turn right onto the eastbound I-70 onramp.

6.8 View of the South Canyon Creek section in the slopes on the south side of the river.

11.6 Turn off I-70 on Exit 116 to Glenwood Springs.

11.8 Turn left at stop sign onto Colorado Route 82.

11.9 Turn right at intersection, following signs for Colorado Route 82.

12.0 Turn right at intersection, following signs for Colorado Route 82 (to Aspen). Drive through Glenwood Springs. The contact between the Eagle Valley Evaporite and the Maroon Formation in this lowest part of the Roaring Fork River valley is exposed low on the valley slopes.

14.5 City limits of Glenwood Springs. Discontinuous outcrops of Maroon Formation redbeds occur on the valley slopes for the next 4.7 miles

19.2 Outcrops of the Eagle Valley Evaporite occur on the valley slopes for the next 2.2 miles.

21.4 More outcrops of Maroon Formation redbeds on the east side of the road.

23.6 Junction with Colorado Route 138 which goes through Carbondale and down the Crystal River Valley. Stay on Route 82.

27.7 Outcrops on the east side of the valley for the next 3 miles are of the Eagle Valley Evaporite.

30.8 Community of El Jebel

34.8 Town of Basalt. Turn left on the Fryingpan River Road (following the signs to the Ruedi Reservoir). Exposures along the road are of the uppermost Maroon Formation and the State Bridge Formation. The State of Colorado has designated the Fryingpan River as "gold medal" fishing waters.

37.8 STOP 8. Pull off and park in wide area on the south side of the road. Outcrops on the north side of the road comprise the uppermost part of the Maroon Formation. The break in slope above the outcrops

Figure 14. View of interbedded fluvial and eolian deposits in the Schoolhouse Tongue of the Weber Sandstone at Stop 7. Clasts in the pebble-lined fluvial channel are as large as 6 cm in diameter.

Figure 15. Thick (125 cm) interval of deformed eolian crossbeds in the Schoolhouse Tongue of the Weber Sandstone, Stop 7.

is the contact between the more resistant Maroon Formation and the less resistant State Bridge Formation. The Schoolhouse Tongue of the Weber Sandstone does not extend this far to the south. The Maroon Formation in these outcrops consists mainly of stacked fluvial channel deposits of pebbly coarse to very coarse grained sandstone (Fig. 16). Bedding is mainly low-angle. Scours within and(or) at the base of the fluvial channel sandstone bodies have as much as 2 m of relief. Paleocurrent data from this area indicate easterly sediment transport ($x = 71°$; $n = 36$)(Johnson, 1987, a). Comparison of these channel deposits with those viewed at STOP 6 on Day 1 of this trip illustrates the dramatic down-stream facies changes in Maroon Formation fluvial systems. The less common fine-grained rocks in these outcrops contain pedogenic carbonate.

39.1 Cliff exposures on the north side of the road are of State Bridge Formation and Chinle Formation redbeds, capped by light-colored beds of the Entrada Sandstone.

42.6 Beginning of exposures comprised of eolianites of the Fryingpan Member of the Maroon Formation.

47.5 Beginning of roadcut outcrops of loessites and loessoidal sediments of the Maroon Formation.

48.6 STOP 9. Pull off the road to the right in the large parking area overlooking the Ruedi Reservoir. Outcrops of reddish-orange, fine-grained rocks of the Maroon Formation on the northwest side of road consist of siltstone and very fine-grained sandstone interpreted by Johnson (1987a, b, in press, b) as loess and loessoidal sediment. Beds are a few tens of centimeters to 25 m thick (bed thickness increases upward in the section) and are bounded by horizontal to low-angle planar surfaces. Many beds are internally massive and contain little or no evidence of primary stratification (Fig. 17). Discolored reddish-brown horizons containing root casts are present at the tops of many beds, indicating pedogenic modification. Beds are generally bounded by these discolored horizons, by thin (< 1 cm) mudstone drapes, or by as much as 3 m of thinly bedded, fine-grained pond deposits (Fig. 18). Mudcracks and current-ripple marks are common features of the mudstone drapes and pond deposits. An eolian loess origin is supported for the massive fine-grained beds in this section by 1) the dominance and uniformity of the sandy-silt grain size, 2) the absence of distinct stratification, 3) the planar to gently undulating bedding contacts, and 4) the relative absence of channel deposits. Sand-sheet deposits (with common deflation lag horizons) in the Maroon Formation to the north are the inferred sediment source. Deposition was probably promoted both by the topographic obstruction presented by the ancestral Sawatch Uplift, and by the surface roughness effects of vegetation along the basin margin.
Turn around and drive west down the Fryingpan River Road toward Basalt.

51.3 STOP 10. Pull off in small turnoff on north side of road. Walk east 150 m into quarry on north side of road to examine outcrops of

Figure 16. View of coarse-grained, vertically stacked, channel deposits in the Maroon Formation, Stop 8. Note the considerable relief (as much as 2 m) on the scour surfaces. Jacob staff in center of photo is 150 cm long.

Figure 17. Thick, massive beds of reddish-orange siltstone to very fine grained sandstone in the Maroon Formation, Stop 9. Beds are interpreted as loessite, and are bounded by reddish-brown paleosol horizons and by mudstone drapes. Jacob staff is 150 cm long.

Figure 18. Thinly interbedded siltstone-mudstone pond deposits in the Maroon Formation, Stop 9. Note how these beds onlap the positive topography in the underlying loessite.

Figure 19. View of the Fryingpan Member of the Maroon Formation at Stop 10. Planar surfaces in foreground are crossbed foresets (regional dip is about 5°). The crossbeds at the base of the quarry may be as thick as 30 m (if there are no undetected bounding surfaces).

the Fryingpan Member of the Maroon Formation (Fig. 19). The Fryingpan Member is restricted to the Ruedi Reservoir area where it conformably overlies loessites and loessoidal sediments of the Maroon Formation. It consists almost entirely of well-sorted very fine to fine grained sandstone of eolian origin. The section is dominated (82 percent of exposed strata) by thick sets of planar crossbeds and less commonly trough crossbeds. Sets are typically 50 cm to 250 cm thick, and foreset laminae of eolian grainflow, ripple, and grainfall origin are common. The planar crossbeds in the lower part of the quarry reach thicknesses of 30 m (if there are no undetected bounding surfaces). The Fryingpan Member has a maximum thickness of about 120 m near Ruedi Reservoir and pinches out to the north, west, and south. To the east, its stratigraphic level has been eroded. Johnson (1987, a) suggested this unit formed as a small basin-margin dune field analogous in many ways to the modern dune field in Great Sand Dunes National Monument (Andrews, 1981). The transition from loess to dune deposition in the Maroon in the Ruedi Reservoir area was probably triggered by slowing and(or) cessation of subsidence in Eagle Basin to the north of this area. The thick bed of granular sandstone viewed in the Schoolhouse Tongue of the Weber Sandstone at stop 6 might provide evidence of such a decrease in subsidence rate. Freeman (1971b) previously considered the Fryingpan Member as the lowest unit in the State Bridge Formation.

END ROAD LOG. RETURN TO DENVER VIA BASALT AND GLENWOOD SPRINGS.

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