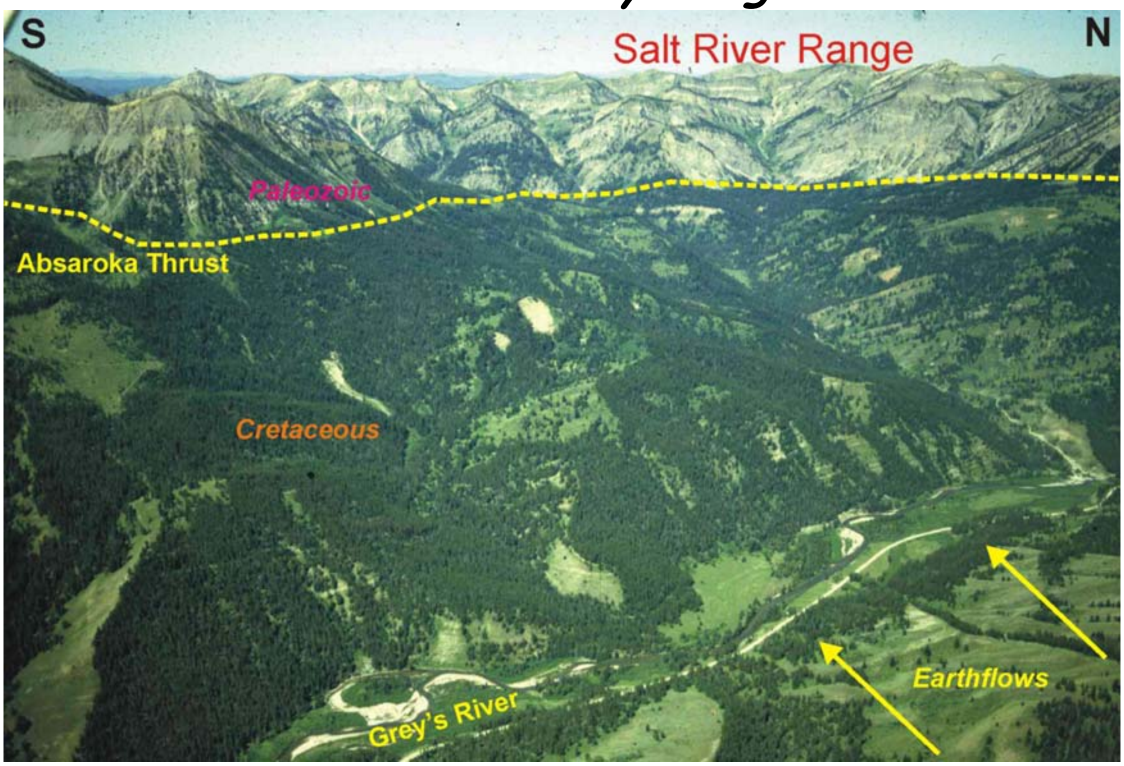
2008 Friends of the Pleistocene Field Trip—Rocky Mountain Cell

Sept. 6-8, 2008

Quaternary Happenings in the Overthrust Belt, Western Wyoming



Salt River Range, WY

Edited by Jim McCalpin

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General Itinerary: a 180-mile loop starting and ending at the southern end of Star Valley, WY.

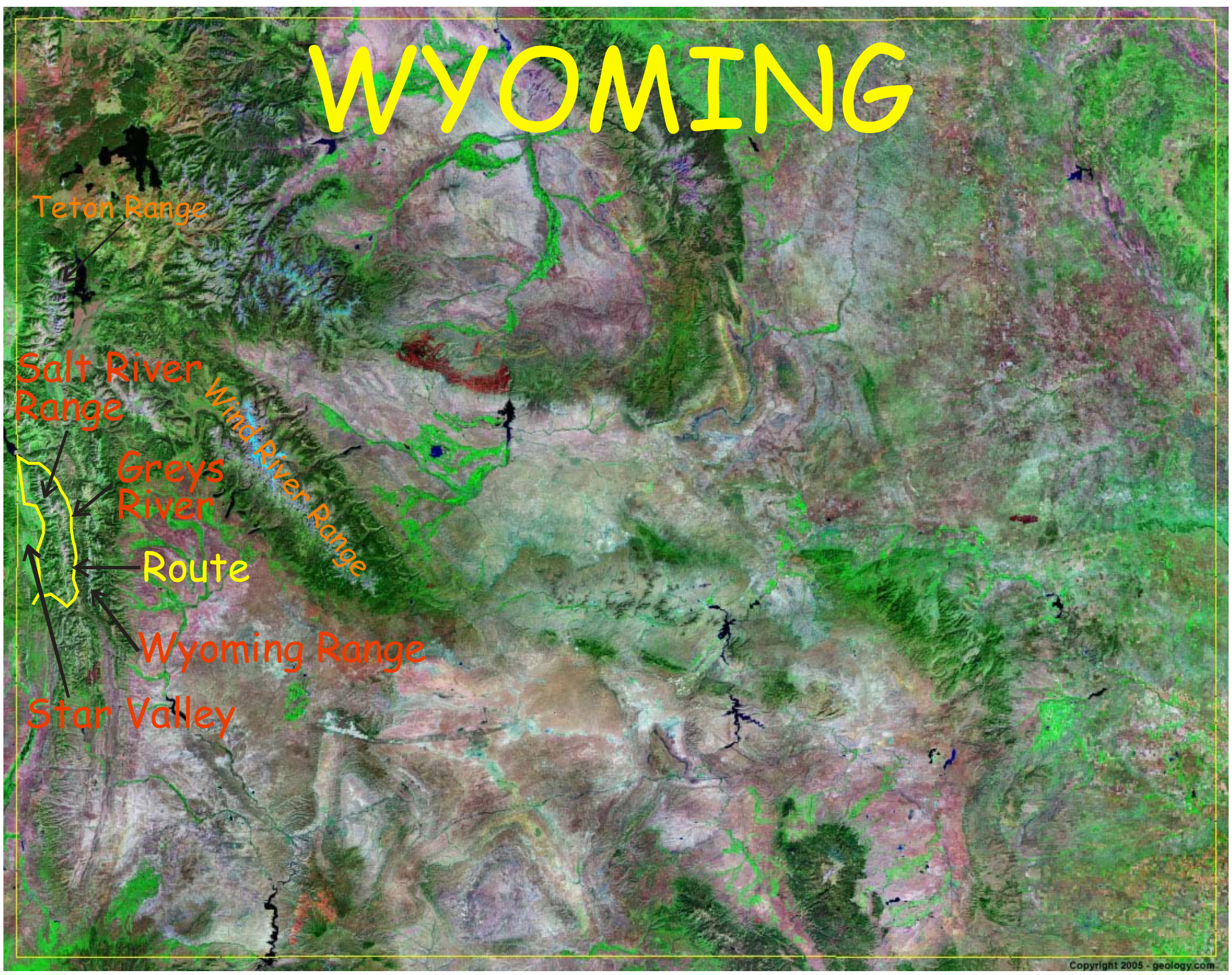


Fig. 1. Route of field trip (thin yellow line at far left) superimposed on a satellite image of Wyoming.

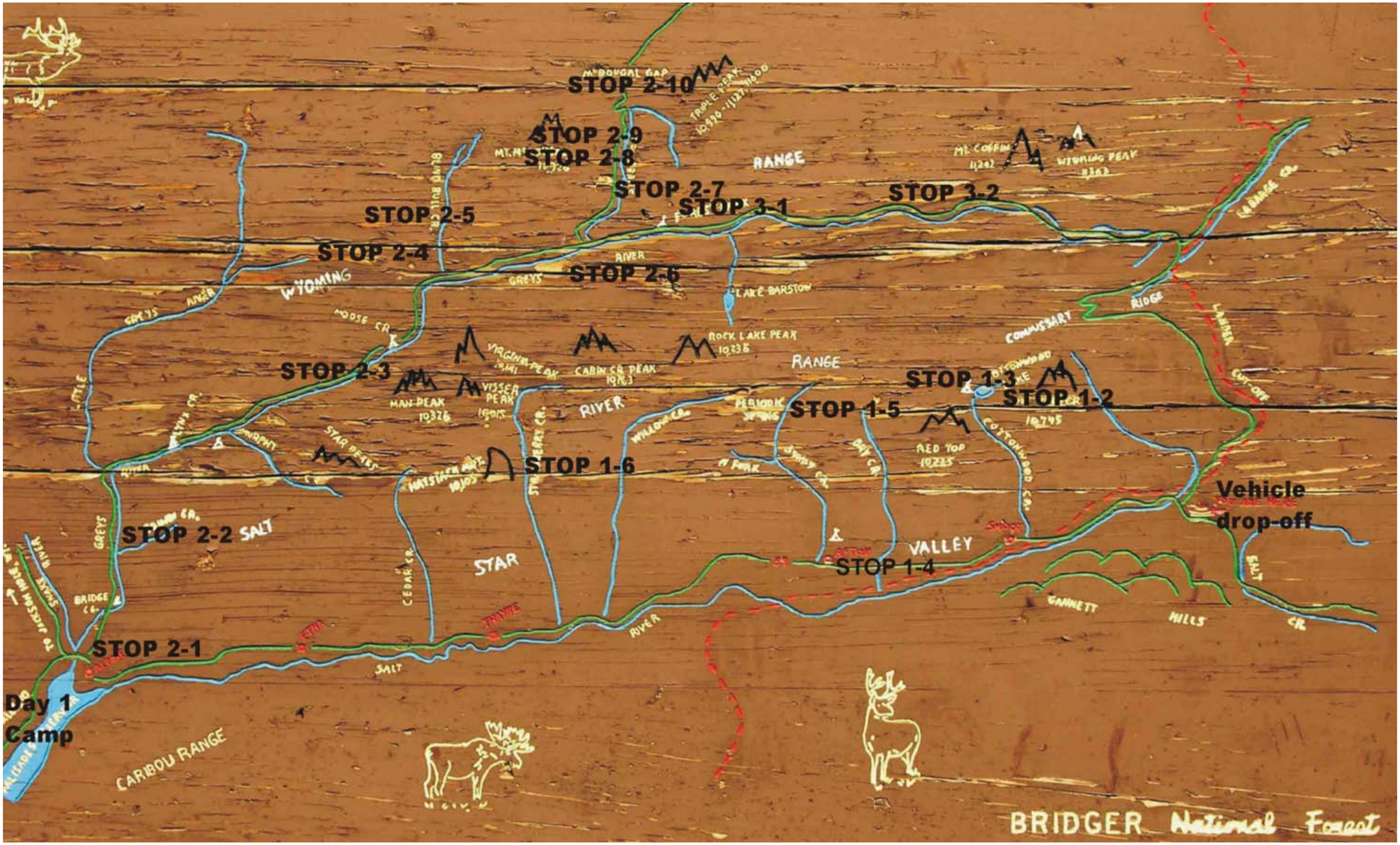


Fig. 2. Field trip STOPS plotted on a pre-Google Earth base map; north is to the left.

Day 0 (Friday, Sept. 5, 2008): arrive in evening at Allred Flats Campground, Bridger-Teton National Forest, Wyoming; on US Highway 89 4 miles south of Salt River Pass, and 20 miles south of Afton, WY).

Day 1 (Saturday, Sept. 6, 2008): Star Valley, WY; begin stops south of the Valley; make 6 stops during the day, progressing northward; at end of the day, drive through Alpine, WY and on to Alpine North Campground (Caribou National Forest), 2 mi NW of Alpine Junction, WY. 83 miles of driving, 2/3 on paved roads and 1/3 on good gravel roads. Evening, 2nd Annual FOP Discriminating Sudsfest.

Fig. 3. Oblique satellite view of Star Valley and US 89 (at left). North is to the top; the blue line at upper left is the Idaho-Wyoming boundary. The Salt River Range is at left center, the Greys River Valley (right center), and the Wyoming Range (right). This image covers the entire field trip route. Day 1 stops in yellow, day 2 stops in red, day 3 stops in blue.

Day 2 (Sunday, Sept. 7, 2008): Grey's River Valley, WY: drive to the mouth of the Grey's River (confluence with Snake River) at Alpine, WY; continue on good gravel road up the Grey's River; 9 stops during the day, either on the Grey's River itself (2 stops), up western tributaries into the Salt River Range (1 stop), or up eastern tributaries into the Wyoming Range (6 stops). Last stop at McDougall Gap on the E side of the Wyoming Range. 69 miles of driving, mostly on good gravel roads. Return at end of the day to the Grey's River and Forest Park Campground (Bridger-Teton National Forest), at mile 32 on the Grey's River Road. Evening, the Soil Circle and propositions for the 2009 FOP trip.

Day 3 (Monday, Sept. 8, 2008): upper Grey's River valley, Commissary Ridge, and return to starting point of trip; 2 stops along the way. 40 miles of driving on pretty rough gravel roads. Trip ends at ca. noon back near the starting point.

ROAD LOG
Day 1

Mi 0.0: Allred Flats Campground [UTM Zone 13, NAD 27; 503188mE/4703920mN]; leave campground and turn left (N) onto US 89, and drive toward Salt River Pass. The roadcuts along the next 4 miles expose steeply dipping Mesozoic sedimentary rocks belonging to the Overthrust Belt province.

Mi 4.0: STOP 1-1. (Jim McCalpin) Salt River Pass [507600mE/4705785mN]. Pull off highway to right (E) and park in front of interpretive signs. This 30-minute stop will be an overview of the pre-Quaternary geology of the Overthrust Belt in general, and Star Valley/Greys River Valley in particular. Good views to the NE of the Salt River Range, which lies between Star Valley and Greys River Valley.

Fig. 4. Typical "angular" topography in the Salt River Range; Swift Creek in foreground, view to SE.

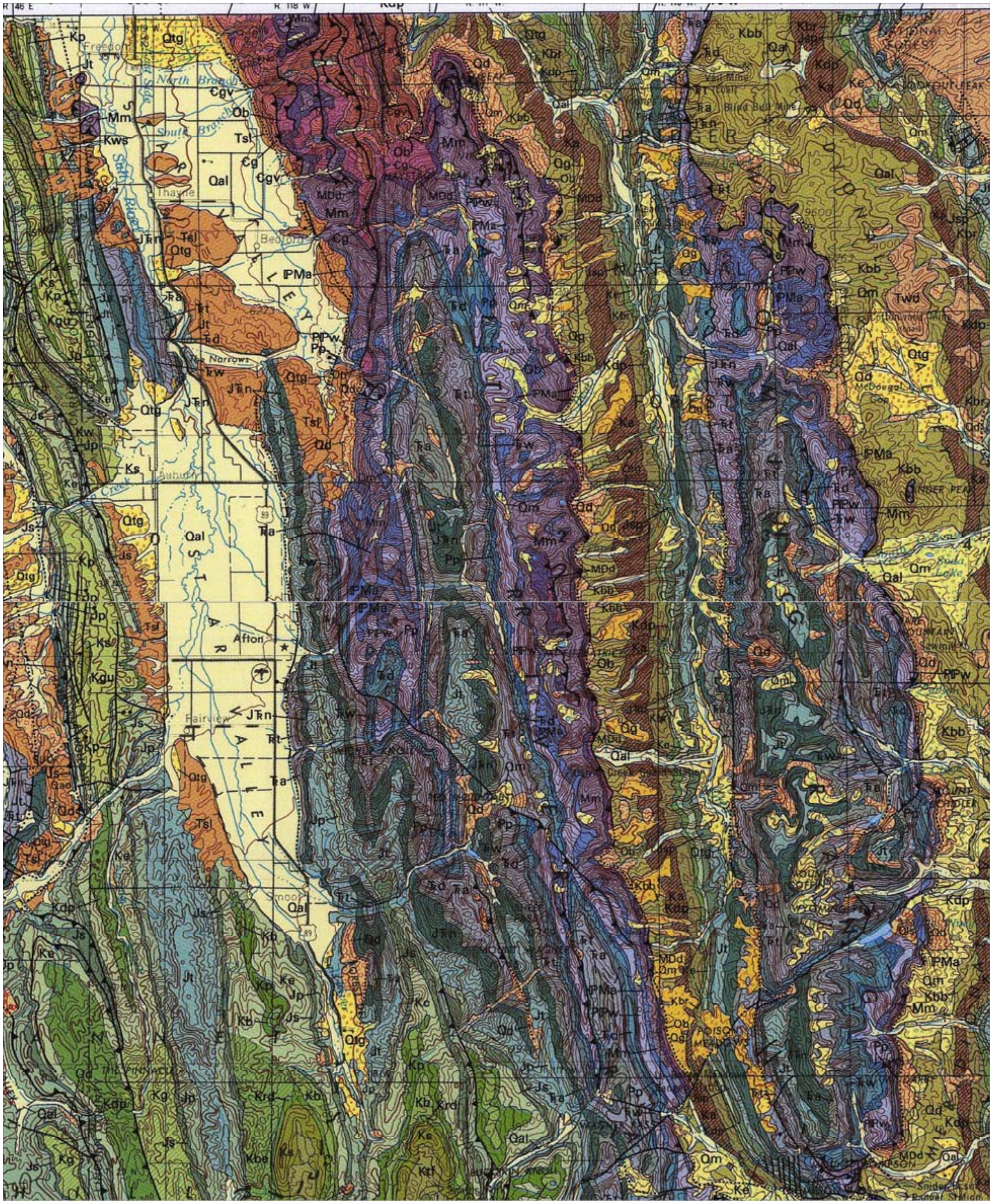


Fig.4. Piece of the 1:250,000 geologic map showing the (mainly) bedrock geology traversed by this trip. Star Valley comprises the two sediment-filled grabens (pale yellow) at left. The Greys River is a narrow river valley at right center. Between them is the Salt River Range, with the Wyoming Range at far right. From

several thousand meters thick; thins basinward and intertongues with Green River Formation

Diamictite—Unsorted boulders and blocks in mudstone matrix; grades into other members of the formation. Apparently several hundred meters thick in places; thins basinward

New Fork Tongue—Dull-red and green mudstone, brown sandstone, and thin limestone beds. As much as 20 m thick

La Barge Member—Red and brown mudstone and conglomerate, yellow sandstone, and minor pisolitic limestone. As much as 500 m thick

Chappo Member (lower Eocene and upper Paleocene)—Red to gray conglomerate and sandstone. As much as 30 m thick

CONGLOMERATE OF SUBLETTE RANGE (LOWER EOCENE OR PALEOCENE)—Boulder- to pebble-sized gravel, sand, and silt, crudely stratified. About 180 m thick

HOBACK FORMATION (PALEOCENE)—Light- to dark-gray mudstone, siltstone, and sandstone; a few beds of impure coal. As much as 4,500 m thick

EVANSTON FORMATION (PALEOCENE AND UPPER CRETACEOUS)—Gray siltstone; sparse red sandstone and lignite. About 250 m thick

BLIND BULL FORMATION (UPPER CRETACEOUS)—Gray to tan conglomeratic sandstone, siltstone, claystone, coal, and bentonite. As much as 2,800 m thick

ADAVILLE FORMATION (UPPER CRETACEOUS)—Brown-weathering gray sandstone, siltstone, and carbonaceous clay; conglomeratic in upper part and coal bearing in lower part. As much as 640 m thick

HILLIARD SHALE (UPPER CRETACEOUS)—Dark-gray to tan claystone, siltstone, and sandy shale; increasing tan sandstone westward and northward. About 1,700 m thick

FRONTIER FORMATION (UPPER CRETACEOUS)—White to brown sandstone and dark-gray shale; beds of oyster shells in upper part; coal and lignite in lower part. About 800 m thick

ASPEN SHALE (LOWER CRETACEOUS)—Light- to dark-gray siltstone and claystone; some quartzitic sandstone and porcelanite. Thins southward from 610 to 330 m

BEAR RIVER FORMATION (LOWER CRETACEOUS)—Black shale, fine-grained brown sandstone, and minor fossiliferous limestone and bentonite. Thins eastward from 550 to 430 m

SAGE JUNCTION FORMATION (LOWER CRETACEOUS)—Gray and tan siltstone and sandstone; minor quartzite, porcelanite, limestone, conglomerate, and coal. As much as 1,000 m thick

WAYAN FORMATION (LOWER CRETACEOUS)—Variegated red, purple, yellow, and gray mudstone, siltstone, and sandstone; minor porcelanite, bentonite, and coal. About 1,200 m thick

Sandstone unit—Gray and tan sandstone and siltstone; possibly a lateral equivalent of the Cokeville Formation. About 200 m thick

QUEALY FORMATION (LOWER CRETACEOUS)—Red and variegated pastel-tinted mudstone and tan sandstone. Thins eastward from 330 to 150 m

COKEVILLE FORMATION (LOWER CRETACEOUS)—Gray to tan sandstone; some tan siltstone, claystone, limestone, bentonite, porcelanite, and coal. Thins northwestward from 900 to 260 m

THOMAS FORK FORMATION (LOWER CRETACEOUS)—Red, purple, brown, and green mudstone; some gray sandstone. Thins southeastward from 530 to 120 m

SMITHS FORMATION (LOWER CRETACEOUS)—Ferruginous black shale and tan to brown sandstone. Thins westward from 260 m to about 90 m

GANNETT GROUP (LOWER CRETACEOUS)—Red sandy mudstone, sandstone, and chert-pebble conglomerate; some thin limestone and dark-gray shale in upper part; more conglomerate in lower part. Thins eastward from 900 to 240 m

Unnamed red unit and Draney Limestone—Upper red mudstone and siltstone (equivalent to Smoot Formation of Eyer, 1969), absent in places. Lower dark-gray calcareous shale and aphanitic limestone. About 60 m thick

Bechler Conglomerate—Red to purplish-gray mudstone, sandstone, and chert-pebble conglomerate. About 400 m thick

Peterson Limestone—Light-gray limestone and pastel-colored calcareous mudstone. About 70 m thick

Ephraim Conglomerate—Red and maroon mudstone and chert-pebble conglomerate; crossbedded tan to brown sandstone. Thins eastward from 1,000 to 150 m

Unnamed red unit, Draney Limestone, and Bechler Conglomerate

Unnamed red unit, Draney Limestone, Bechler Conglomerate, and Peterson Limestone

Bechler and Ephraim Conglomerates—Where Peterson Limestone is poorly developed or absent

STUMP FORMATION AND PREUSS REDBEDS (UPPER AND MIDDLE JURASSIC)

Stump Formation (Upper and Middle Jurassic)—Glauconitic siltstone, sandstone, and limestone. Thins eastward from 100 to 50 m

Preuss Redbeds (Middle Jurassic)—Purple, maroon, and reddish-gray sandy siltstone and claystone; halite, alum, and gypsum in irregular zones. Thins eastward from 500 to 110 m

TWIN CREEK LIMESTONE (MIDDLE JURASSIC)—Greenish-gray argillaceous limestone and calcareous siltstone. Thickens westward from 300 to more than 1,000 m

NUGGET SANDSTONE (JURASSIC? AND TRIASSIC?)—Buff to pink, crossbedded, well-sorted sandstone and quartzite. 300 to 180 m thick

ANKAREH FORMATION (UPPER TRIASSIC)—Red and maroon shale and pale-purple limestone; minor white to red, fine-grained quartzite. Thickens eastward from 140 to 280 m

TIMOTHY SANDSTONE (LOWER TRIASSIC)—Yellowish-gray calcareous sandstone. About 100 m thick

THAYNES LIMESTONE (LOWER TRIASSIC)—Gray limestone and brown-weathering gray, calcareous siltstone; dark-gray shale and limestone abundant in lower part. Thins eastward from 500 to 300 m

WOODSIDE SHALE (LOWER TRIASSIC)—Red siltstone and shale; minor sandstone and gray limestone. Thickens eastward from 120 to 180 m

DINWOODY FORMATION (LOWER TRIASSIC)—Gray limestone and olive to greenish-brown siltstone. Thins eastward from 500 to 75 m

PHOSPHORIA FORMATION (PERMIAN)—Upper part dark- to light-gray chert and shale; lower part brown-weathering phosphatic shale and limestone. Thins eastward from 110 to 70 m

WELLS FORMATION (PERMIAN AND PENNSYLVANIAN)—Interbed gray limestone and pale-yellow calcareous sandstone; minor gray d mite; cherty in lower part. Thins eastward from 600 to 180 m

AMSDEN FORMATION (PENNSYLVANIAN AND UPP MISSISSIPPIAN)—Red and gray cherty limestone and yellow siltst sandstone, and conglomerate. Thins eastward from 170 to 100 m

CHESTERFIELD RANGE GROUP (UPPER AND LOW MISSISSIPPIAN)—Gray bioclastic limestone and silty, bro weathering limestone; recrystallized to tan silty dolomite in places. Ab 500 m thick

Monroe Canyon Limestone (Upper Mississippian)—Gray, thick-bedd bioclastic and partly sandy limestone containing abundant corals. 28 thick

Little Flat Formation (Upper and Lower Mississippian)—Gray, t bedded, brown-weathering, sandy and silty limestone and siltst Thins eastward from 300 to 250 m

LODGEPOLE LIMESTONE (LOWER MISSISSIPPIAN)—Blue dark-gray, thin- to medium-bedded very fossiliferous cherty limest Thins eastward from 250 to 110 m

MADISON LIMESTONE (UPPER AND LOWER MISSISSIPPIAN)—Mas light-gray limestone in upper part and thin-bedded dark-gray limest in lower part. 300 to 560 m thick

DARBY FORMATION (LOWER MISSISSIPPIAN AND UPP DEVONIAN)—Black, yellow, and red sandstone and siltstone in up part and dark-gray dolomite and dolomitic limestone in lower part. 14 thick

BEIRDNEAU FORMATION (UPPER DEVONIAN)—Thin-bedded dolor limestone and tan sandy dolomite in upper part; pink sandstone and g limestone in lower part. 250 m thick

HYRUM DOLOMITE (UPPER AND MIDDLE DEVONIAN)—Finely cry line light- to dark-gray, thin-bedded dolomite. In southwestern par quadrangle includes Lower Devonian Water Canyon Formation mapped by others. Thins eastward from 500 to 350 m

DEVONIAN ROCKS UNDIVIDED

LAKETOWN DOLOMITE (UPPER AND MIDDLE SILURIAN)—Medium light-gray, white-weathering, finely crystalline, thick-bedded dolom Thins eastward from 400 to 300 m

BIGHORN DOLOMITE (UPPER ORDOVICIAN)—Light-gray mas dolomite. Thins eastward from 250 to 120 m

FISH HAVEN DOLOMITE (UPPER ORDOVICIAN)—Dark-gray, bro weathering, thin-bedded dolomite containing bioclastic beds. T eastward from 150 to 80 m

SWAN PEAK QUARTZITE (MIDDLE ORDOVICIAN)—White, tan, and p wel-sorted, well-rounded fine- to medium-grained massive quart Thins eastward from 350 to 200 m

GARDEN CITY LIMESTONE (MIDDLE AND LOWER ORDOVICIAN Dark-gray limestone; minor dolomite. Abundant bioclastic and intra mational conglomerate and chert, increasing toward top. 360 m t

GALLATIN LIMESTONE (UPPER CAMBRIAN)—Gray and tan mo limestone. 120 m thick

GROS VENTRE FORMATION (UPPER AND MIDDLE CAMBRIAN)—C and tan, partly oolitic limestone; greenish-gray micaceous shale in t dle. Thins eastward from 400 to 200 m

Fig. 5. Explanation for the geologic map in Fig. 1.

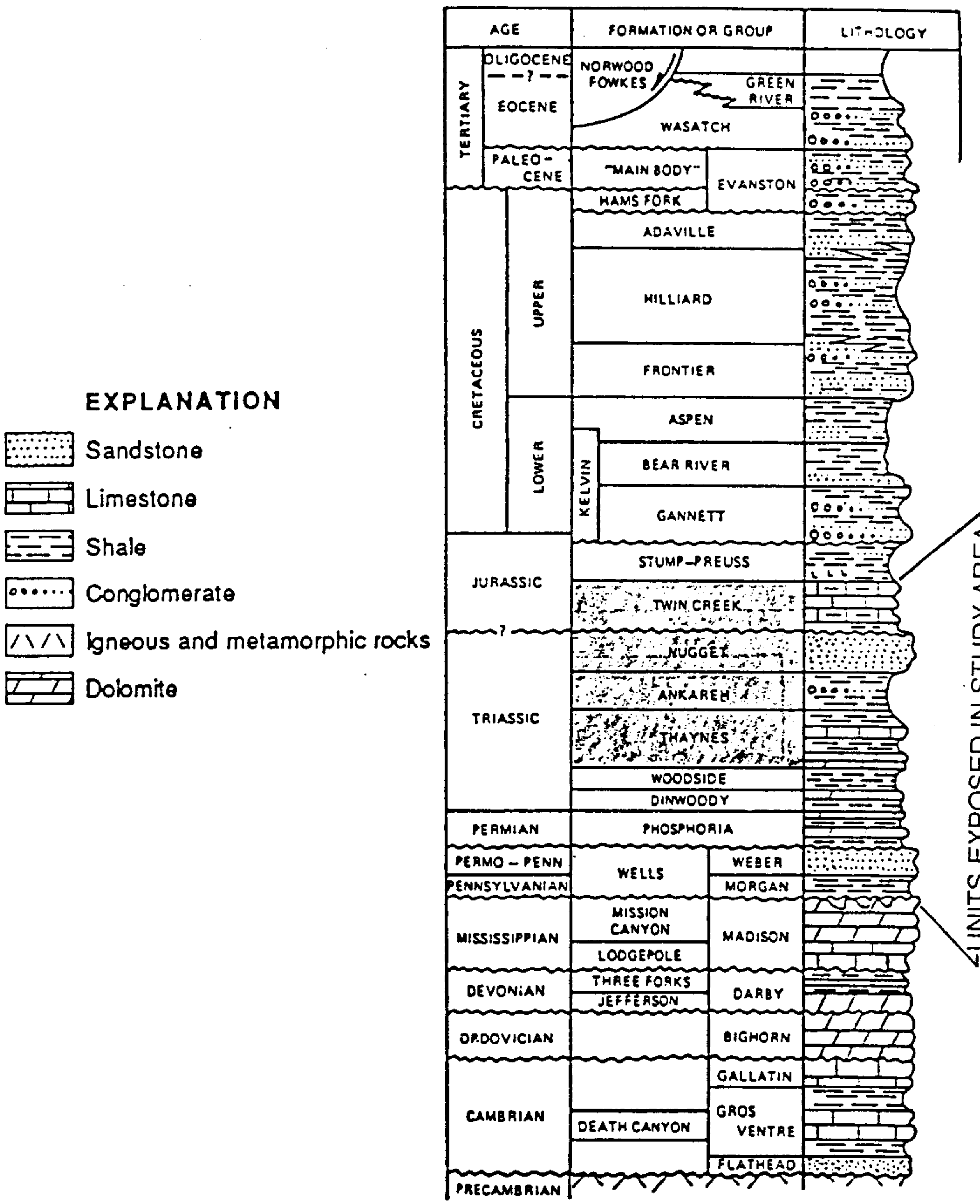


Fig. 6. Stratigraphic column of the Salt River Range.

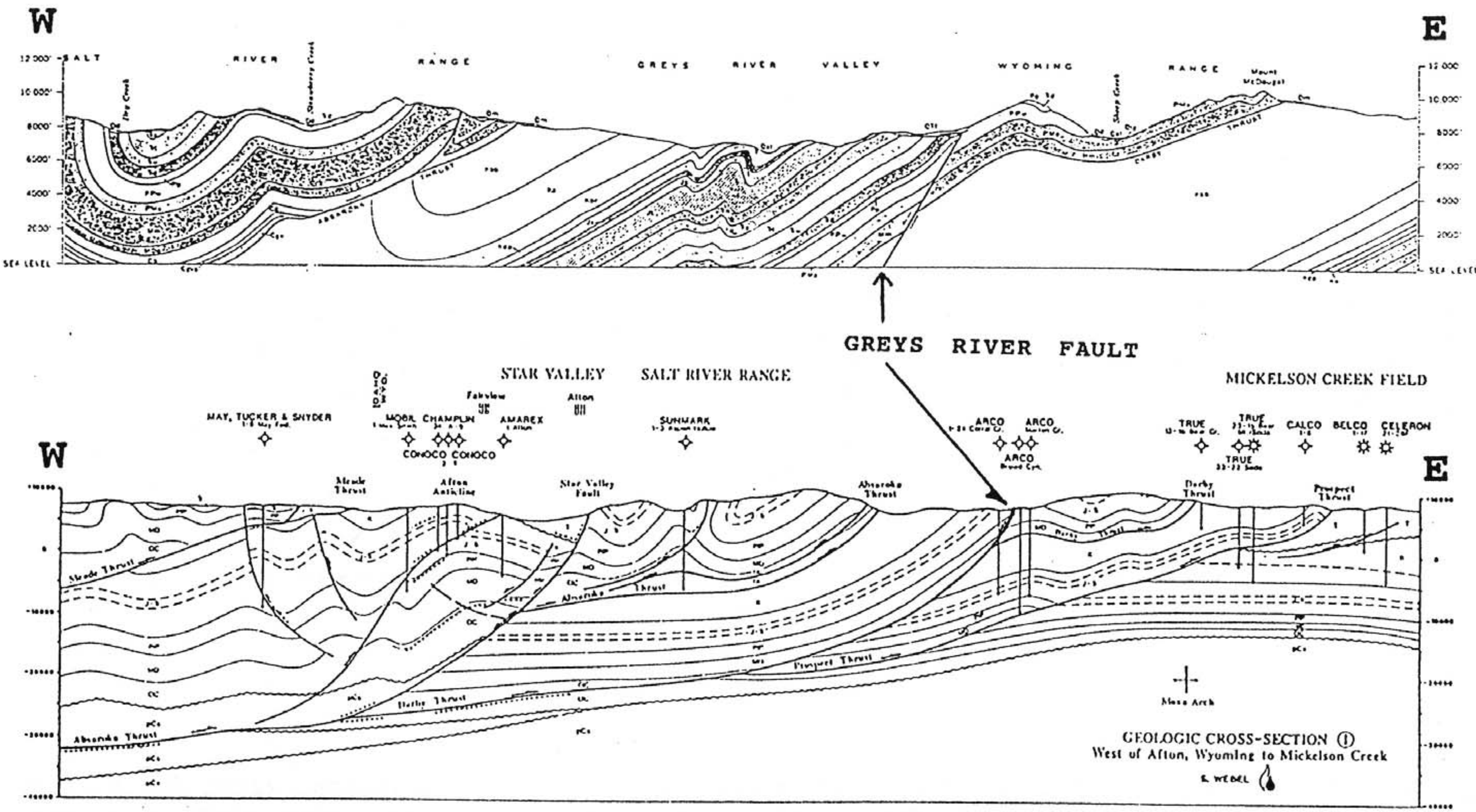


Fig. 7. E-W geologic sections through Star Valley-Greys River Valley, from Rubey, 1973 (top) and Webel, 1987 (bottom),

	YR B.P. X10³	WIND RIVER MOUNTAINS, WY (Miller and Birkeland, 1974, Porter et al., 1983)	FRONT RANGE, CO (Benedict, 1973, Porter et al., 1983)	SALT RIVER RANGE, WY (SOUTHWEST FLANK) (this study)
HOLOCENE	0.1-0.3	GANNET PEAK	ARAPAHO PEAK	Nt 4?
	1	AUDUBON EQUIVALENT	AUDUBON	Nt 3?
	2			
	3			
	4	EARLY NEOGLACIAL	TRIPLE LAKES	Nt 1-2?
	5			
	6			
	7			
	8			
	9			
	10			
PLEISTOCENE	11	TYPE TEMPLE LAKE	SANTANTA PEAK	EHt ?
	12			
	13			
	14			
	15? ↓ 30?	LATE PINEDALE	LATE PINEDALE	Pt
	>30	EARLY PINEDALE/ BULL LAKE	EARLY PINEDALE/ BULL LAKE	Bt (?)

Fig. 8. Quaternary stratigraphic nomenclature for the Salt River Range, used by Warren (1992).

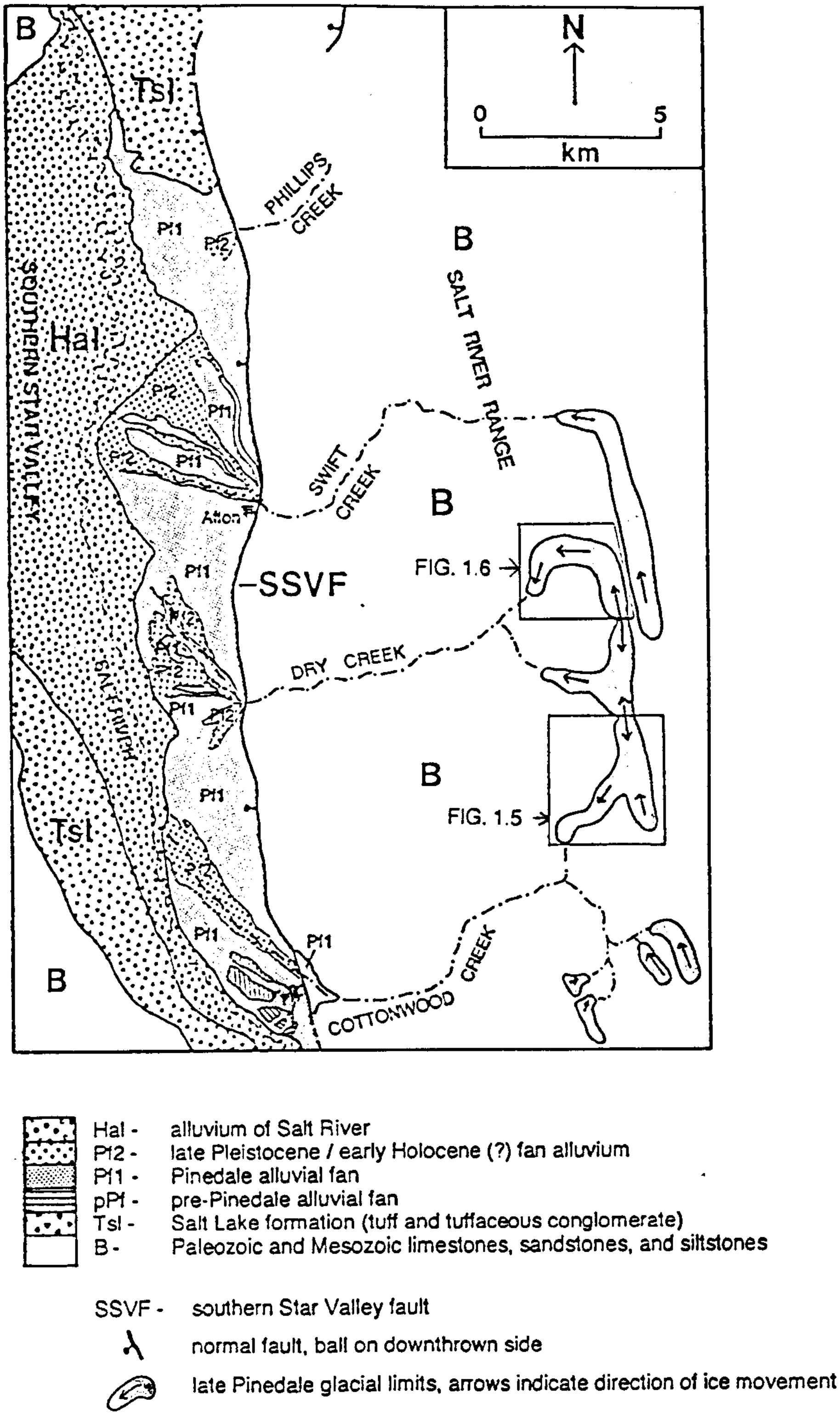


Fig. 9. Pinedale ice limits in the southern Salt River Range and the southern Star Valley fault (Warren, 1992).

Relative Dating (RD) Parameters (Rice, 1987)

Type	Parameter	Abbrev	Definition
Landform Modification	Ridge crest width	RCW	Width of the crest of moraine and pressure ridges where slope angles were less than 5° (in m)
	Maximum inner and outer slope angles	SAI, SAO	Maximum inner and outer slope angles of moraine and pressure ridges (degrees)[1]
	Surface Boulder Frequency (SBF)	SBF	Number of boulders (>30 cm) exposed at ground surface in 180 m^2 area
	Boulder Burial Factor	BBF	Percentage of boulders on the surface of a deposit which are partially buried *TIMES* average volume percentage of boulder burial[2]
Clast Weathering	Weathering rind thickness		Maximum thickness of weathering rind (in mm) measured perpendicular to rock edge; measured on 25 boulders
	Depth of boulder pitting	PIT	Depth of pits on boulders (in mm), measured below the rim; measured on 25 boulders
	Resistate inclusion height	RES	Height of resistate inclusions (in mm) above the general boulder surface; measured on 25 boulders
	Soil profile development	SPD	Arbitrary "development values" were assigned to 5 stages of soil development[3]
Biologic	Lichen diameter		Largest inscribed circle diameter of the largest lichen found on a deposit (*R. geographicum*)

[1] On moraine ridges, the inner slope faces toward the paleoglacier (i.e., toward today's valley axis); on a landslide pressure ridge, the inner slope faces toward the center of the landslide.
[2] Range=0 to 1.0; 0= all boulders sitting loose on surface, no boulders partially buried; 1.0= no boulders are sitting loose on surface, and only the teeny tops of boulders appear at the surface
[3] no soil=0; incipient soil lacking discernable horizons, mostly eolian=5; incipient horizonation or CaCO3 coats on clasts (Stage I)=10; well developed Stage I CaCO3 coats, well developed horizonation=15; Stage II CaCO3 coats or Textural B horizon=20)

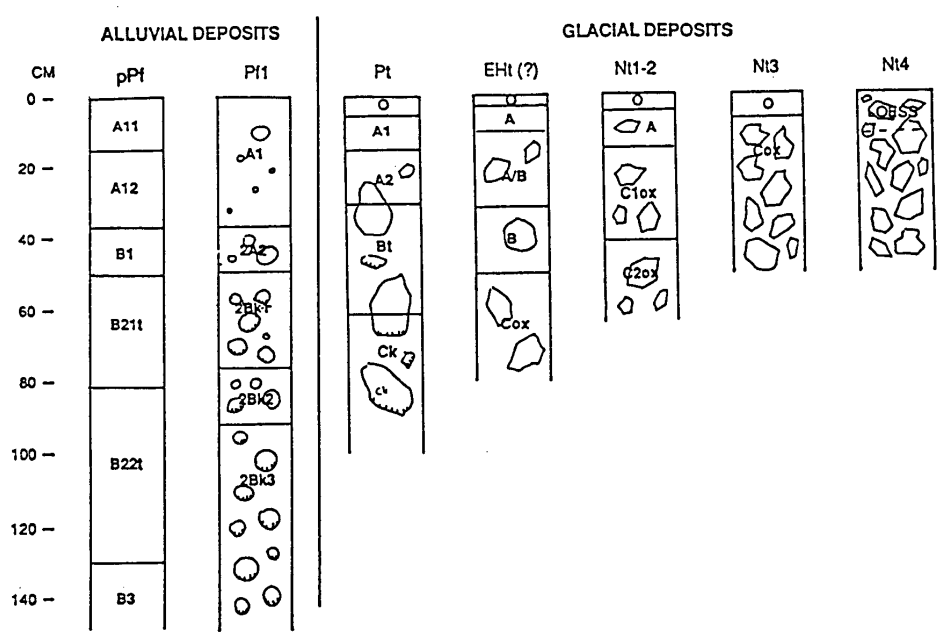


Fig. 10. Soil chronosequence for various Quaternary deposits in southern Star Valley (alluvial deposits) and in the Salt River Range (glacial deposits). From Warren, 1992.

Continue N on US Highway 89

Mi 6.0: Smith's Fork Road on right [508468mE/4708357mN]. Some attendees (especially those alone in a vehicle) may wish to leave their vehicle here and carpool with others. We will return here at the end of the trip. This will help decrease the number of vehicles in the FOP "train." If so, turn right (E) on Smith's Fork Road and proceed 0.4 mi to the USFS information kiosk and small parking area [508744mE/4707829mN]. The Smiths Fork Road here follows the track of the famous "Lander Cut-Off", a short-cut of the Oregon Trail that ran north through Star Valley.

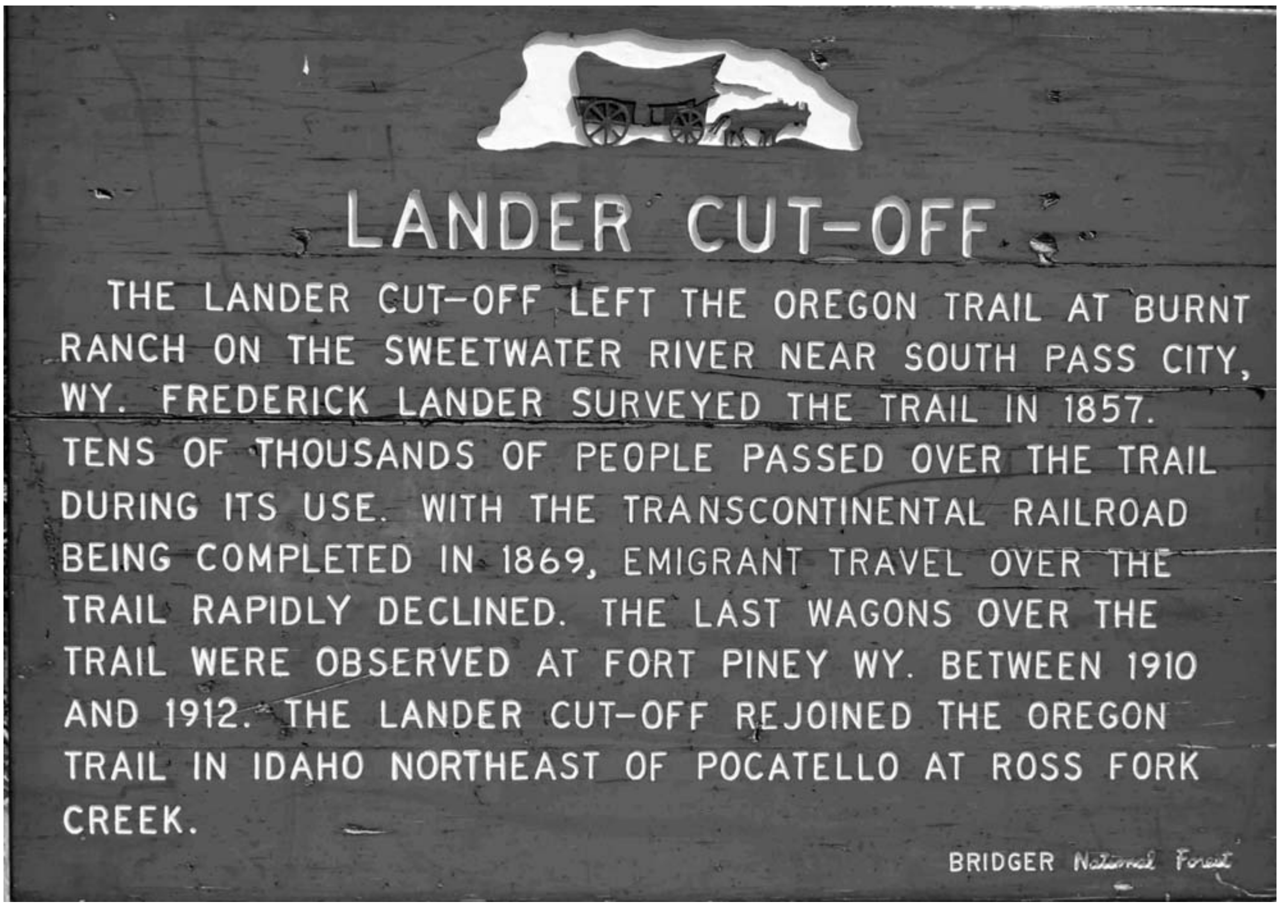


Fig. 11. USFS sign at the Smith's Fork Road kiosk.

Return to US Highway 89 and turn right (N); proceed towards Star Valley.

Road enters the southern part of Star Valley, which begins as a narrow alluvial valley of the Salt River, but soon widens into a graben. Between Mi 11 and Mi 13, US 89 ascends onto Pinedale, and then pre-Pinedale, alluvial fan surfaces emanating from Cottonwood Creek, a major drainage flowing west out of the Salt River Range.

Mi 13.3: turn right (E) onto County Road 153; proceed toward the mouth of Cottonwood Creek on the Pinedale alluvial fan; road enters the canyon and begins a 6-mile course of narrow and winding dirt road; the canyon walls expose north-striking, steeply dipping strata of Mesozoic sedimentary rocks, folded during the Sevier orogeny (Cretaceous).

Mi 19.5: arrive at Cottonwood Lake Campground [514948mE/4720468mN]. Proceed straight ahead to T intersection, then turn right (S) toward the day Use Area and Slide Lake Trailhead; continue on a very narrow dirt road along the E side of Cottonwood Lake.

Mi 19.7: STOP 1-2, Slide Lake Trailhead (John Rice) [515837mE/4719830mN]. Park at trailhead and walk S on combination horse and foot trail. Note: after about 100 m, horse and foot trails diverge slightly to permit foot traffic to use 2 wooden bridges; thereafter trails rejoin.

Walk 1 mile south, crossing a large avalanche chute to the west, after which the trail ascends a series of switchbacks in the trees to reach the elevation of the landslide that creates Slide Lake. Hiking time approximately 20-25 minutes.

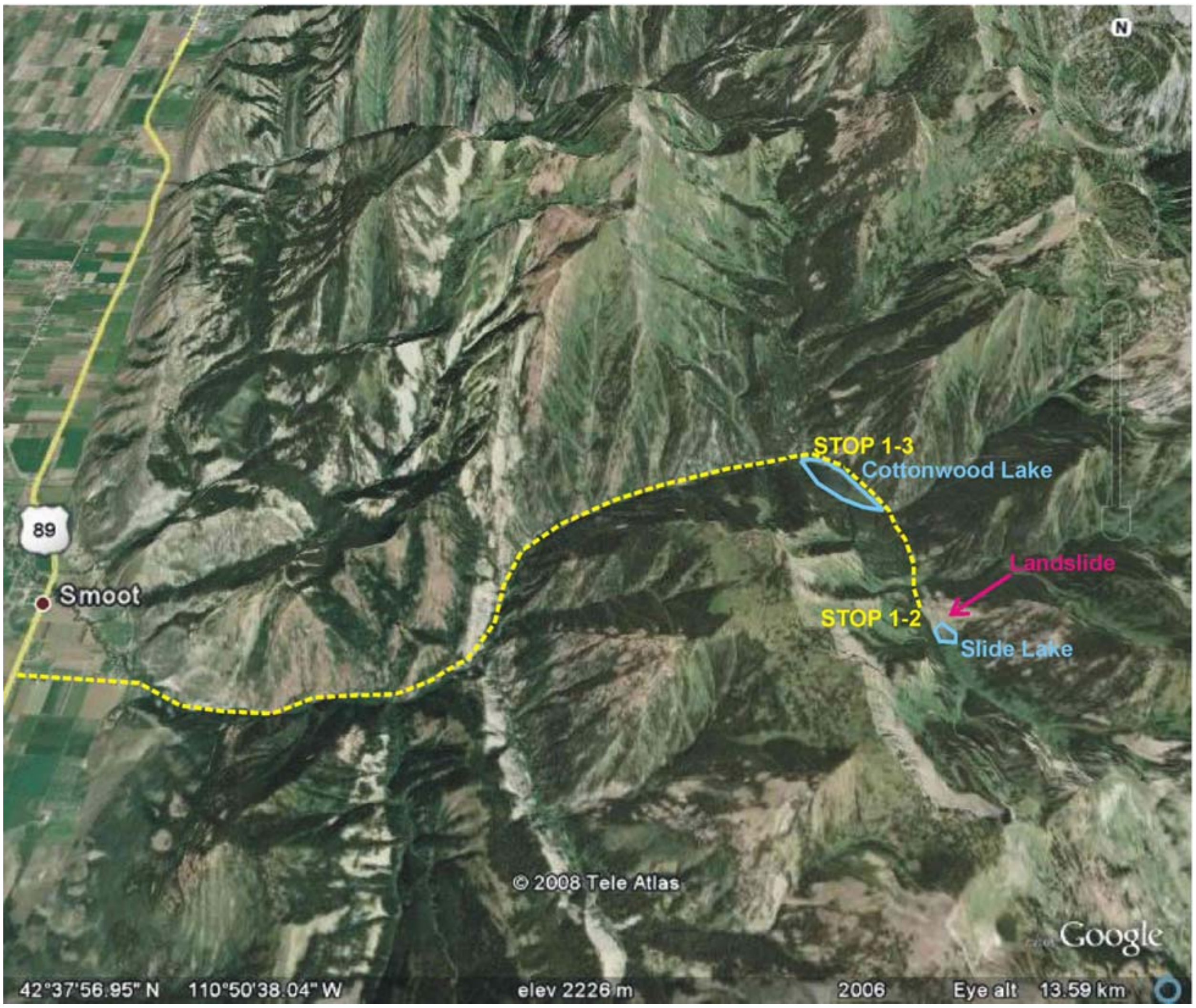


Fig. 12. Oblique satellite image of the trip route (yellow dashed line) up Cottonwood Creek, to STOPS at Slide Lake and Cottonwood Lake. North is at the top.

The landslide that formed Slide Lake initiated on a 35° dipslope of Nuggett Sandstone (Jurassic-Triassic), which makes up the east limb of a major syncline. The axis of the syncline is in the valley, so the beds dip steeply out of the east valley wall (they "daylight" on the slope). The weak formation that underlies the Nugget, the Ankareh

Shale (Triassic) is not shown as involved in the landslide, according to the 1:62,500 map of Rubey (1973), but that may be the result of the map's small scale.

Fig. 13. Photo of the rockslide that dammed Slide Lake. The slide is composed solely of Nugget Sandstone.

The lake shows no signs of ever having overtopped the landslide dam; that is, no channels are visible. Instead, the lake water evidently flows through the permeable sandstone rubble of the landslide mass, and emerges at the toe of the landslide to form a sizable stream. This same phenomenon occurs at Lake Alice, but there the landslide dam is 1.6 km wide, so the water flows underground for that entire length!

Q: was this slope oversteepened, perhaps by glacial erosion?
Mt. Wagner is one of the highest peaks in the Salt River range, and lies just S of this drainage.
Where are the glacial limits here???

Return on same trail to Slide Lake Trailhead. Drive back (N) to Cottonwood Lake Campground. At T intersection, continue straight and drive to the end of this campground loop.

The relationship between Landsliding and Geology (J.B. Rice)

For the purpose of evaluating the relationship between landsliding and geology in the Salt River Range, it is useful to subdivide the area into the three major lithologic age groups present, which include the Cretaceous section, the Triassic-Jurassic section, and the Paleozoic section. The Cretaceous section contains only slump-earthflow type slides, because the Cretaceous lithologies in the area are almost exclusively composed of fine-grained shales and siltstone which weather to produce relatively low permeability soils. Landslide mapping indicates that all four Cretaceous Formations in the area are highly susceptible to landsliding. Thick unconsolidated surficial deposits of till and fanglomerate, which overlie the Cretaceous section particularly in the northern part of the area, also tend to frequently fails, again as slump-earthflows and earthflow slides. Only about 10-15% of this northern portion of the Cretaceous section is stable, non-landslide terrain.

Styles of movement are similar in the Paleozoic and Triassic-Jurassic sections, because the characteristics and sequences of lithologies which make up these sections are similar, i.e. massive and/or coarse-grained resistant units alternating with finer-grained, thinner-bedded, less resistant units. Some of the resistant units occasionally fail as massive rockslides, though the most common type of mass movement over these units is debris sliding and the resulting debris flows. Landslide terrain in the Paleozoic section is most extensive in the northern portion of the area, where the shales of the Gros Ventre Formation, which are not exposed in the central and southern portions of the area, produce large numbers of slides. The Darby and Amsden Formations, which contain siltstones, also produce relatively high densities of landslides in the Paleozoic section, with the Amsden in particular producing a large number of debris flows. In the Triassic-Jurassic section, again we see the most extensive landslide terrain in the outcrop area of the finer-grained units, including the Stump Sandstone, the Preuss Redbeds, and the Ankareh Formation. In both the Triassic-Jurassic and the Paleozoic sections, the more massive, resistant lithologies tend to produce some of the more spectacular rockslides. Large rockslides, though not as common in the area as other slide types, were identified in the Nugget Sandstone and Thaynes Formations in the Triassic-Jurassic, and in the Madison Limestone, Gallatin and Gros Ventre Formations in the Paleozoic section. Glacial oversteepening of slopes appears to be a frequent cause of rockslides, though at least one large rockslide that occurs on the western range front of the Salt River Range appears to have been caused by seismic oversteepening.

Attempts to evaluate the temporal story associated with landsliding in the area, using aerial photo analyses of degree of morphological modification, and Relative Dating (RD) measurements in the field with subsequent statistical analyses, were somewhat inconclusive. In general, landslide mapping in the area suggests that slides have occurred throughout the late Pleistocene and Holocene, probably with some regularity, but probably with increased frequency during deglaciation in the late Pleistocene, and during extended wet periods and when triggered by earthquakes and rare severe storms throughout the Holocene.

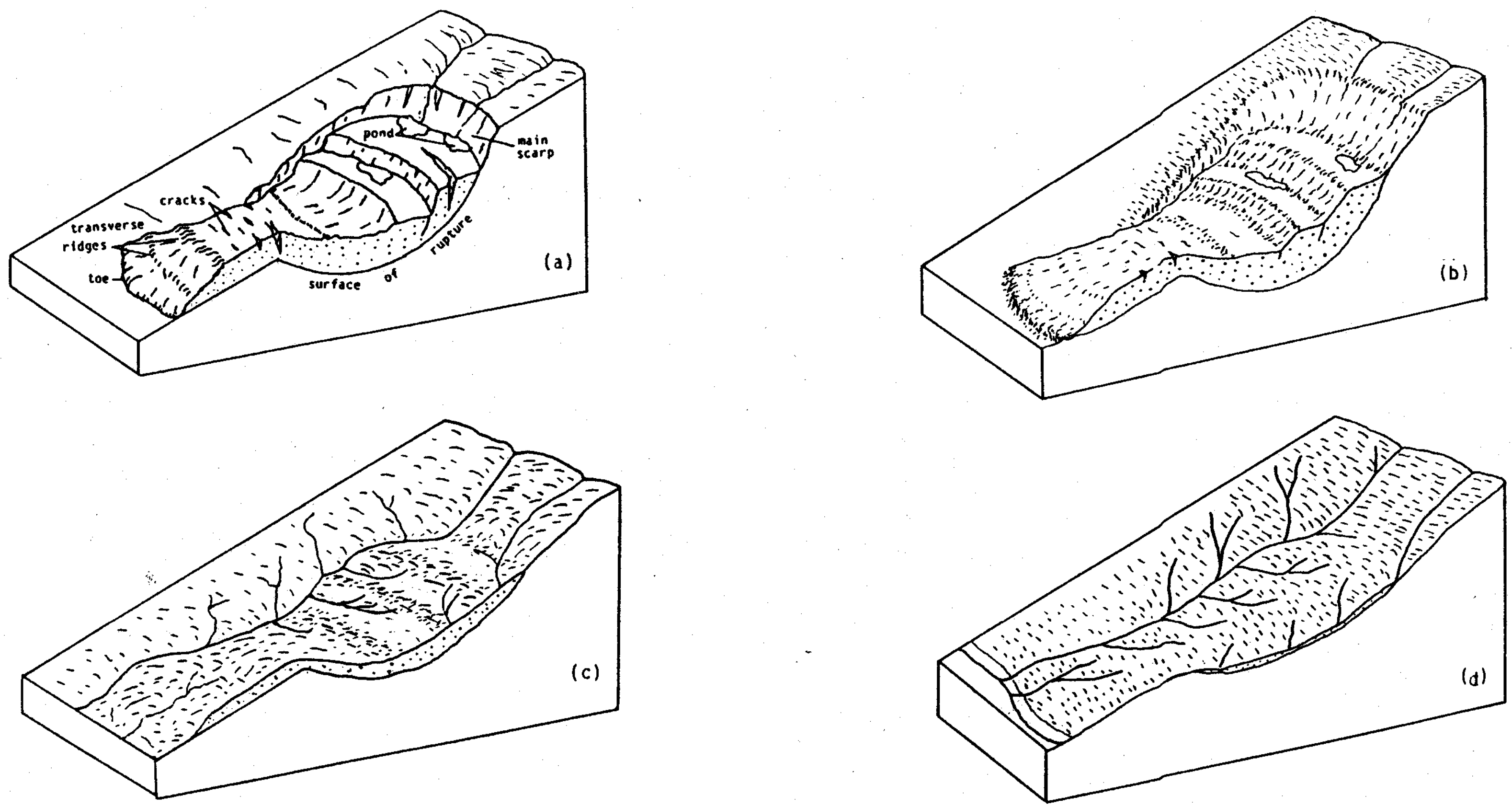


Figure 2.--Block diagrams of typical active, Age-Class 1 (a), inactive-young, Age-Class 2 (b), inactive-mature, Age-Class 3 (c), and inactive-old, Age-Class 4 (d), landslides showing how initial morphology becomes altered with time (from McCalpin, 1984).

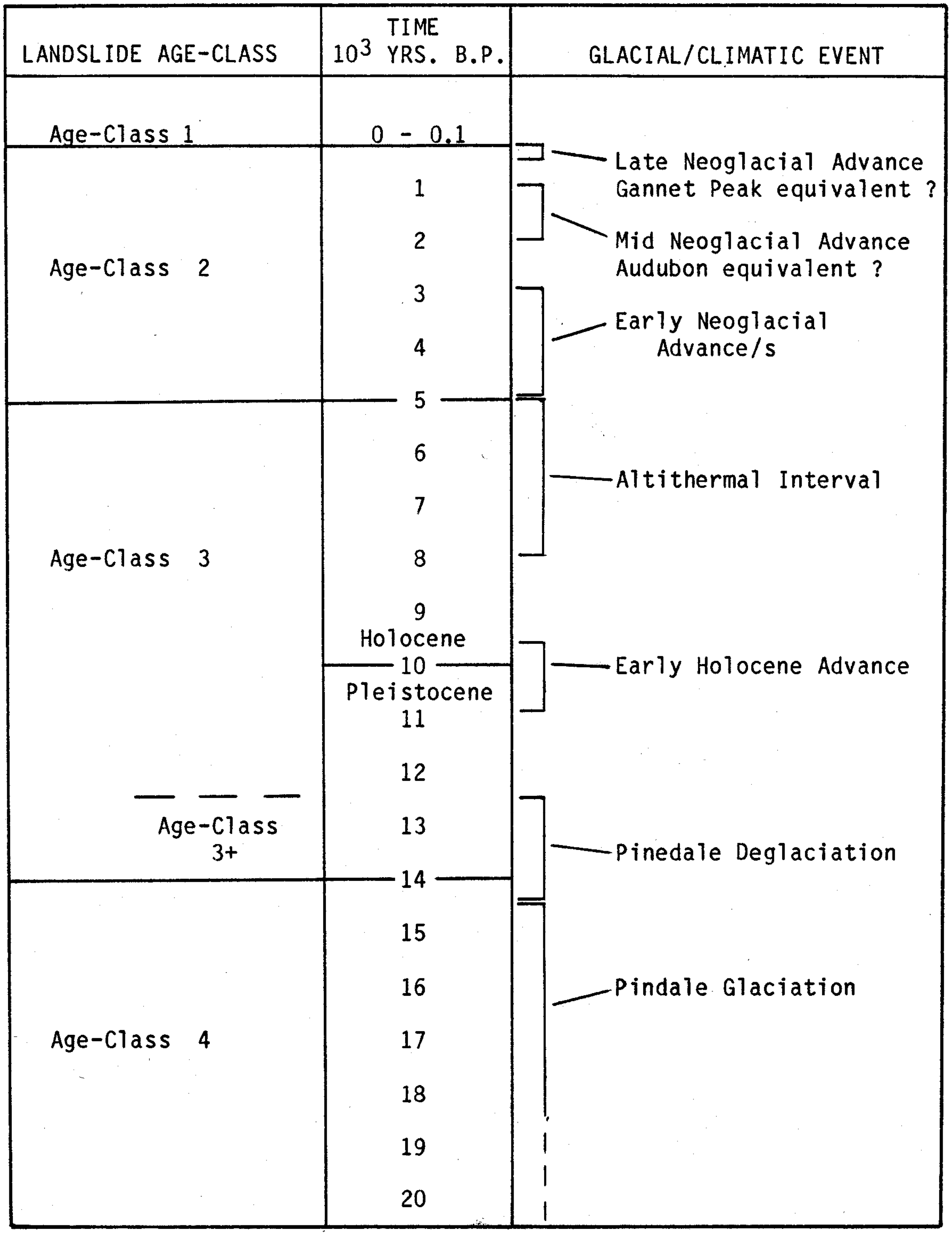


Figure 1.--Tentative late Pleistocene - Holocene glacial/climatic chronology for the Salt River Range, Wyoming. Chronology and absolute ages of glacial/climatic events from Miller and Birkeland (1974), Mahaney (1978), and Porter and others (1983).

Table 7.--Landslide inventories from areas used for spatial analyses

Paleozoic Section:

Landslide Type	Landslide Age 1	1+2	2	2+3	3	3+	4	Total	% of Age-Class 1 and 2 slides
Rockslide	3	-	9	-	14	3	3	32	10
Slump-earth flow	7	-	30	-	52	1	28	117	31
Debris flow	17	26	26	3	1	-	-	73	59
Total	27	26	65	3	67	3	31	222	100
% in 4 Age-Classes	18	-	36	-	32	-	14	-	100

Triassic-Jurassic Section:

Landslide Type	Landslide Age 1	1+2	2	2+3	3	3+	4	Total	% of Age-Class 1 and 2 slides
Rockslide	1	-	8	-	16	3	7	25	8
Slump-earth flow	12	-	37	2	89	2	40	182	44
Debris flow	8	11	33	3	13	-	-	68	48
Total	21	11	78	5	108	5	47	275	100
% in 4 Age Classes	10	-	31	-	42	-	17	-	100

Cretaceous Section:

Landslide Type	Landslide Age 1	1+2	2	2+3	3	3+4	4	Total	% of Age Class 1 and 2 slides
Slump-earth flow	16	-	82	36	83	3	10	230	91
Earth flow	1	-	10	-	2	-	-	13	9
Total	17	-	92	36	85	3	10	243	100
% in 4 Age Classes	7	-	45	-	44	-	4	-	100

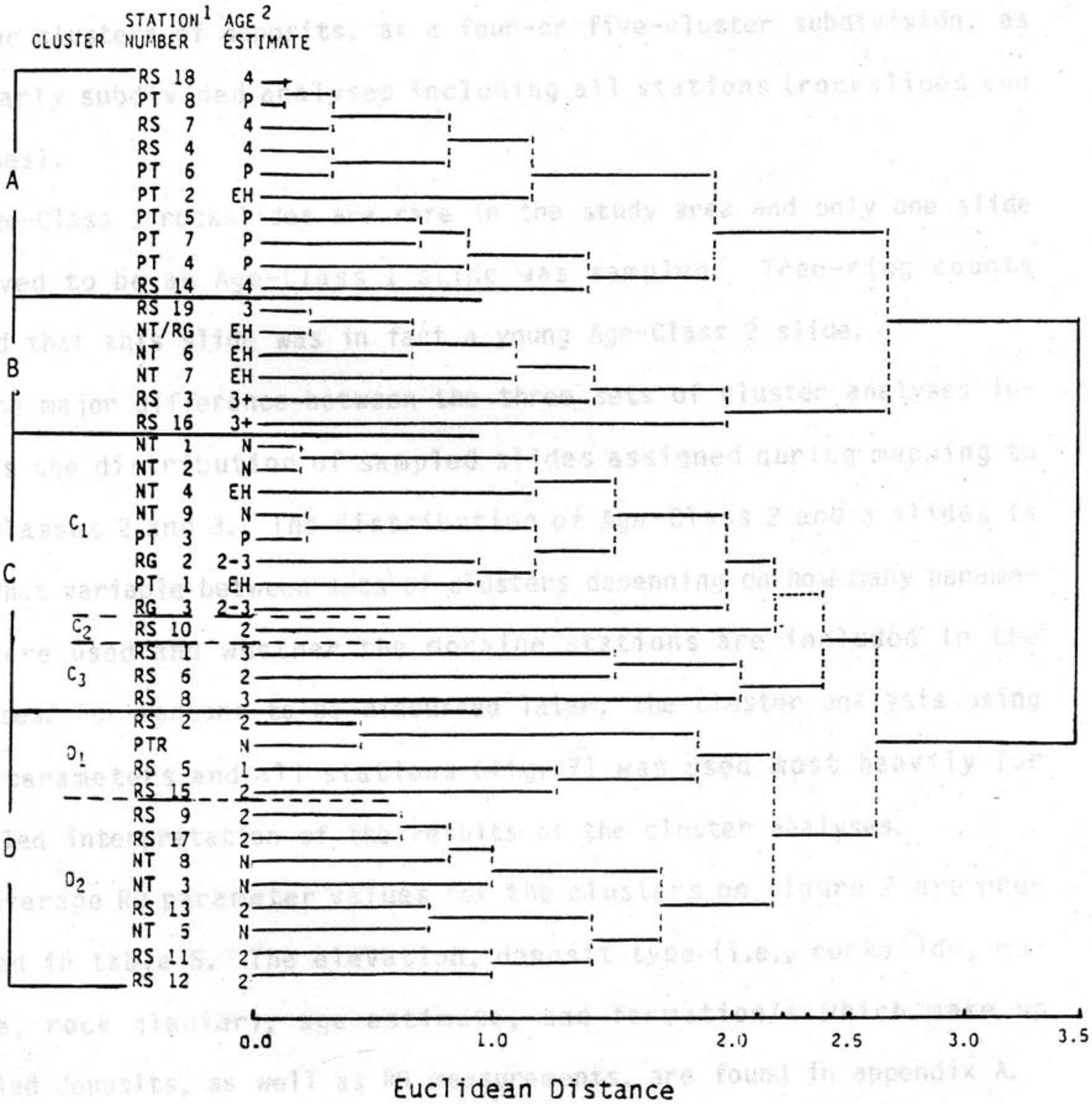


Figure 7.--Dendrogram of cluster analysis using all stations and five RD parameters. RD parameters-boulder pit depth, surface boulder frequency, ridge crest width, outer slope angle, soil profile development. Cophenetic Correlation Coefficient = 0.6237. [1]Station symbols: RS-rockslide; NT, PT-moraine; RG-rock glacier; PTR-protalus rampart. [2]Age symbols: 1,2,2-3,3,3+,4-landslide age classes; N-Neoglacial; EH-early Holocene; P-Pinedale.

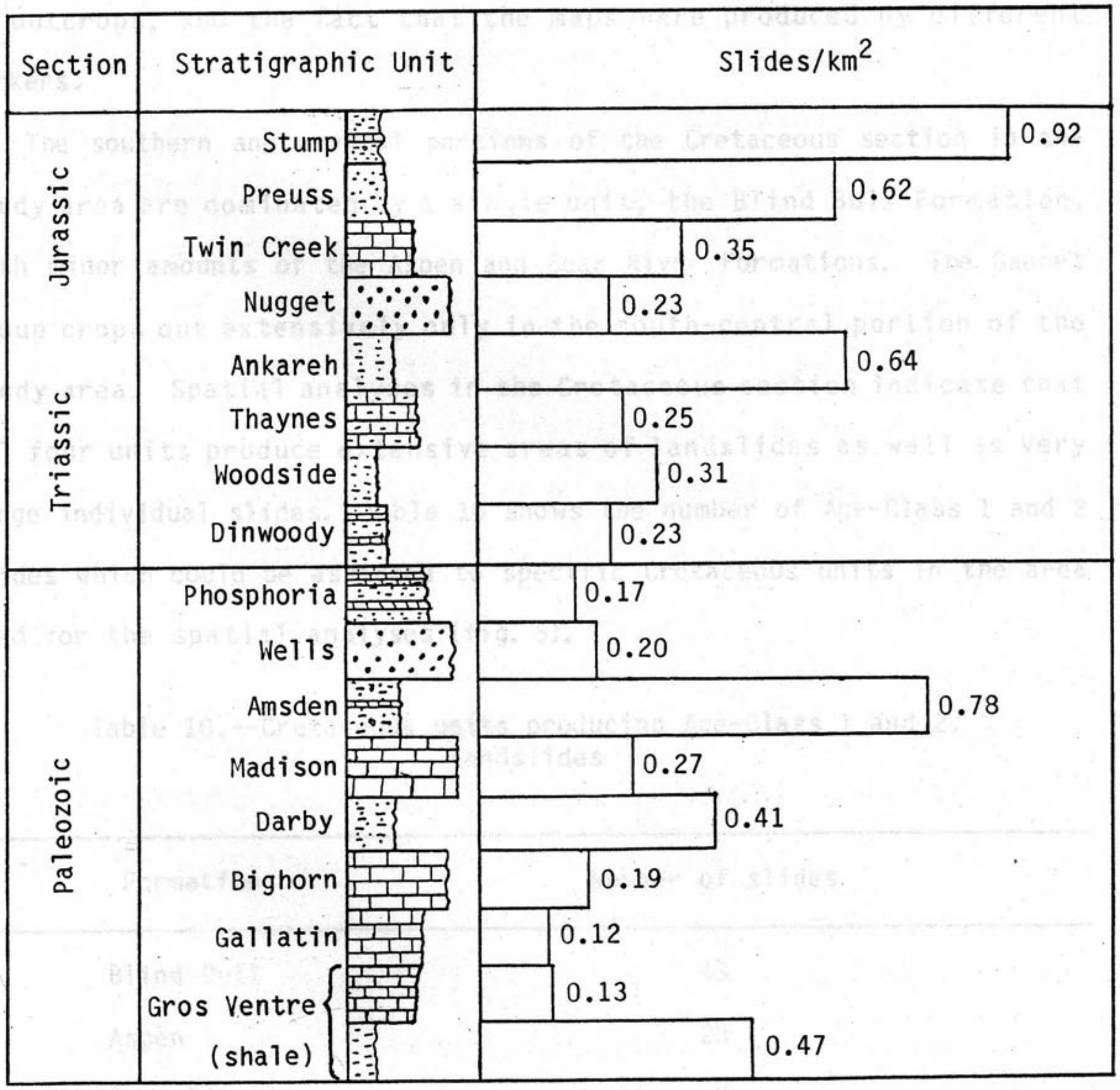


Figure 8.--Landslide densities (numbers of Age-Class 1 and 2 slides/km2) in Paleozoic and Triassic- Jurassic section stratigraphic units.

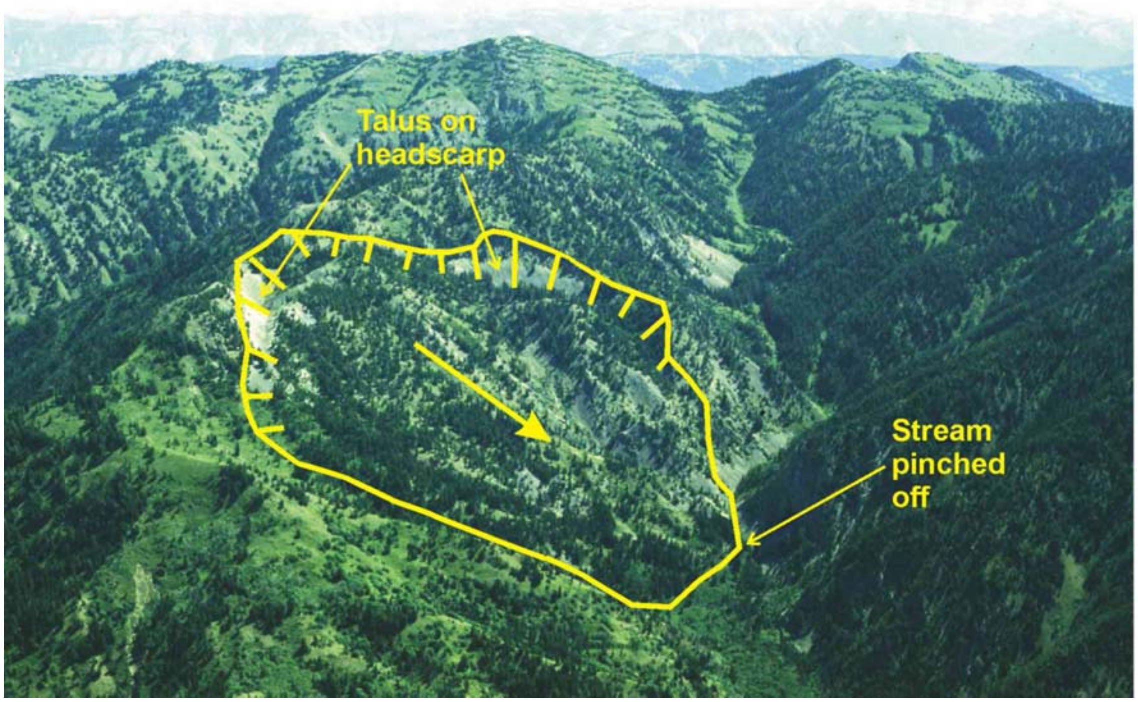


Fig. 14. Translational bedrock slide in an unglaciated drainage of the Salt River Range, Paleozoic section. Intermediate morphologic age, because: (1) gullies have developed on slide body and along margins, (2) headscarp vegetated or covered with talus, and (3) stream has cut through toe.

[Slide Lake is similar to, but smaller, than Lake Alice, Wyoming, which is the largest natural lake in the Bridger-Teton National Forest. (see http://en.wikipedia.org/wiki/Lake_Alice_(Wyoming)). Despite Lake Alice's large size, few people know of its existence, and the age of the landslide that formed it is unknown; it has never been studied by a Quaternary geologist.]

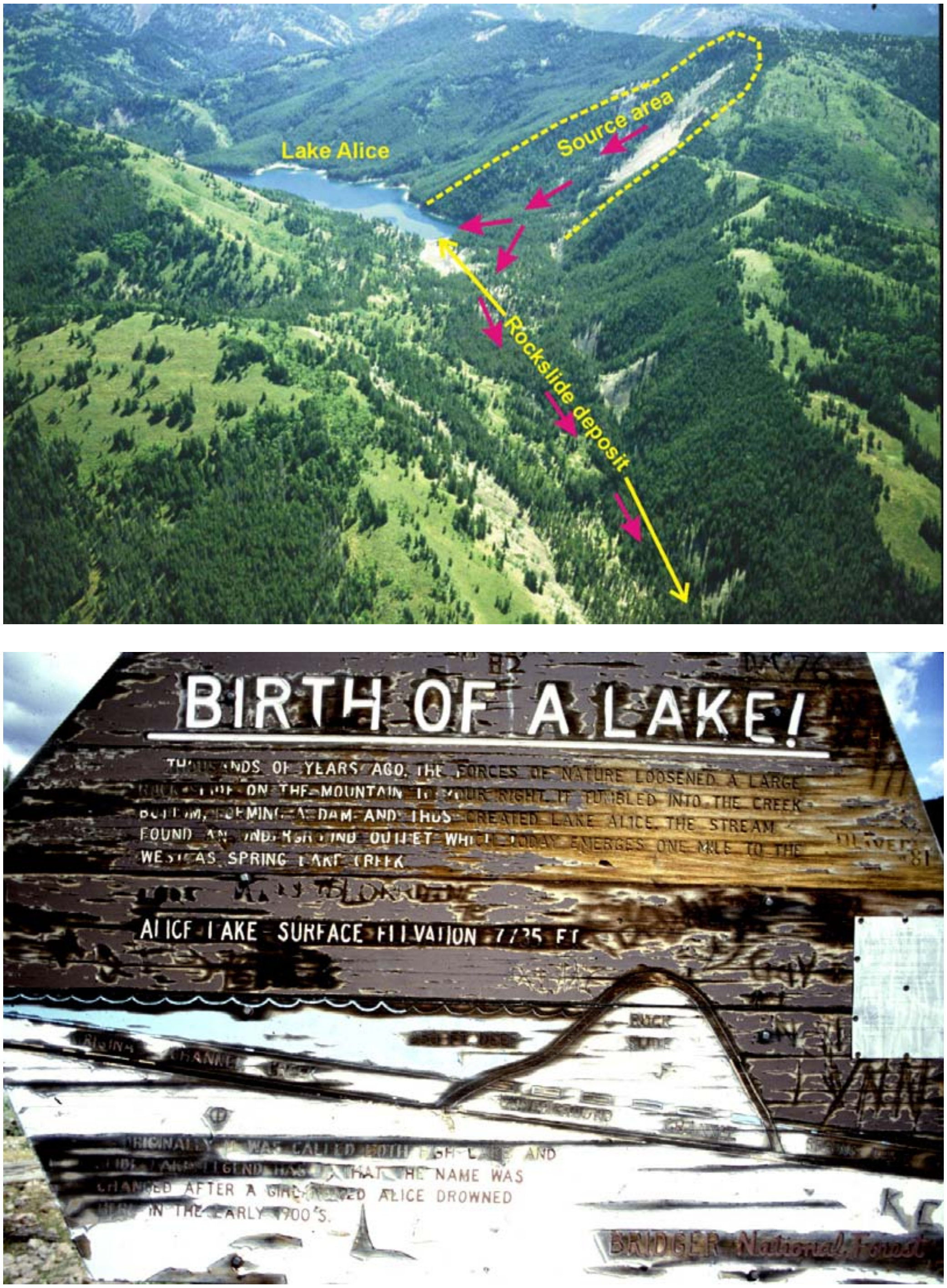


Fig. 15. Lake Alice, WY (top) and the USFS interpretive sign there (bottom).

Mi 20.0: STOP 1-3; Mysterious diamicton (Qda) that dams Cottonwood Lake (Greg Warren)

Cottonwood Lake is dammed by a valley-bottom debris avalanche. These valley-bottom deposits of debris avalanche strongly resemble ground moraine; and in some places appear to be intermixed with glacial till. The deposits in Cottonwood Creek valley are hummocky, bouldery, well-vegetated, and consist mainly of angular clasts of Thaynes Limestone. The source areas of the debris avalanches are obscure, but appear to have originated as slumps or dip-slope block slides that mobilized into debris avalanches. These debris avalanche deposits extend 2 km beyond the inferred lower limits of Pinedale glaciation. Less-weathered, more bouldery areas within the debris avalanche deposits indicate that likely there are several generations of mass movements. Relative-age assignments based on RD data suggest that the debris avalanche deposits are mostly late Pleistocene in age; but some are Holocene in age.

Fig. 16. Photo of the Qd deposit that dams Cottonwood Lake (STOP 1-3).

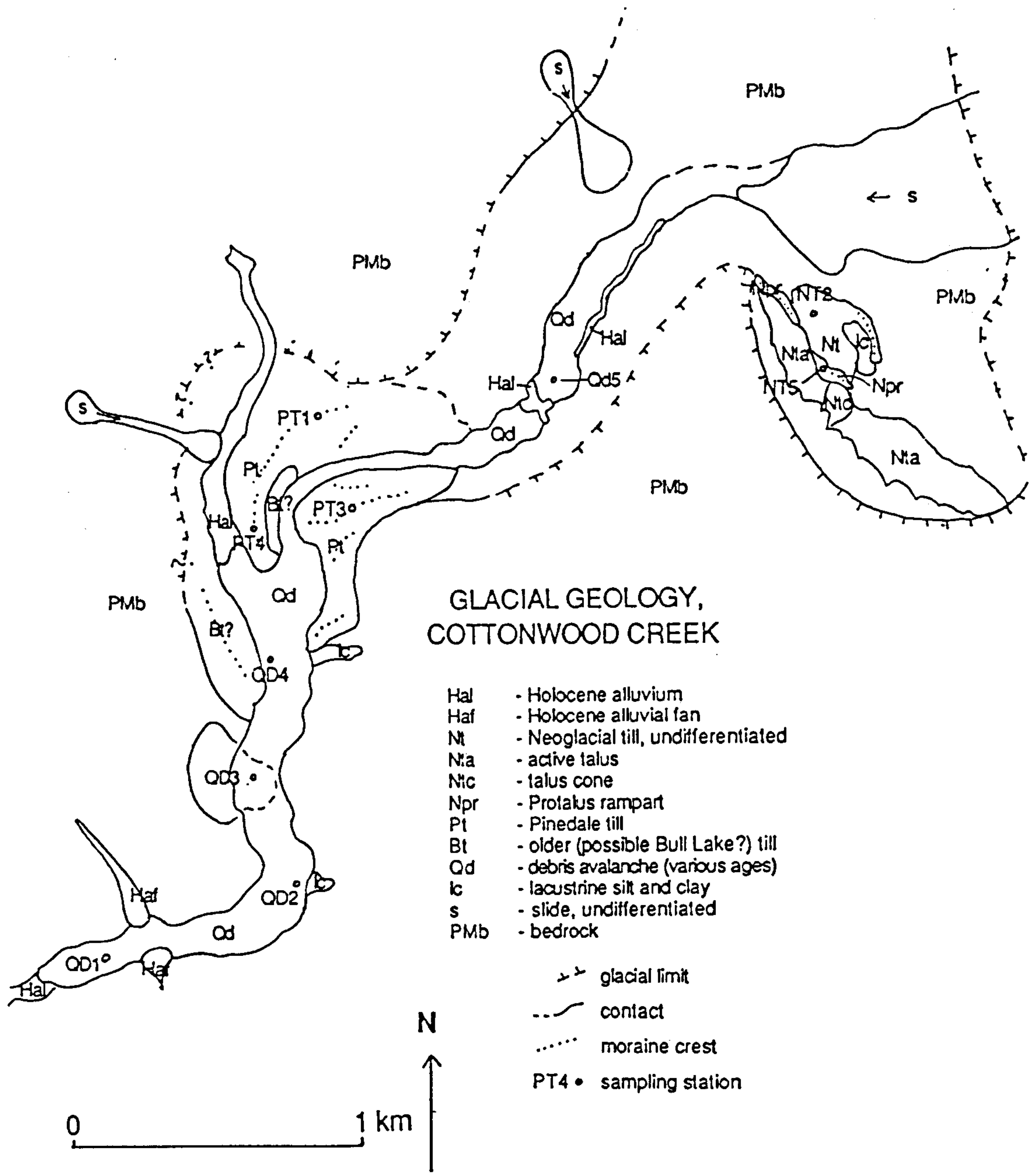


Fig. 17. Quaternary geologic map of the glaciated part of Cottonwood Creek, Salt River Range. From Warren, 1992. Our STOP 1-3 is near RD sampling station QD2.

RD station[1]	Deposit	Elev. (m)	Lith.[2]	SBF[3] (#)	BBF[3] (%)	SPD[3] (#)	MOA[3] (deg)	MIA[3] (deg)	RCW[3] (m)	ART[3] (mm)
NT1	Nt3	2768	ss	63	15	5	30	32	2.0	1.5
NT2	Nt2	2716	ls	30	20	10	22	26	4.0	-
NT3	Nt1-2?	2755	ls	215	27	10	25	21	2.5	-
NT4	Nt1-2	2745	ls	245	26	10	29	30	4.0	-
NT5	Nt1?	2835	ls	126	12	5	35	26	3.0	-
NT6	Nt3	2804	ss	24	30	10	32	28	3.0	1.3
NT7	Nt4	2804	ss	182	16	5	21	22	1.5	0.8
NT8	Nt1-2	2804	ss	50	45	10	32	31	2.5	1.0
NT9	Nt1-2	2792	ss	32	48	10	27	23	3.5	1.6
EH1	EHt	2743	ls	16	49	10	5	27	3.5	-
EH2	EHt	2768	ls	26	56	10	32	17	10.0	-
PT1	Pt	2475	ls	33	53	20	21	27	9.0	4.6
PT2	Pt	2509	ss	36	59	20	21	34	4.0	4.0
PT3	Pt	2597	ls	17	55	20	21	30	7.0	-
PT4	Pt	2462	ls	12	84	20	24	32	7.0	-
PT5	Pt	2377	ss	27	68	20	34	24	3.5	4.0
PT6	Pt	2633	ss	25	53	20	27	36	4.5	3.9
PT7	Pt	2462	ls	21	54	20	27	23	2.0	-
PT8	Pt	2512	ss	21	66	20	31	32	2.5	2.5
QD1	Qd	2219	ls	28	59	20	20	25	11.0	3.6
QD2	Qd	2286	ls/ss	30	54	15	29	34	4.0	-
QD3	Qd	2310	ls	75	10	10	30	36	1.5	-
QD4	Qd	2341	ls	28	78	15	19	27	7.0	4.6
QD5	Qd	2524	ls	49	54	10	26	29	5.5	-
QD6	Qd	2560	ss	25	54	20	13	30	5.0	3.5

1 The first two letters indicate inferred age of deposit (NT = Neoglacial, EH = early Holocene/latest Pleistocene, PT = late Pinedale, QD = late Pleistocene (?) non-glacial deposits). Numbers refer to station numbers on Figs. 1.5 and 1.6.

2 ss = quartzarenite sandstone
ls = thin-bedded, sandy, limestone

3 See text for abbreviations and definitions of RD parameters

Fig. 18. RD data from alpine Quaternary deposits of the western side of the Salt River Range. From Warren, 1992.

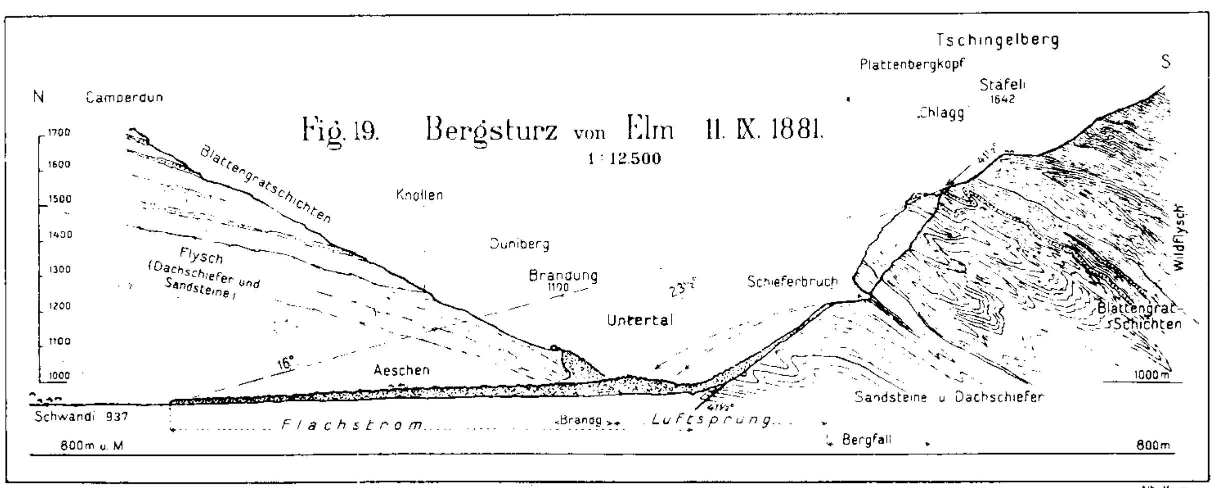


Fig. 4. A sketch of the geometry of the Elm sturzstrom (reproduced from Heim, 1932).

Fig. 19. The Elm rockfall avalanche of 1881. From Hsu, 1978.

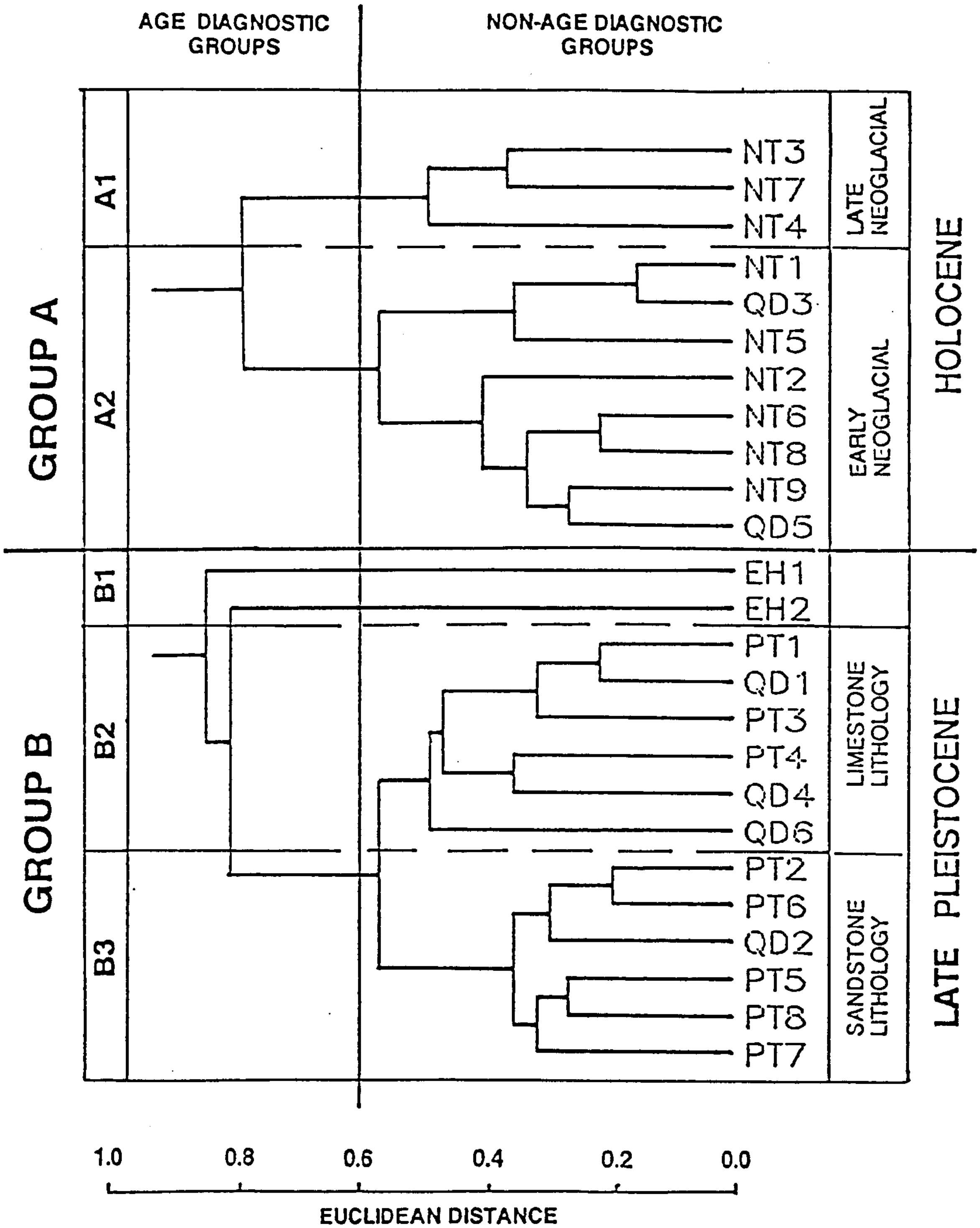


Fig. 20. Cluster analysis of 5-parameter RD data from alpine Quaternary deposits of the western side of the Salt River Range. NT, Neoglacial till; QD, debris avalanche; EH, early Holocene till; PT, Pinedale till. From Warren, 1992.

m. The main surge, however, was deflected 60° toward the northwest and went down the Sernf Valley. The tip of the sturzstrom moved another 1.5 km along the nearly horizontal valley floor (Fig. 1). Its motion was colorfully described by a survivor, Kaspar Zentner, who was only one jump ahead of the speeding debris (Heim, 1882, pp. 94—95):

> "The debris mass did not jump, did not skip, and it did not fly in the air, but was pushed rapidly along the bottom like a torrential flood. The flow was a little higher at the front than in the rear, having a round and bulgy head, and the mass moved in a wave motion. All the debris within the stream rolled confusedly as if it was boiling, and the whole mass reminded me of boiling corn stew. The smoke and rumble was terrifying. I now ran breathlessly over the bridge and bent around the corner of Rudolf Rhyner's house (leaning house, Fig. 2). Then I turned back and held myself firmly against the house. Just as I went past the corner the whole mass shot right past me at a distance less than 1 metre away. The debris flow must have been at least 4 metres high. A single step had saved me. During the last jump I noticed that small stones were whirling around my legs like leaves in the wind. The house crunched, moved and seemed to be breaking apart. I fled on hands and knees through the garden until I got to the street. I was then safe. I had no pain anywhere and no stones had hit me. I did not feel any particular air pressure. I went back to my home at Müsli down the street and found it in ruins, some 80 steps from its original position. Later I retracted my steps from the spot where I first saw the rock begin to fall to the corner of Rudolf Rhyner's house, and found the distance measured 200 to 300 steps. The time of my running is estimated to be about 40 seconds."

During these 40 seconds the sturzstrom travelled about 2 km. Except for its tremendous speed, this description of the Elm sturzstrom, with phrases such as "round and bulgy head" and "wave motion" reminds me of the conventional characterization of mud flow movement (see Sharp and Noble, 1953; Johnson, 1970; Hampton, 1972). The sturzstrom was indeed likened to a "torrential flood" or a "boiling stew"; the interstitial "fluid" between the colliding blocks was not, however, a wet mud, but a dry dust!

There may be a general impression, perpetuated perhaps by Shreve's (1968a) hypothesis of air-layer lubrication, that the *surge* of the Elm sturzstrom was underlain by a layer of compressed air and that eyewitnesses could see people and houses under the *surge*. This misunderstanding can perhaps be traced to an insufficient distinction between Acts II and III of the Elm event. During the second act, the debris jumped off a platform like a ski jumper flying off his chute. Teacher Wyss and others who looked across the path of the jump indeed saw houses and trees, and fleeing cattle under the descending debris. On the other hand, during the third act the surge hugged the ground and plowed its way down the gentle incline of the valley bottom. A water-pipe, originally buried at 1 m depth, was plucked out by the surge and was later found more than 1 km downstream, among debris on a lateral ridge in the Sernf Valley. The surge also carved parallel furrows, genetically akin to groove casts found at the bottom of turbidite beds. Houses at the

From Hsu, 1978.

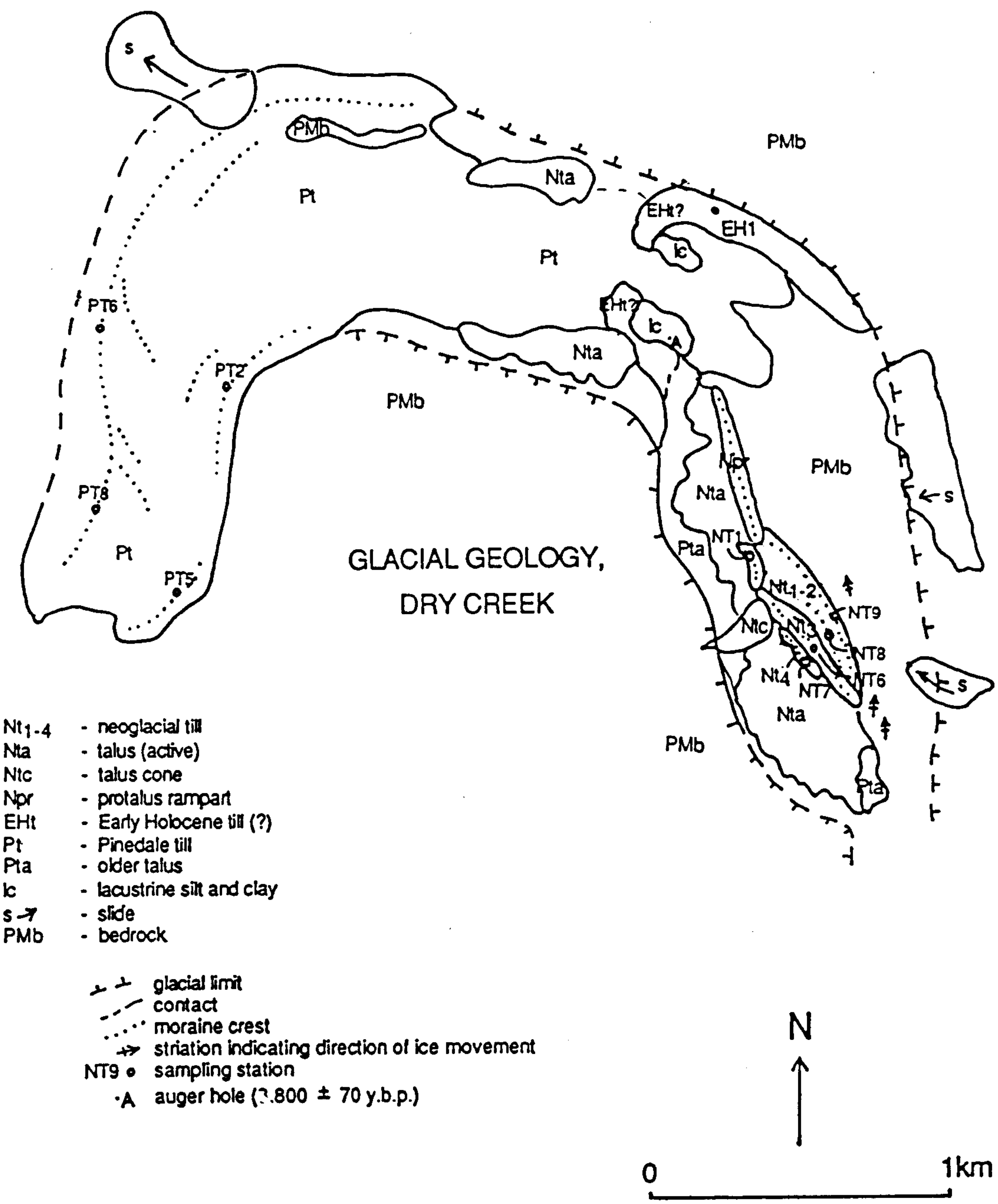


Fig. 21. Quaternary geologic map of the glaciated part of Dry Creek, Salt River Range. From Warren, 1992.

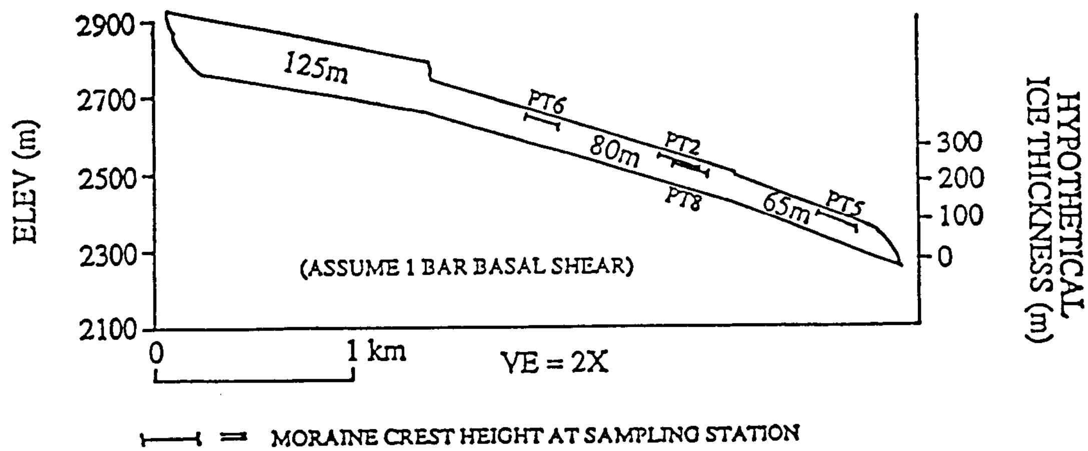


Fig. 22. Reconstructed ice thicknesses for the Pinedale Dry Creek paleoglacier (Warren, 1992).

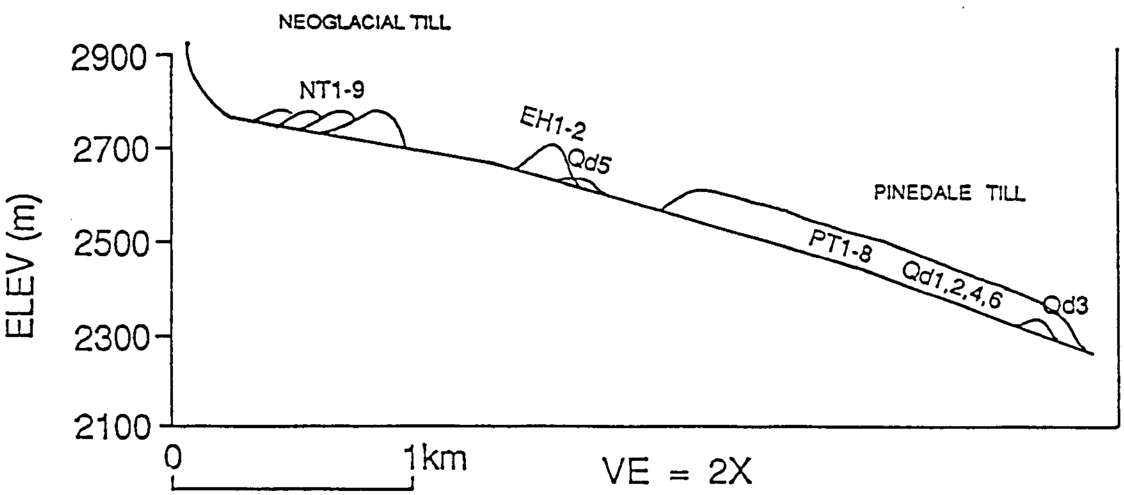


Fig. 23. Schematic relative positions of glacial deposits on the west side of the Salt River Range.

Retrace route back to US Highway 89

Mi 26.2: turn right (N) onto US 89 and continue to Afton, WY. We are now driving through “Upper Star Valley.”

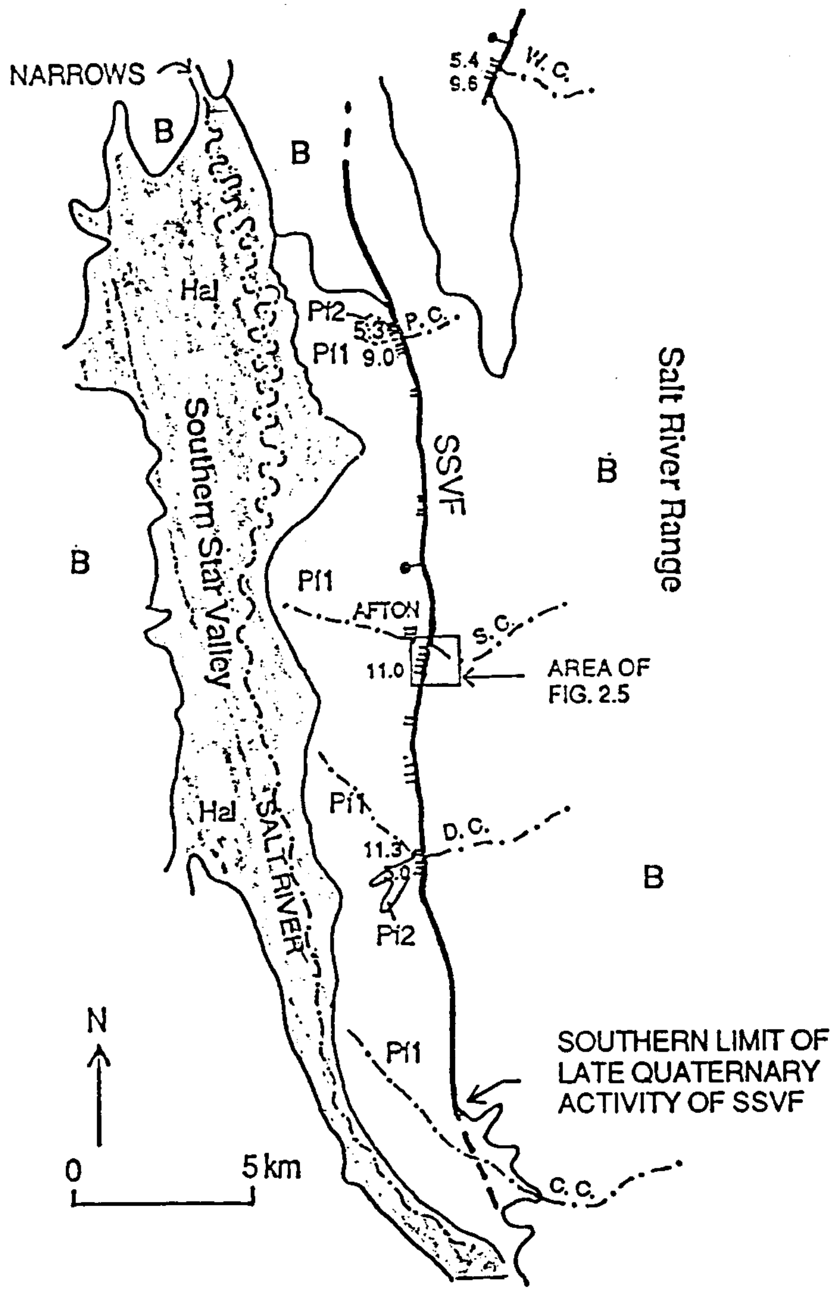
AFTON, WYOMING

Afton boasts the “World’s Largest Elk Antler Arch” which spans Main Street and contains over 3,000 antlers. The Periodic Spring just outside of town is North America’s only cold water geyser and the largest of three fluctuation springs in the world. Fall is the best time to view the spring’s activity, which turns on and shuts off every 12-20 minutes.

Mi. 34.2: Once in downtown Afton, turn right (E) on 4th Avenue and drive 2 blocks. Park on the left (N) side of the street between Jefferson and Madison Streets, or turn left on Jefferson Street and park on the street.. From here, we will walk 2 more blocks E on 4th Avenue to the fault scarp of the Star Valley fault.

STOP 1-4. Scarp of the Star Valley fault (Greg Warren); displaces the Pinedale alluvial fan of Swift Creek, on the eastern margin of Afton.

Fig. 24. Oblique satellite image of the range front of the Salt River Range at Afton; view is to the east. Note the good development of faceted spurs. However, the geometry of faceted spurs is often influenced more by the structure of the range-front rocks, than by the uplift rate on the normal fault (see Zuchiewicz and McCalpin, 1992, 2000). The best-developed facets on normal faults are developed on horizontal to subhorizontal sedimentary rocks, such as those here and at the classic locality of Spanish Fork, UT on the Wasatch fault zone.



Hal - Holocene alluvium of Salt River
Pf1 - Late Pleistocene Pinedale outwash fan
Pf2 - Late Pleistocene/early Holocene (?) alluvium
B - Paleozoic and Mesozoic bedrock

SSVF - southern Star Valley fault

Fig. 25. Map of the southern Star Valley fault, showing scarp vertical surface offsets (m); Warren, 1992.

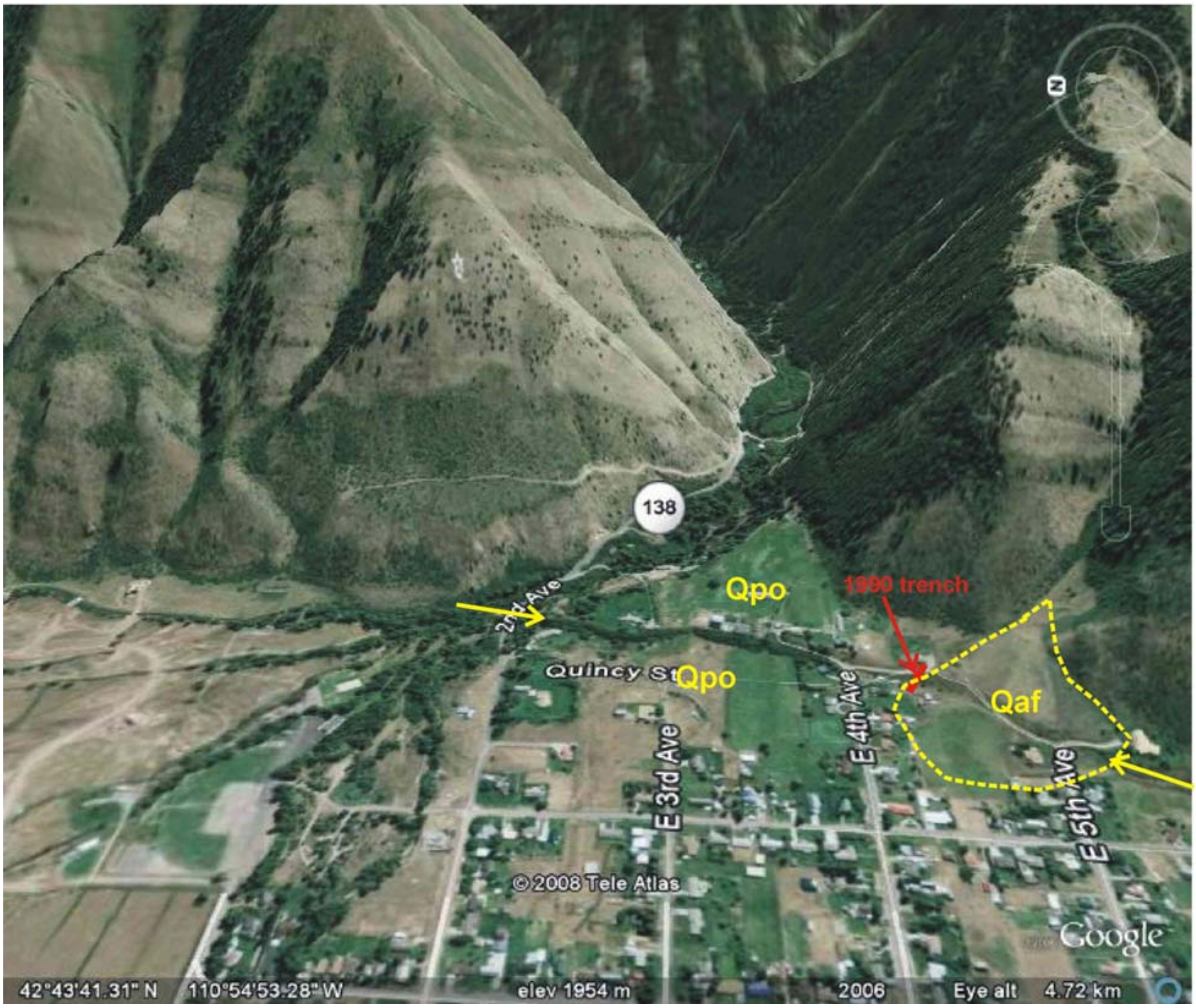


Fig. 26. Oblique airphoto view of the fault scarp (between yellow arrows) of the Star Valley fault on the eastern margins of Afton, WY; view to the East. We will stop at the site of the 1990 trench (red) of Warren (1992), which lies at the boundary between the Pinedale outwash fan of Swift Creek (Qpo) and a small tributary alluvial fan (Qaf).

Stop 1-4: Scarp of the Star Valley Fault – Afton Trench

We excavated a backhoe trench across the fault scarp at Swift Creek to evaluate the number, magnitude, and timing of the paleoearthquakes that formed the scarp. The surficial geology of the trench site is dominated by the Pinedale alluvial fan surface. An alluvial fan from a small tributary is graded onto the Swift Creek fan and has been displaced where it crosses the Star Valley Fault. The trench was dug on the extreme distal portion of the tributary alluvial fan; and therefore the trench stratigraphy included the Pinedale alluvial fan as well as the toe of the tributary alluvial fan. The age of the Pinedale fan surface was estimated to be ca 10-15 ka in age by Piety and others (1986) based on correlations of soil development indices.

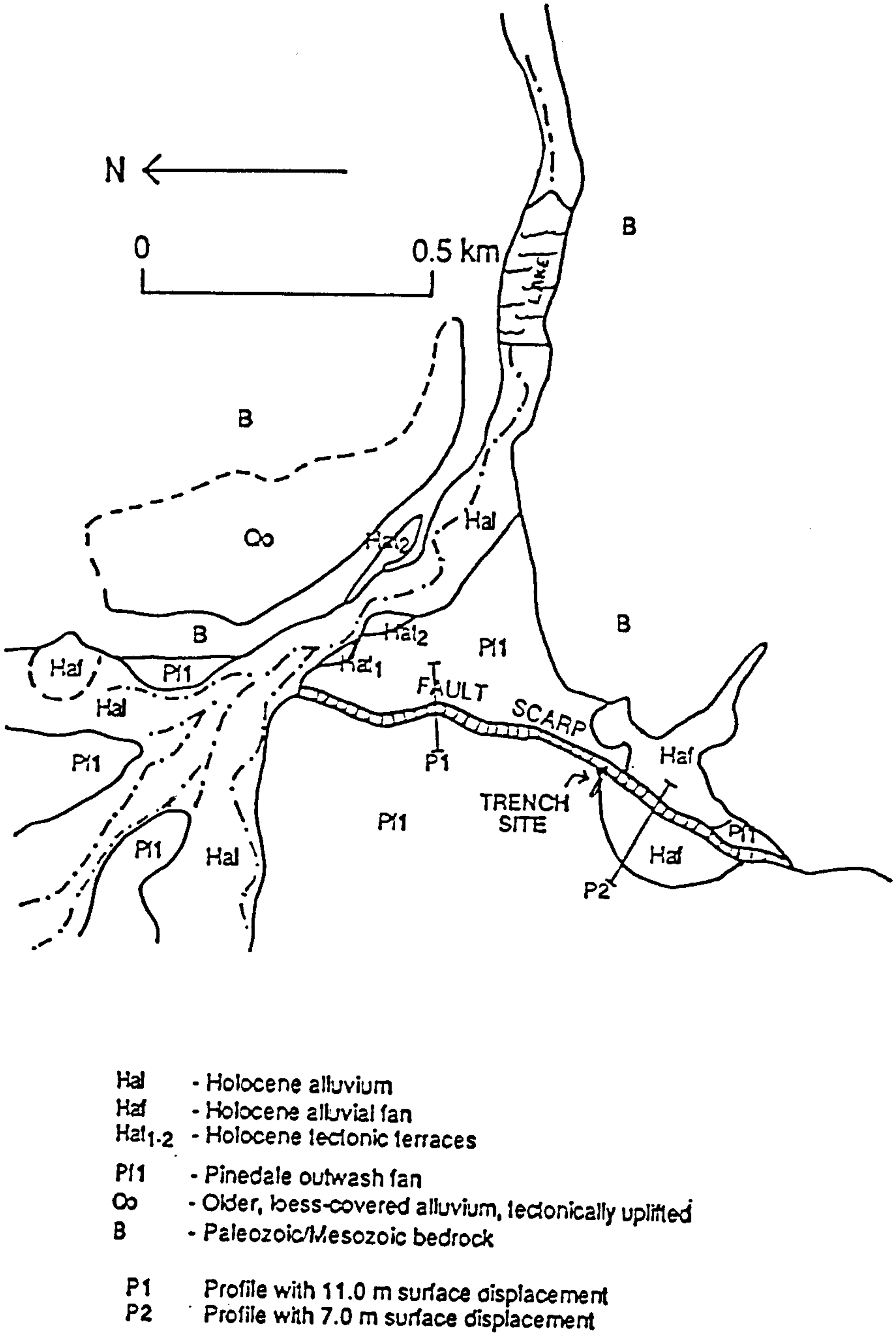


Fig. 27. Quaternary geology of the head of the Swift Creek alluvial fan and fault scarp. Scarp is 11 m high across Pf1 and about 7 m high across Haf.

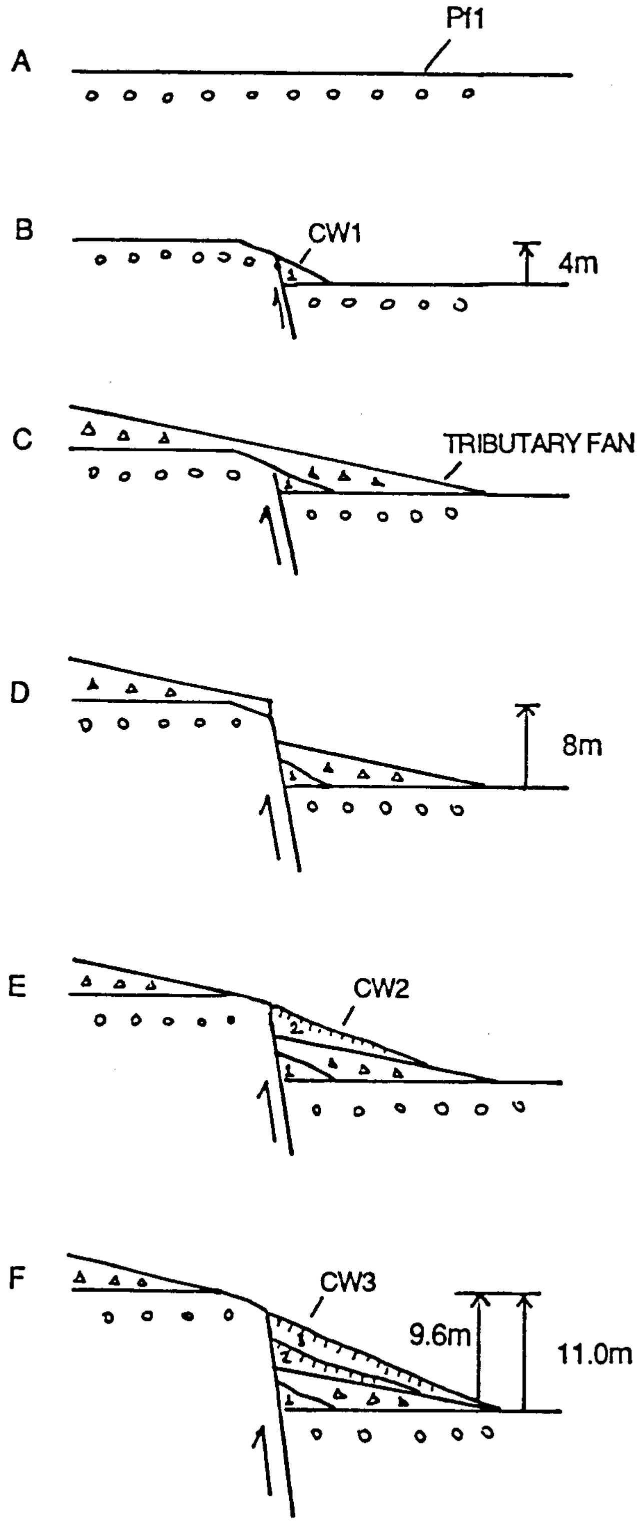


Fig. 28. Predicted geometry of Quaternary deposits across the Afton fault scarp, based on geologic mapping prior to trenching. This diagram was made to help Warren tell the backhoe when to stop digging.

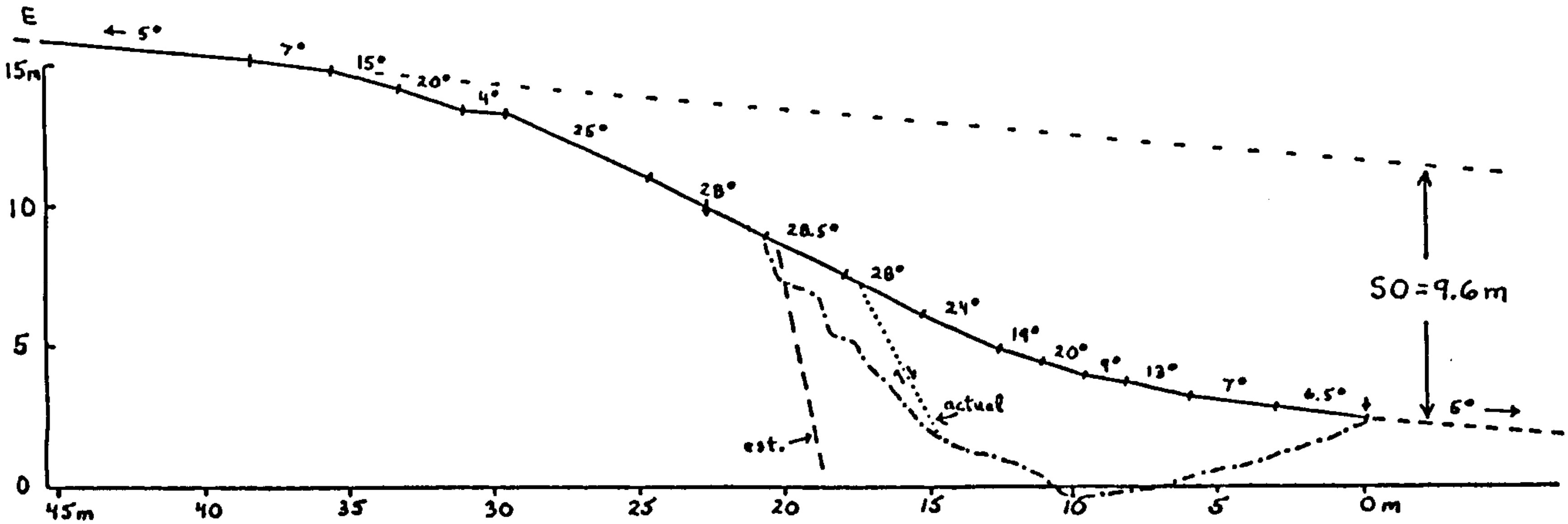


Fig. 29. Topographic scarp profile at the Afton trench site, made prior to trenching. The purpose was to guess where the fault plane lay beneath the scarp, so we could know how far up the scarp to begin the trench. We could not trench the entire scarp profile because a different landowner owned the upper scarp face. The assumption was that the fault plane ("est.") would lie beneath the center of the steepest profile segment (28.5°). However, the fault actually lay downslope from that position ("actual"). The floor of the trench dug later is shown by the dash-and-dot line. Surface offset (aka, vertical surface offset, or vertical separation) is the vertical distance between the projection of the upthrown faulted surface and the downthrown surface. This measurement is a proxy for dip slip on the fault, but only if the TWO SURFACES ARE IN FACT COEVAL. Commonly, the lower surface is a younger deposit, so the surface offset is only a minimum proxy for fault displacement since the deposition of the upper surface.

The stratigraphy of the trench is dominated by stream gravels of Swift Creek, distal alluvial fan deposits, and scarp-derived colluvium. The units are shown on the Trench Log. The major stratigraphic units include pre-faulting alluvium of Swift Creek, colluvium from earliest event, alluvial fan of small tributary, fault zone material, colluvium from penultimate event, locally derived debris flow, and colluvium from latest event.

The structure exposed in the trench was dominated by the major fault strand on which almost all of the stratigraphic displacement occurred, with a small synthetic fault about 1.5 meters west of the main fault strand. A wedge-shaped tension fissure containing vertically-oriented rocks is adjacent to the main fault plane. Sheared gravels and the unusually steep top of the Unit 2 colluvium suggest hanging-wall drag during the latest faulting event. A graben-like tension crack was also mapped approximately 7 meters west of the main fault plane, which suggests extension away from the main fault plane.

Stratigraphic evidence from the trench confirmed that three (3) discrete surface ruptures formed the scarp. The evidence suggests that the vertical offset on the three events from oldest to youngest were 4 meters, 4 meters, and 3 meters, respectively. Radiocarbon samples collected from the “A” Horizons of Units 3f and 5d were used to date the two most recent faulting events. A radiocarbon age of 8,090 $\pm$ 80 yrs BP post-dates the second event, and a radiocarbon age of 5,540 $\pm$ 70 yrs BP post-dates the third event. The earliest event was estimated to have occurred 12-15 ka, based on lack of soil development on the surface of the Swift Creek fan prior to initial faulting.

The late Quaternary slip rate of the Star Valley fault was determined by dividing the net slip of the fault of 11 meters in ca. 12-15 ka, which yields slip rates of between 0.73 and 0.91 mm/yr. These rates are consistent with slip rates of other active normal faults in the region. The moment magnitudes (M_w) of the paleoearthquakes generated by the Star Valley fault, based on displacement per event and rupture length regression equations, were estimated to be approximately 7.0 to 7.1 for the first two events, and 6.9 to 7.0 for the third (latest) event.

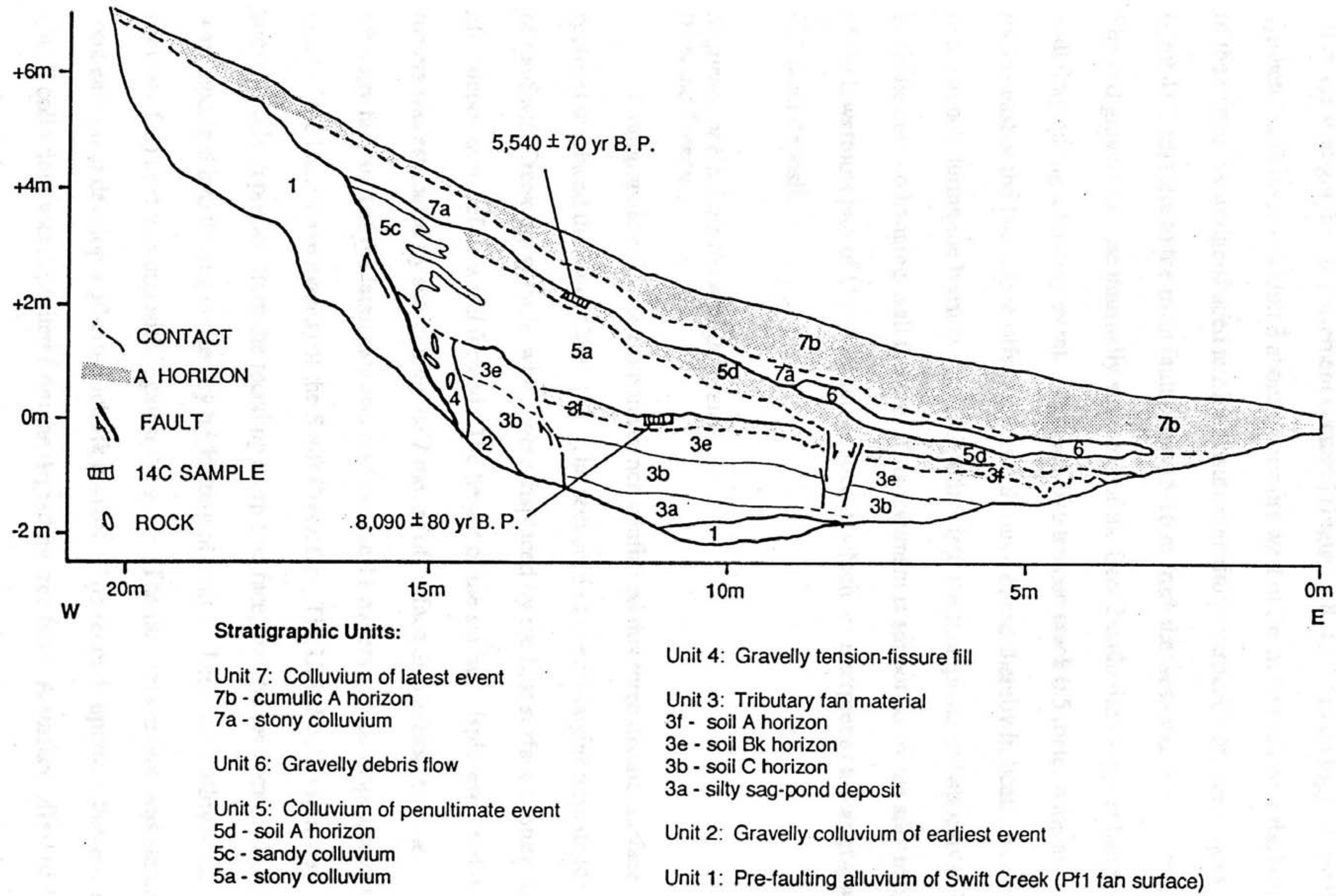


Fig. 30. Log of the Afton trench. The C-14 date from unit 5d (5540 C-14 yr BP) gives a close minimum age constraint on the Most Recent Event (MRE). The C-14 date from unit 3f (8090 C-14 yr BP) gives a close minimum age constraint on the Penultimate Event (PE). The prior event must have occurred before the deposition of the sag pond sequence (unit 3) and its underlying scarp-derived wedge (unit 2), but after the deposition of the late Pinedale fan (ca. 15 ka).

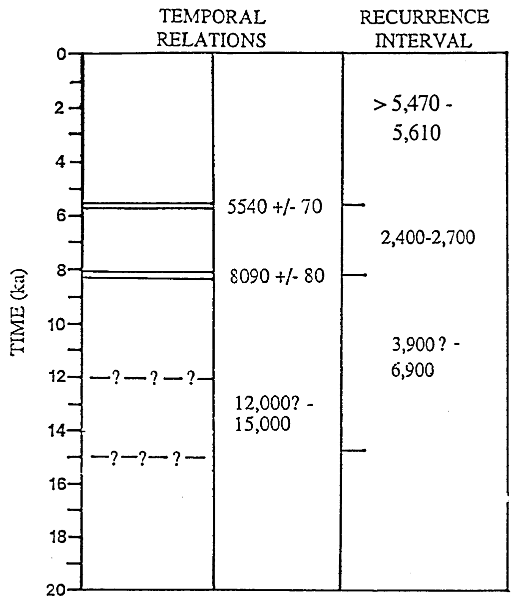


Fig. 31. Recurrence diagram for the latest 3 paleoearthquakes at Afton, WY.

Mi 34.2: drive N on Jefferson St. to 2nd Avenue; turn right (E) and drive toward mouth of Swift Creek; continue up into canyon of Swift Creek.

Mi. 38.2: road turns right into main fork of Swift Creek. This stretch of the canyon was the site of a 1985 debris flow that blocked the creek for a while (see following Figures).

Fig. 32. 1985 debris flow from the south wall of Swift Creek. Note dam blockage at lower left.

Fig. 33. Debris-flow deposit just above transition from deposition to erosion in channel.

Fig. 34. Transition between gully eroded down to bedrock (top) and head of debris fan (bottom).

Mi 39.7: STOP 1-5, Periodic Spring (Jim McCalpin**)**. Park at the parking area and hike 0.1 mi S to the orifice of the Periodic Spring.

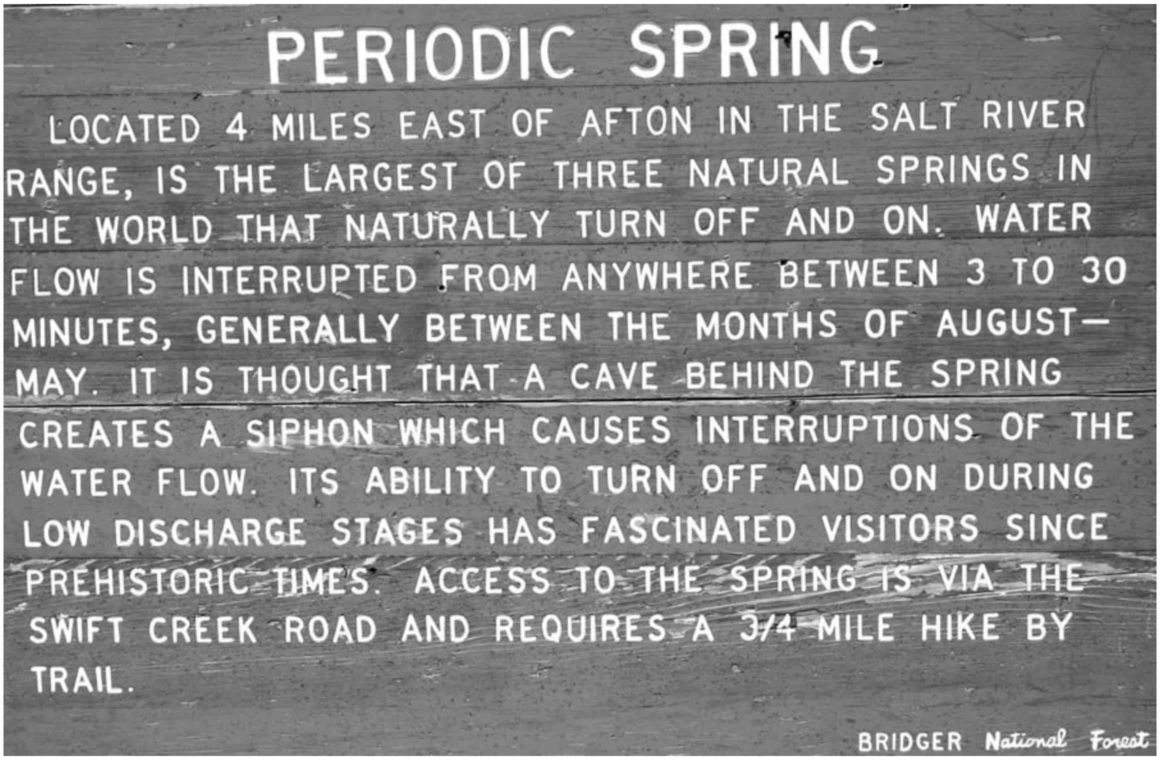
Fig. 35. Orifice of the Periodic Spring as it existed in 1985. Pensive young John Rice for scale.

FROM http://www.ultimatewyoming.com/sectionpages/sec1/extras/periodicspring.html

What Is It? The Periodic Spring is North America's only cold water geyser and is the largest of the three known fluctuation springs in the world. Its name is descriptive of the periodic flow, which during the fall and winter, turns on and shuts off every 12-20 minutes. These periodic flows are less noticeable during high water months in spring and summer.

The water at Periodic Spring has given life to the land, the wildlife, and the people of Star Valley. Historically, Native Americans traveled great distances to cure their ills by bathing in "the spring that breathes." Since 1958, the spring's water has been piped to the City of Afton for its municipal water supply, and is used for drinking, irrigation, and generating electricity.

No one knows for certain what makes the Periodic Spring start and stop. One theory is that underground streams carry melting snow and rain water to a lake deep in the Salt River Mountains. When the lake level gets high enough, a natural siphon draws the water from the lake to the surface like a faucet being turned on and off. The water then gushes out of a sheer ledge and cascades down a wild, moss-covered ravine to join Swift Creek. The flow continues until the water level in the lake drops below the siphon's intake level, allowing air to enter the siphon from the lake cavern. The flow stops until the lake rises again and the cycle repeats.



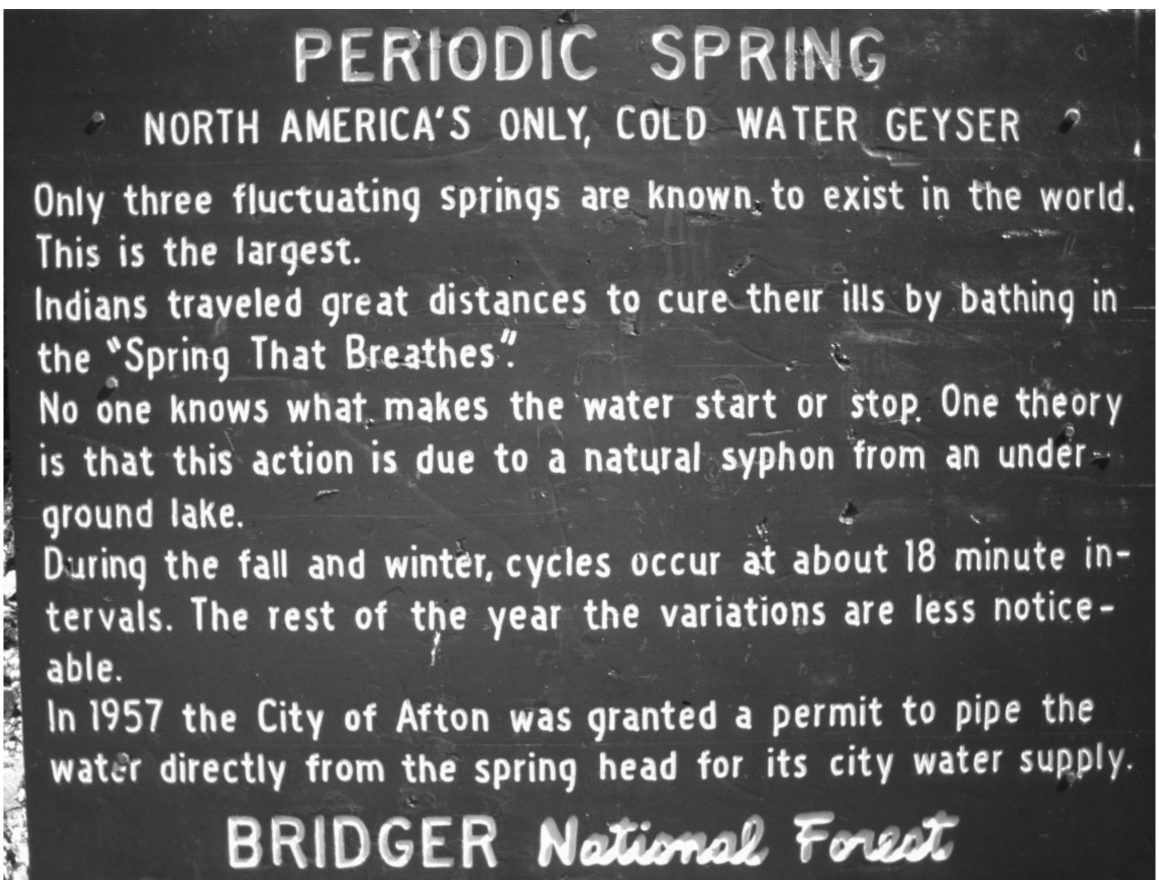


Fig. 36. Signs at Salt River Pass (top) and at Spring Trail (bottom).

Mi 39.7: return to the parking lot and retrace route back down Swift Creek to Afton;

Mi. 45.2: where 2nd Avenue intersects US 89, turn right (N) and proceed north toward Grover, WY.

Mi 49.7: pass through "downtown" Grover, and then as US 89 bends 45 degrees to the NW, immediately turn right (E) onto County Road 172; proceed E and then N as road turns to gravel and ascends the Neogene fault block (?) that separates Upper Star Valley from Lower Star Valley. Pass through some nice informal camping spots in the forest at the summit of the pass (but no water). Descend pass and onto the floor of Lower Star valley. The paved road works its way N and W in a series of right-angle turns.

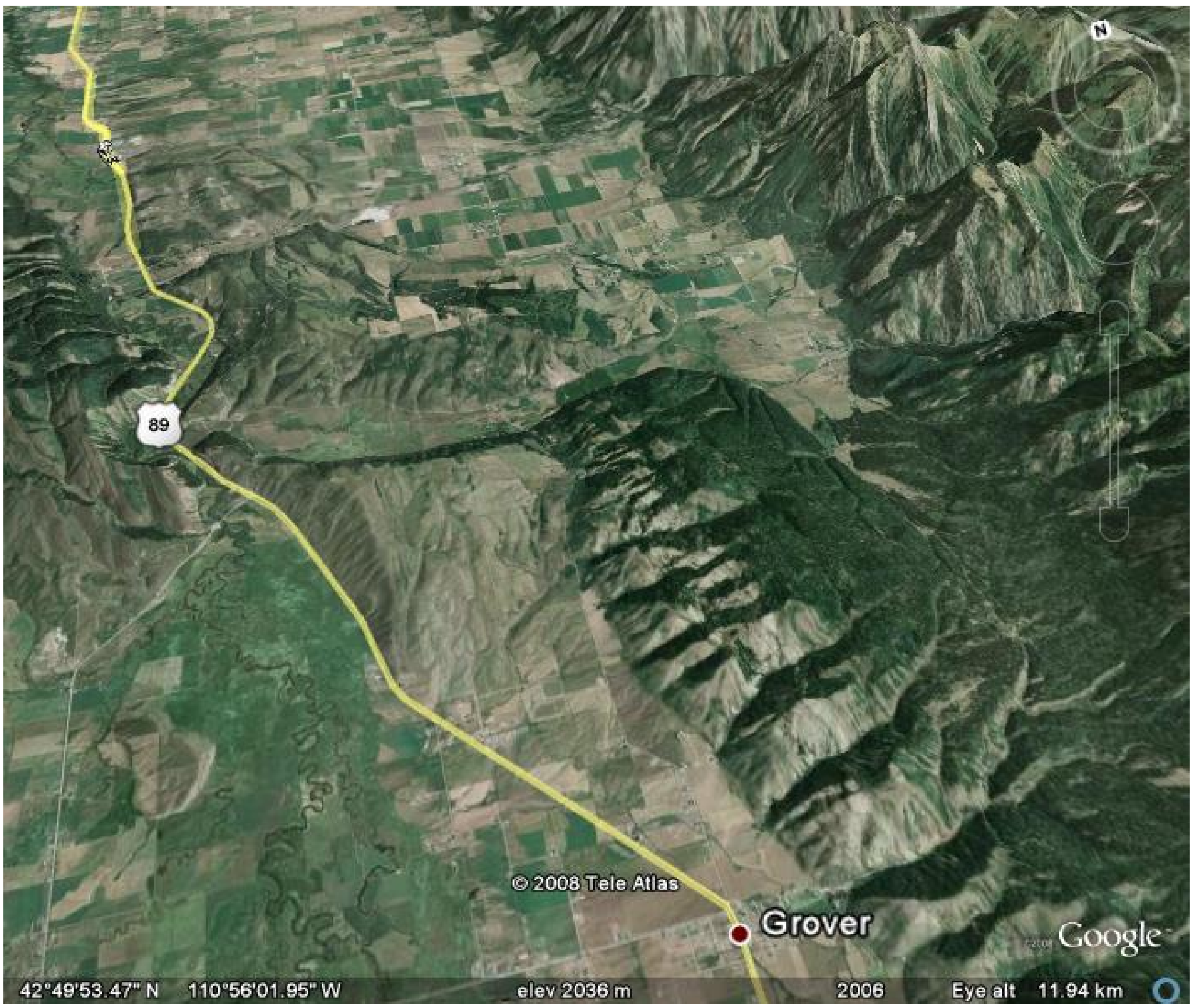


Fig. 37. Oblique satellite image of the Neogene horst (right center) that separates Upper Star Valley (lower left) from Lower Star Valley (upper left); north is at top. Note the incised valley of Willow Creek (left center) and Strawberry Creek (upper left center), both of which have eroded through the horst.

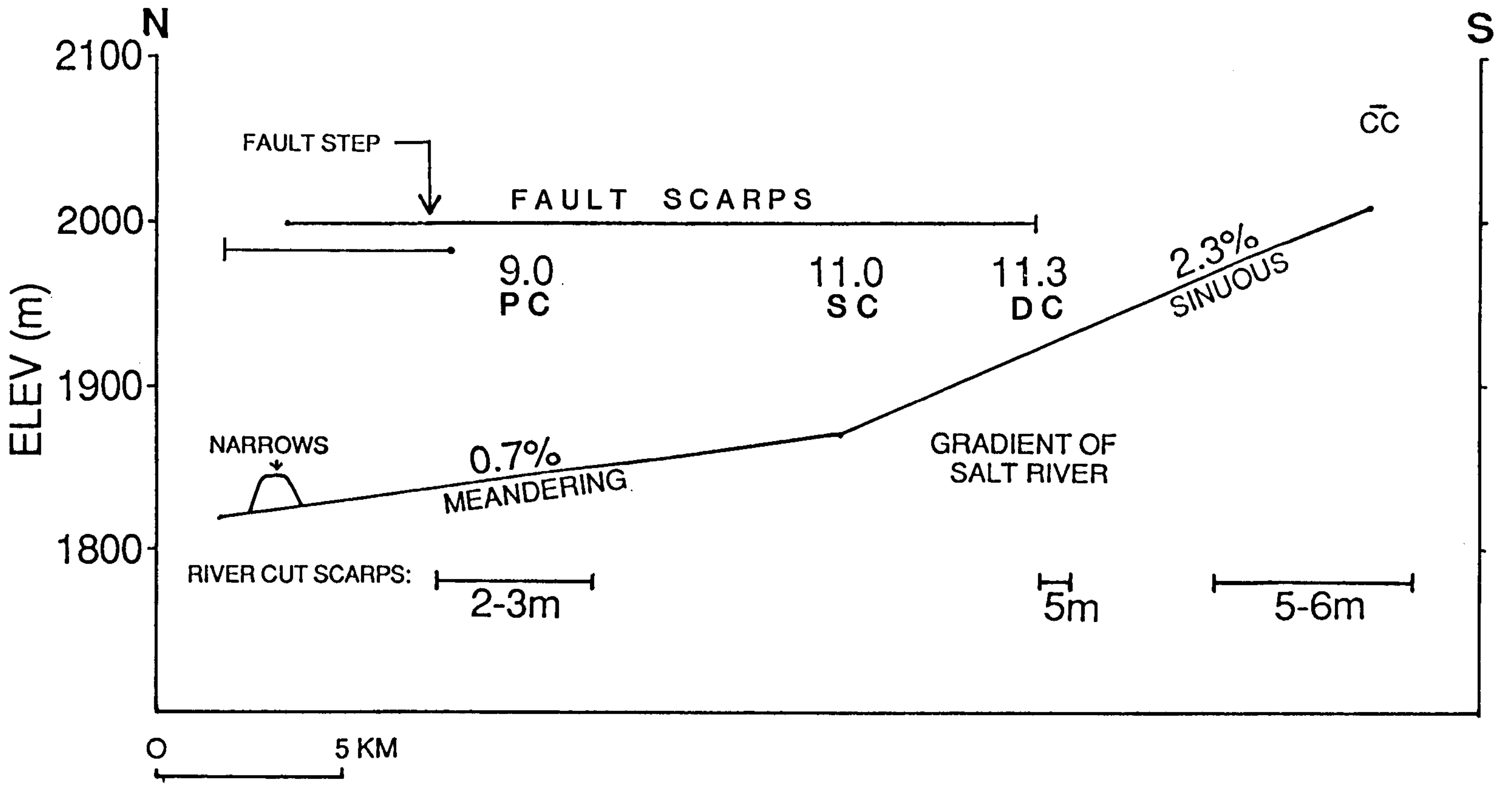


Fig. 38. Schematic diagram showing the longitudinal profile of the Salt River in southern Star Valley (lower line) compared to the extent of range-front fault scarps (upper 2 lines) and their surface offsets (in meters). DC, Dry Creek; SC, Swift Creek; PC, Phillips Creek.

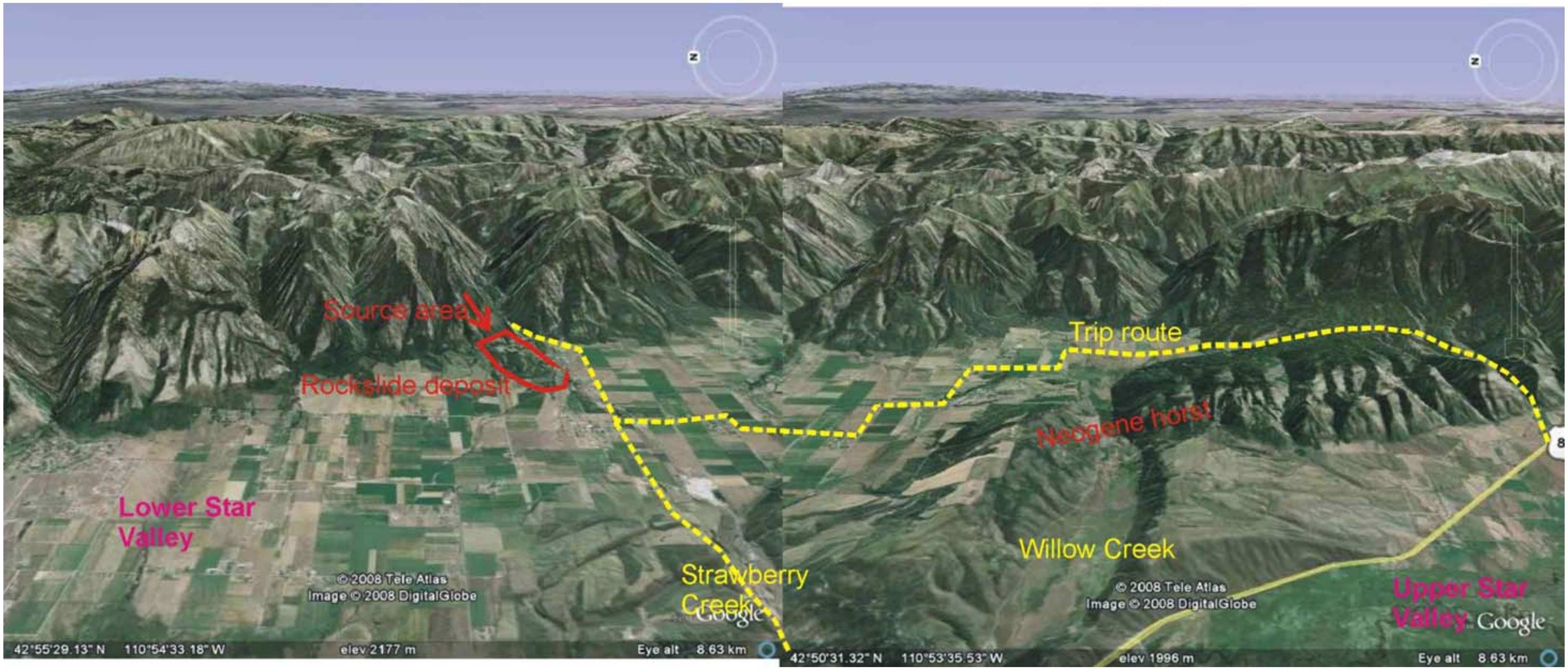


Fig. 39. Trip route (yellow dashed line) between Upper and Lower Star Valley; view to the east toward the Salt River Range. The route diverges from US 89 at far right, at the town of Grover, WY, and ascends a low pass perched on the Neogene horst that separates Upper from Lower Star Valley. Willow Creek and Strawberry Creek have cut valleys through the Neogene horst, rather than going around it to the north. WHY? At left center is the Bedford rockslide deposit (our STOP 1-6) and its source area on the faceted spur of Madison Limestone directly above.

Mi 59.8: T intersection with County Road 126; turn right (E) and proceed toward the mouth of Strawberry Creek. Continue into the mouth of the canyon.

Mi 62.3: turn vehicles around at the Power Plant and retrace route to the mouth of the canton; park wherever you can. **STOP 1-6, "Bedford Rockslide" and Fault Scarp**. (John Rice). Here we hike up the steep hillslope N of the road to attain the crest of the high fault scarp of the Star Valley fault. This is the only vantage point of the Bedford Rockslide left open to the public, because all roads on the slide deposit itself are now private.

The Bedford Rockslide:
Rubey (1973) mapped this landslide deposit as two different bedrock units lying on the hanging wall of the Star Valley fault. The majority of the deposit he mapped as Tsl, Salt Lake Formation of Tertiary age. This is the older valley fill unit (Miocene-Pliocene) that is widely mapped on the margins of Neogene grabens in the eastern Basin and Range Province, notably in northern Utah. That unit also underlies the hills that lie west and south of Bedford, and separate Upper Star Valley from Lower Star Valley. Rubey mapped the southern margin of the landslide deposit as Madison Limestone, albeit with very different dip of bedding (35°, 50°, and 58° north) than is present on the faceted spur (20°-25° SW).

Rubey's (1973) map implies that the deposit is a block of bedrock that is somehow at a very high structural level even though it is on the hanging wall of the graben-margin fault. Such an interpretation would require another normal fault lying just west of the deposit, to bring these bedrock units up to the surface. However, Rubey does not map or infer such a fault.

Dips on the facet composed of Madison Limestone (Mississippian) are to the west (out-of-slope) at 26°, 30°, 34°, 40°, 42° (Amsden Fm. at base of facet). At the base of the facet the overlying Amsden Formation crops out (Pennsylvanian-Mississippian). The unit underlying the Madison Limestone, the Darby Formation (MDd, Mississippian-Devonian) is not exposed on the facet face, so may not be involved in the landsliding.

Our interpretation is that the deposit is a late Quaternary rockslide avalanche deposit that lies atop older Quaternary sediments, and then the Salt Lake Formation, in the sequence of graben-fill sediments. Thus, we think the deposit is a "rootless" mega-landslide deposit that contains blocks of bedrock so large, that Rubey mapped them as in-place Madison Limestone.

UNRESOLVED QUESTIONS:
1—Why did Rubey map Tsl on the footwall of the Star Valley fault trace south of Bedford? This would require that there be either: (1) very little throw on the Star Valley fault, or (2) a zone of stepfaults. There are problems with both of these options.

North of Bedford, we interpret his Tsl as a Quaternary landslide deposit. Might this also be true of the Tsl he mapped south of Bedford? If so, then the two problems cited above go away.

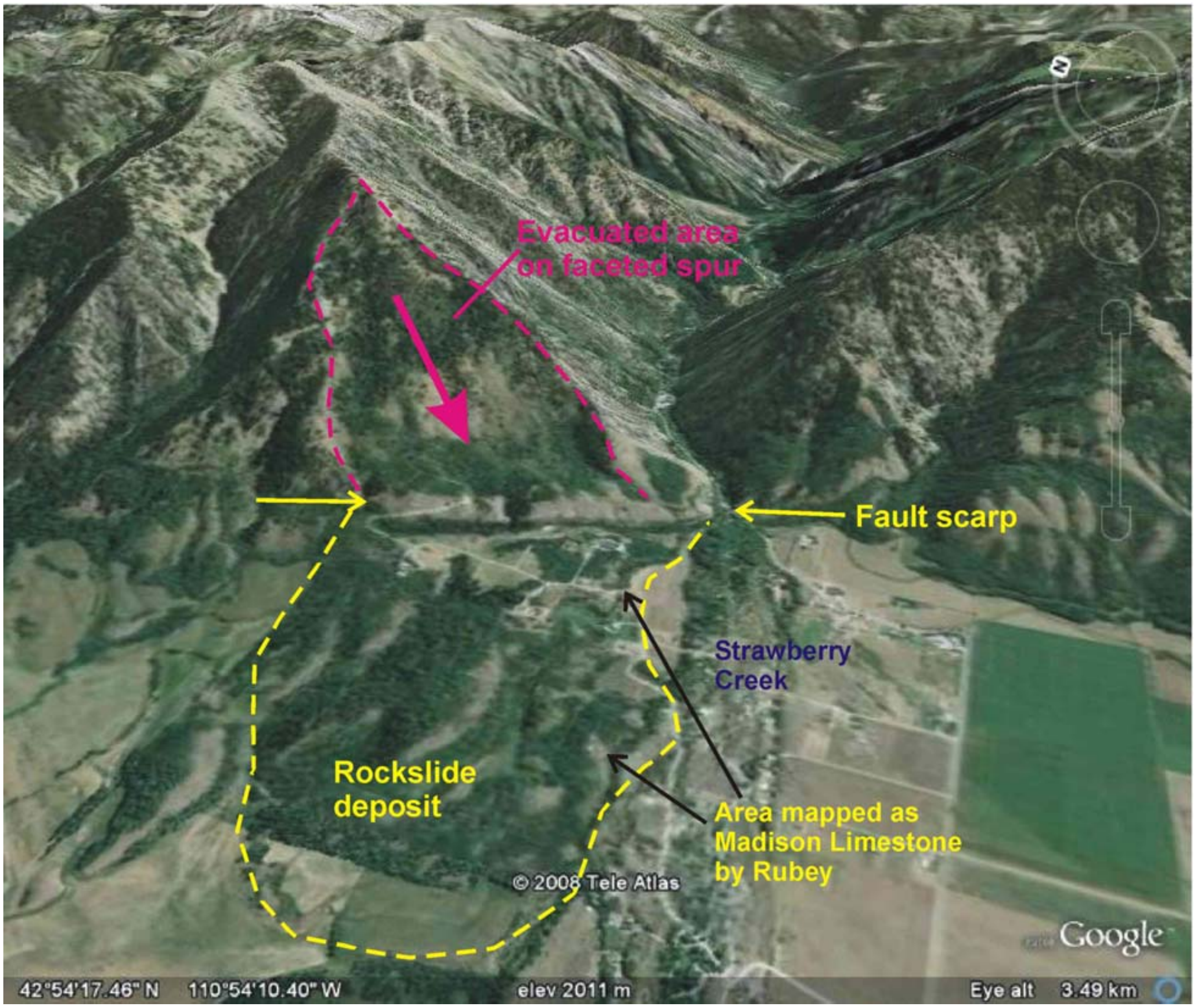


Fig. 40. Oblique satellite image of the Bedford rockslide and its source area on the faceted spur; view is to the east.

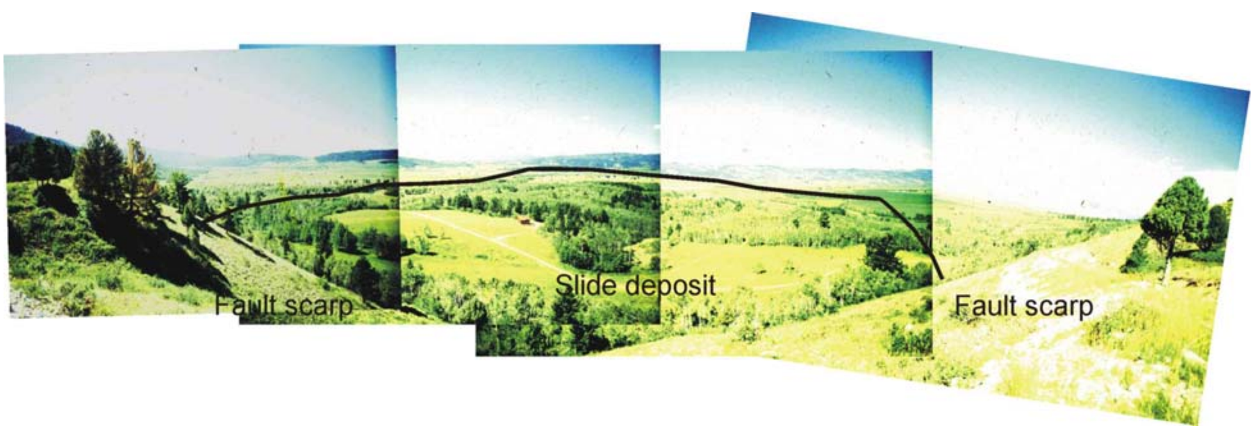


Fig. 41. Panorama of the slide deposit from atop the fault scarp; view to SW.

2—Do the hills separating Upper and Lower Star Valley compose a horst? Rubey does not map faults on either side of the hills. If the hills are not a horst, then what created them?

3-- How did Willow Creek cut through these hills? [A similar situation exists for Strawberry Creek to the north]. One option is that the stream was already running west to the Salt River in that area before the horst came up, and it merely superimposed itself across the rising horst. This explanation presupposes the hills are a horst, which is not how Rubey mapped them. In addition, this argues for a long history of downcutting, which should be represented by terraces along the creek. But no such terraces have been mapped.

An alternative is that stream capture occurred when a tributary of the Salt River eroded through the Tsl hills and captured upper Willow Creek. In this scenario, prior to the capture Willow Creek must have flowed north toward Bedford. If that happened, then all the deposits south of Bedford should be old (pre-capture), and all of the deposits in the present course of Willow Creek should be young (post-capture). We do not know if this is true, but at least it is a testable hypothesis.

Hike back down to the cars and proceed W on CR 126.

Mi 67.8: pass T-junction of CR 126 with the road from Grover; continue straight ahead on CR 126.

CR 126 follows Strawberry Creek as it cuts through the Neogene fault block. To the south Willow Creek cuts an even deeper canyon through the fault block. It is unknown whether these cuts resulted from stream superposition or capture. The timing of the incision might be determined by mapping terraces remnants in the gorge versus outside of the gorge.

Mi. 71.1: junction of CR 126 with US 89; turn right (N); proceed through Lower Star Valley. Although the Star Valley fault continues to bound the eastern valley margin, it has not been studied in detail by us. Nor has the Quaternary geology of the valley floor, or of the mountains.

Mi 73.5: enter Thayne, WY. This area was settled by Swiss immigrants in the late 1800s and is a dairy and cheese center.
Thayne is the small community where “cutter racing” first started. Local ranchers still compete on snow covered tracks throughout the region to see whose team of horses is fastest.

Mi 92.2: arrive in Alpine, WY. Optional stop at grocery store on E side of town. From there, continue N across the bridge over the Snake River. At the junction of US Highways 89 and 26, continue straight ahead onto US 26, which soon bends to the NW.

Mi 94.2: entrance to Alpine North Campground; turn left (W) into entrance. Then immediately turn left again into the Group Sites area and take the 2nd right into loop B the middle of 3 loops). CAMP SITE FOR SATURDAY NIGHT.

ROAD LOG
Day 2
Reset trip meters to Zero!!

Mi. 0.0: leave North Alpine Campground; at entrance, turn right (S) and drive back to Alpine Junction (junction of US 89 and US 26). Continue south across Snake River Bridge.

Mi 2.6: turn left (SE) onto Greys River Road (also parking lot for grocery store of previous evening). [498638mE/4778756mN).

Mi 3.4: pavement ends at USFS boundary. **STOP 2-1**. (Jim McCalpin). Pull off to left (N) onto large paved snowmobile parking lot. Overview of Greys River area and Grand Valley

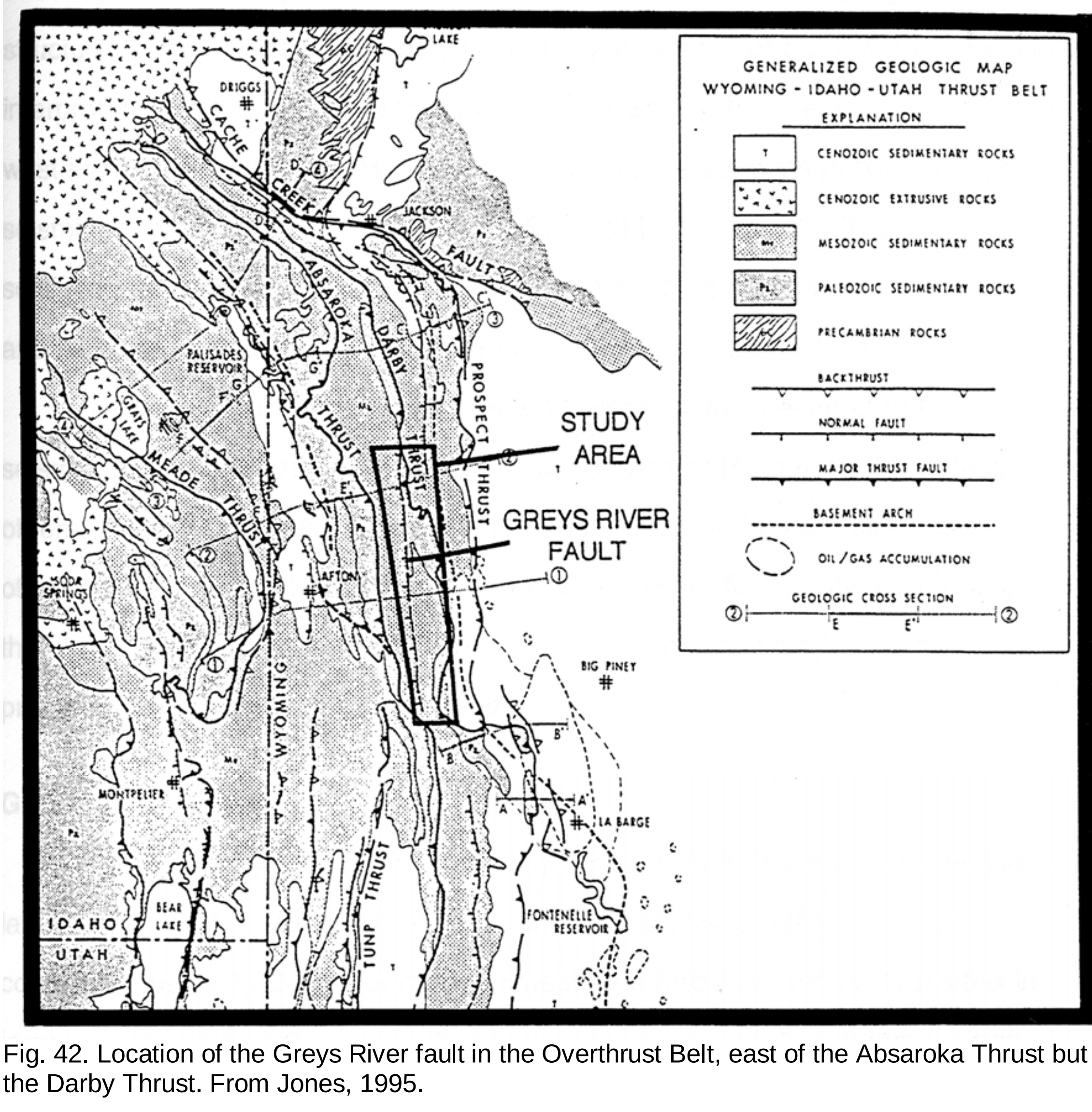


Fig. 42. Location of the Greys River fault in the Overthrust Belt, east of the Absaroka Thrust but west of the Darby Thrust. From Jones, 1995.

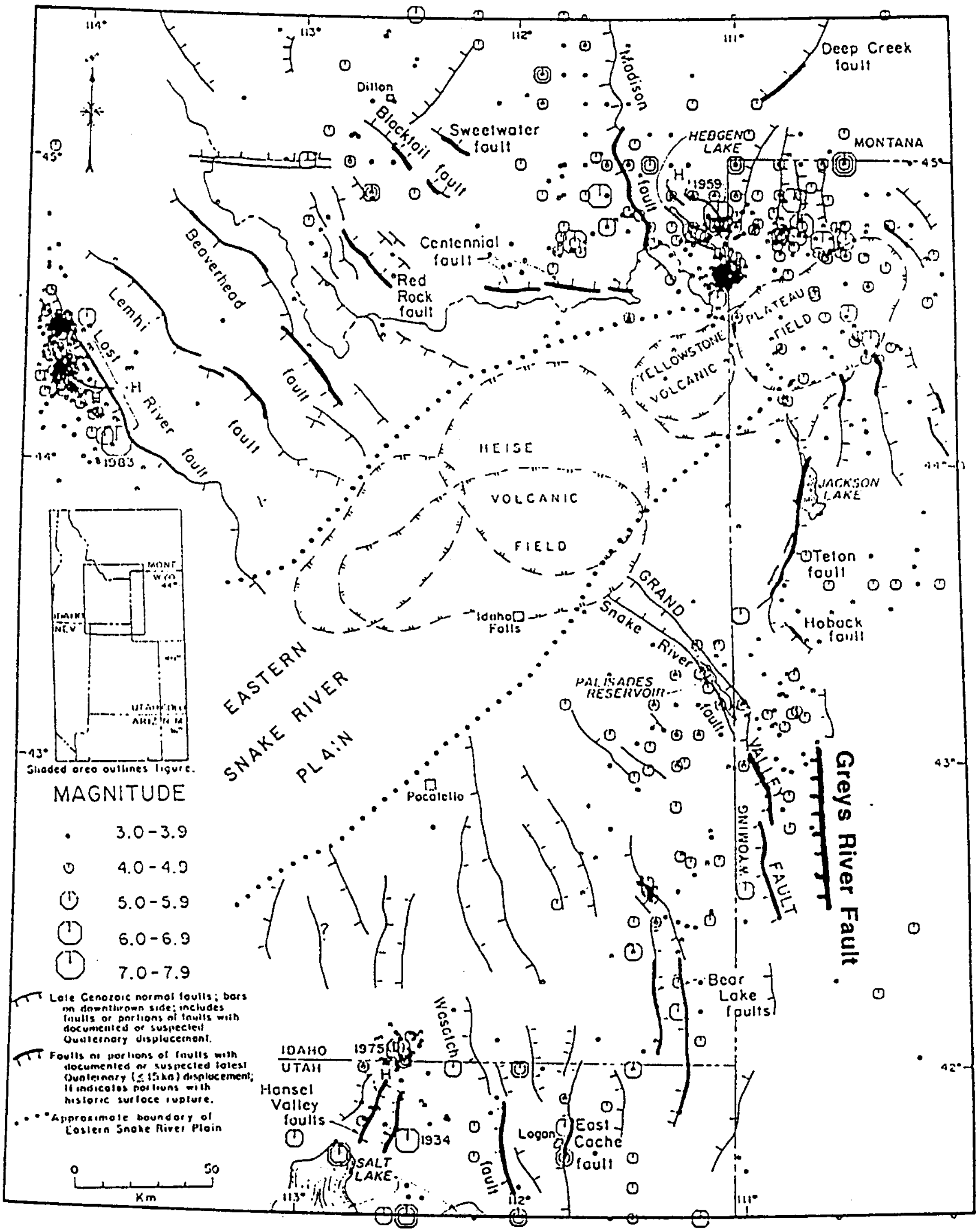


Fig. 43. Map of Neogene normal faults flanking the Snake River Plain. The Star Valley and Greys River faults are highlighted at lower right. Thicker lines indicate faults with known Holocene paleoearthquakes (Greys River, Star Valley, E and W Bear Lake, E. Cache, and Wasatch faults). The Hansel Valley rupture is historic (1934, M6.6). Later work proved Holocene displacement on the West Cache fault.

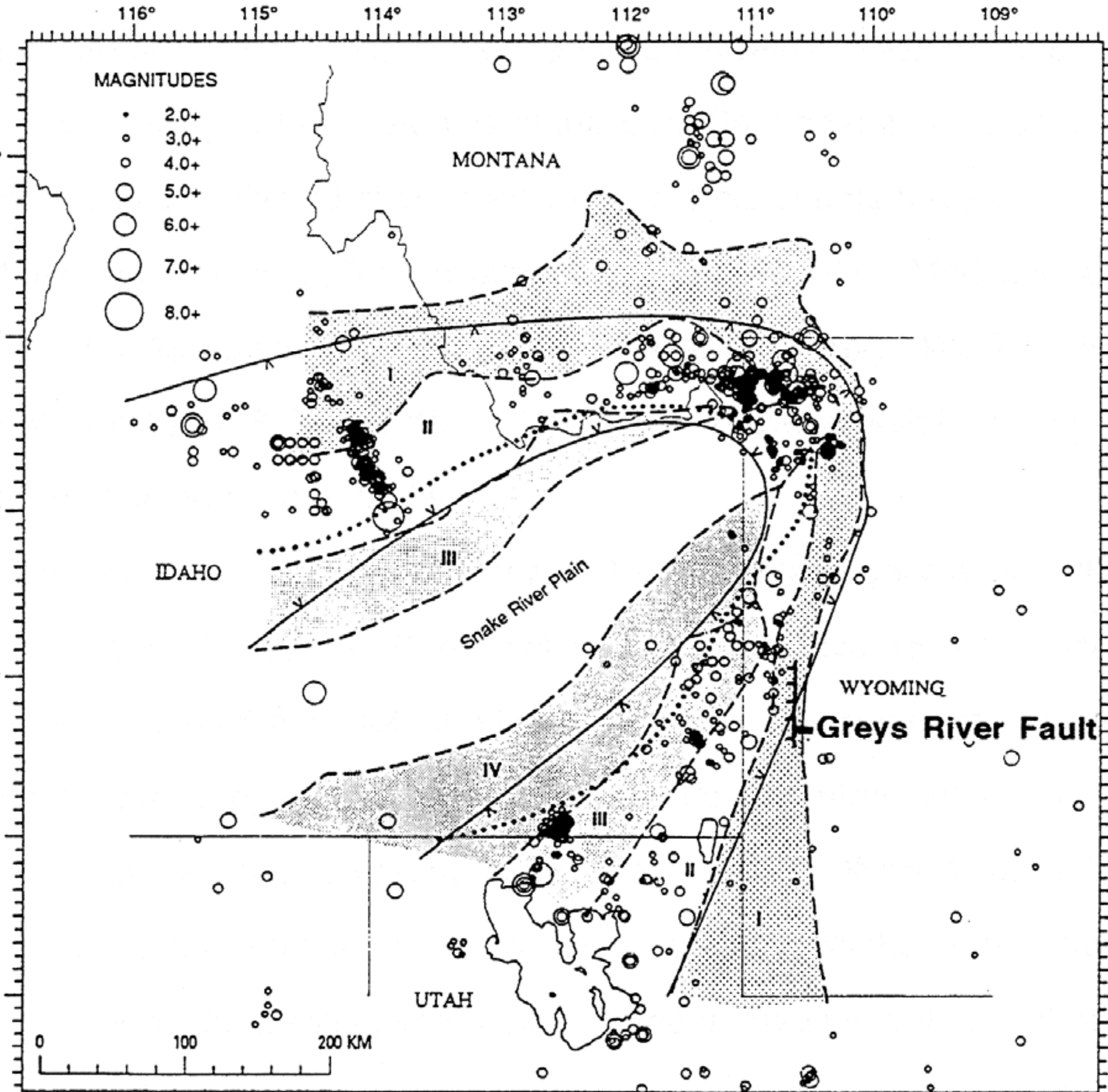


Fig. 44. The "seismic parabola" around the track of the Yellowstone hotspot, from Pierce and Morgan, 1992. Zone IV has the oldest normal faulting, Zone I has the youngest. Ask Ken Pierce for details.

Continue south on Greys River Road (graded gravel).

Mi 6.5: recent landslide on opposite side of Greys River. [504167mE/4776511mN]. This is a typical failure in the steeply folded Mesozoic rocks of the Salt River Range, like that at Slide Lake. The failed unit here is the Ankareh Shale (Jurassic-Triassic). We will see many such failures in the lower part of the Greys River Valley in the first half of today. However, in the upper reaches of Greys River the landslides visible from the road will mainly be earthflows emanating from Cretaceous shales.

Mi 8.2: STOP 2-2. (Al Jones) [506789mE/4776340mN]. Pull off to right side of road. Carefully. On the opposite side of the Greys River is a large landslide that occurred in May of 1991 and partially blocked the Greys River. The headscarp exposes reddish Ankareh Formation. The slide mass was completely forested in 1991 and trees were being undermined by river erosion and falling into the river. The trees apparently all died a natural death in the ensuing 17 years.

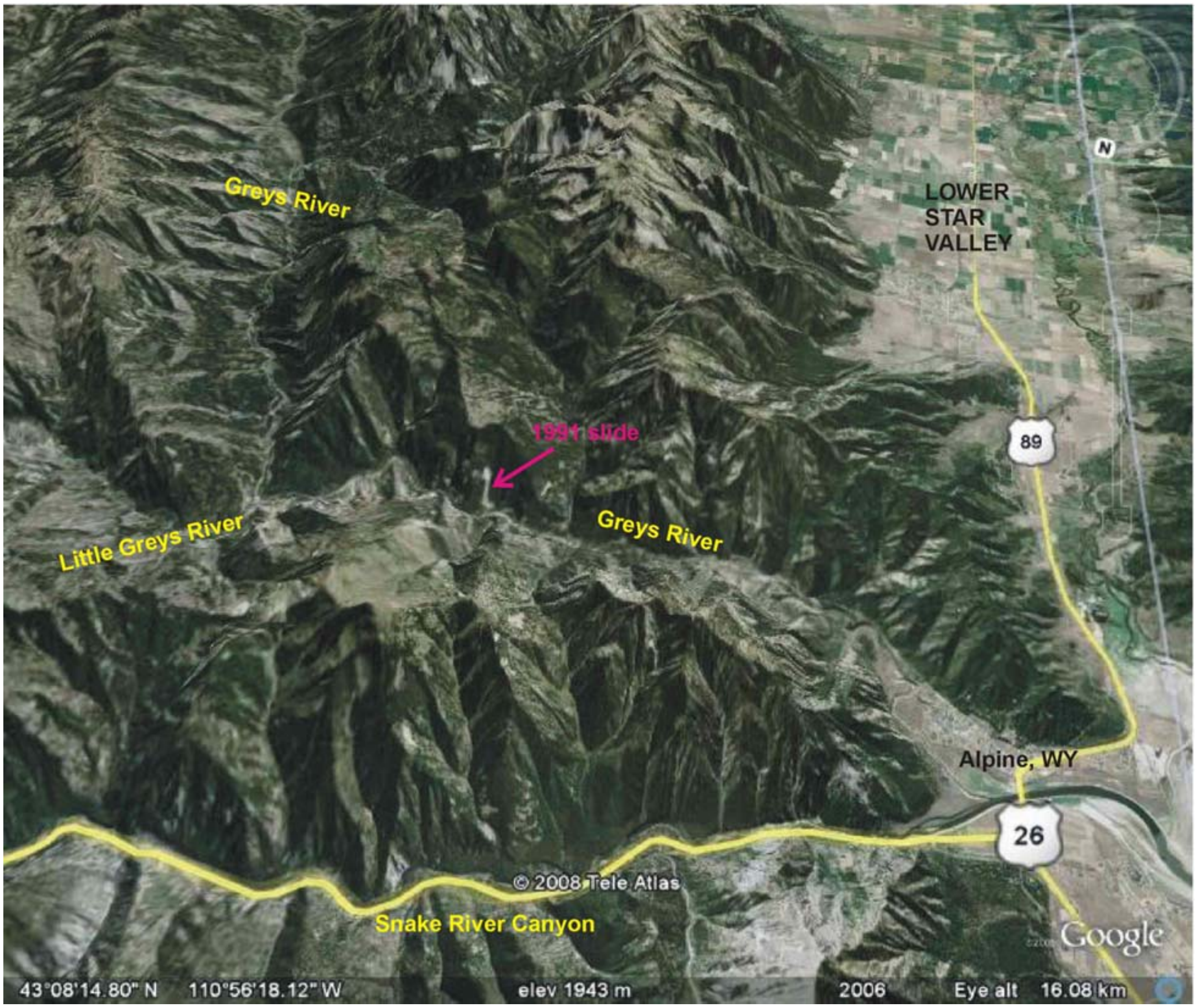


Fig. 45. Satellite image (south is at the top) of the northernmost part of the Salt River Range and the town of Alpine, WY (at lower right, junction of US 89 and US 26). The Snake River Canyon and US 89 are at bottom. The Greys River extends SE from Alpine and crosses the center of the photo, before turning south at left center. The 1991 landslide scar (STOP 2-2) can be seen as a narrow clearing on a densely-forested hillslope just left of dead center of the photo, on the south bank of the Greys River.

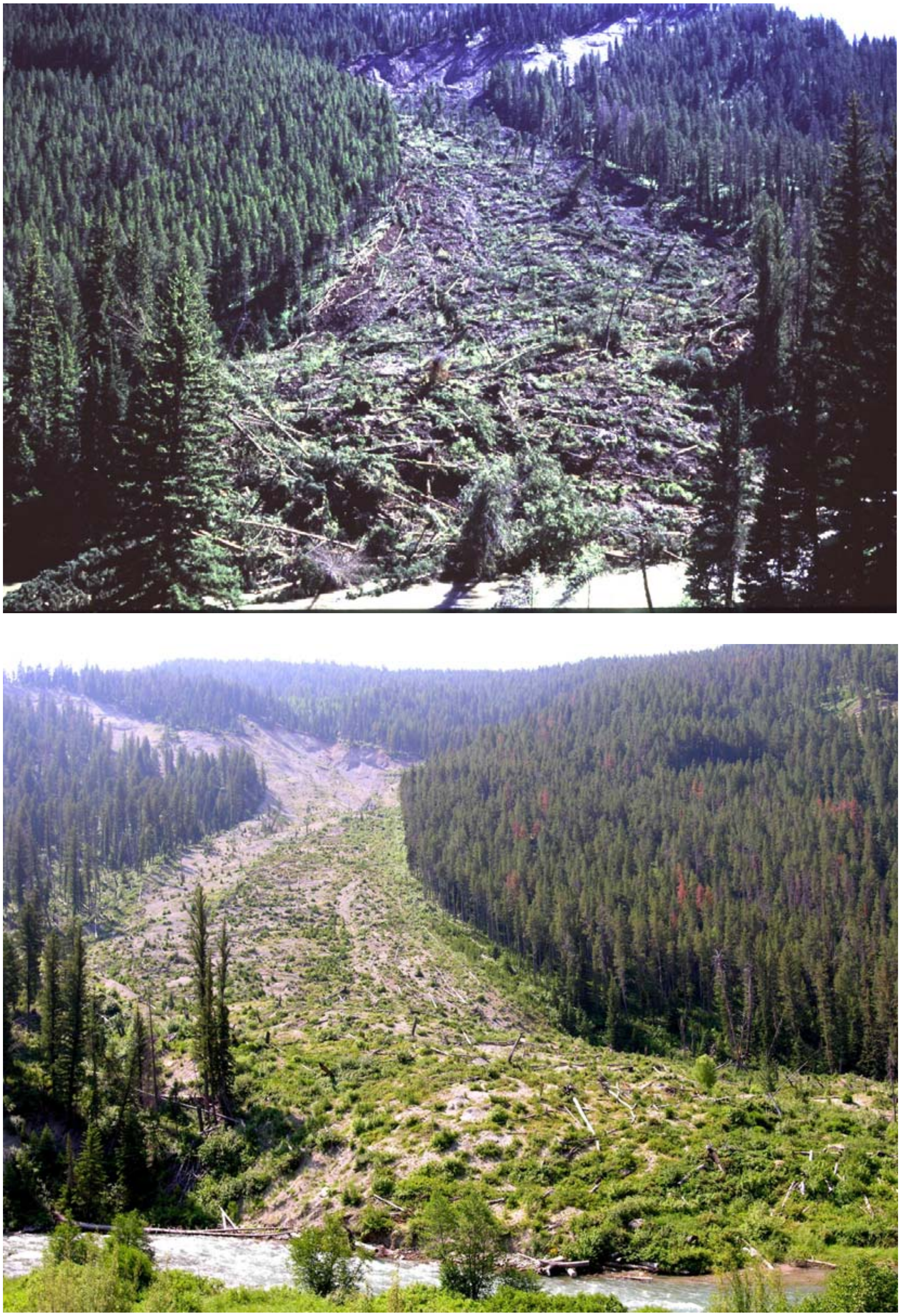


Fig. 46. 1991 photo (top) and 2008 photo (bottom) of the 1991 slide into the Greys River.

Mi 10.9: junction with the Little Greys River, which continues due east. [510477mE/4776816mN]. Continue south on main road.

Mi 12.5: large slump-earthflow across river in the southern part of the Pine Creek quadrangle. [510995mE/4775086mN]. Typical of earthflows from Cretaceous rocks (mainly the Blind Bull Formation, Kbb). These earthflows perturb the channel of the Greys River throughout its length.

Mi 14.3: small dipslope rockslide on left (E) side of road. [512312mE/4772904mN]

Mi 18.0: junction with Murphy Creek Road to right. Continue south on Greys River Road. The Murphy Creek Road is one of the few roads that bridge the Greys River and permit access into the large glaciated valleys of the eastern flank of the Salt River Range. The bridge across the Greys River is only possible here due to the constricting effects of a large earthflow toe coming in from the east, down South Doe Creek.

Mi 18.4: STOP 2-3. **Influence of landslides on river**. (Jim McCalpin). Pull off on right side of road. View of a large (but curiously, unnamed) aggraded section of the Greys River.

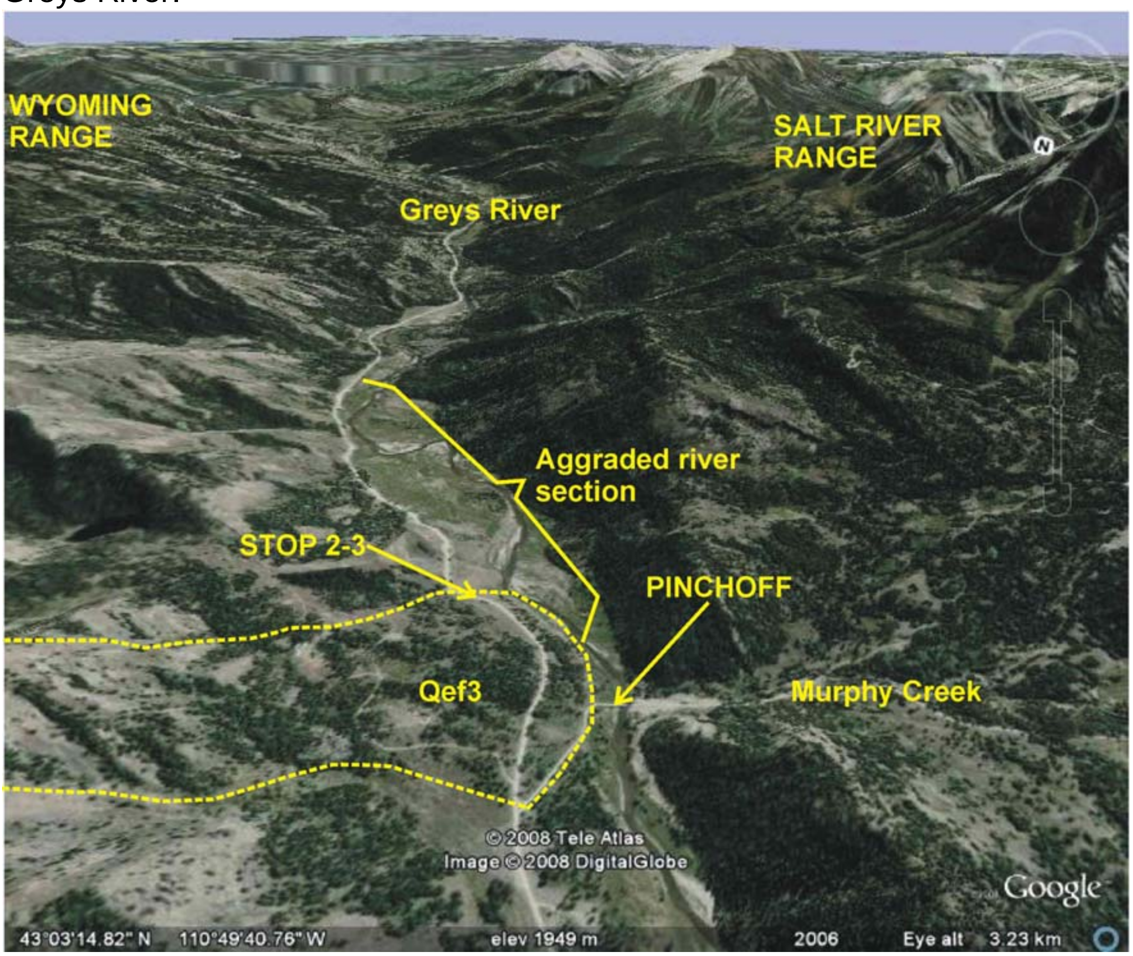


Fig. 47. Oblique satellite view of the Greys River (view is to south) where it is pinched off at Murphy Creek, by a large earthflow (Qef3).

Effect of Landsliding on Axial Stream Processes (J.P. McCalpin)

The Greys River exhibits a strange morphology over most of its north-flowing, along-strike course (but not in the lower, across-strike course downstream of the Little Greys River). In the N-flowing section, the valley bottom is composed of a series of wide aggraded basins (called “flats” by locals) separated by narrow constrictions. The constrictions are caused by toes of landslides (typically earthflows from Cretaceous rocks) impinging on the Greys River from one or both sides. This impingement has not been known (at least historically) to totally block the Greys River and form a lake, although this conceivably could have happened prehistorically. Instead, the impingement raises the local base level at the pinchoff point, which forces aggradation upstream, creating a “flat.”

In theory, the history of aggradation in each of the “flats” is tied directly to the history of toe advances of the impinging landslides. The flats lie about 6 m below a prominent gravel terrace in parts of the valley, which we correlate with latest Pinedale outwash. If this correlation is correct, then the flats post-date the Pinedale deglaciation, which means that either: (1) the earthflow toes did not reach the river until after the deglaciation, or (2) the earthflow toes were there during the Pinedale glaciation, but the River was so active that it basically overwhelmed them with stream erosional power and outwash aggradation.

A possible future study would be to date episodes of movement on the earthflows that create a pinchoff (not an easy task, but has been done), and then core & date the flat upstream. The goal would be to correlate the alluvial response to the landslide movement history.

Mi 19.9: road crosses Dead Dog earthflow, which pinches off river and creates Kennington Flat. This name is one of many morbid names of the Greys River country (Deadman Creek, Dead Horse Gulch, Dead Dog Creek, Blind Bull Creek, etc.).

Mi. 20.5: road is pinched by landslide toes from both sides of the valley.

Mi 21.4: view south of two high peaks of the Salt River Range; Man Peak (on right, 10,326 ft) and Virginia Peak (on left, 10,144 ft).

Mi 22.5: junction with White Creek Road On right), which also crosses river and permits access into the Salt River Range. The bridge site is at another “pinchoff” between landslide toes of Holocene age (age class 3 of Rice, 1987). This pinchoff creates Indian Grave Flat upstream.

Mi 23.3: sign near fence describes “A Dynamic System”, but it’s not about the landslide-stream aggradation story we have been discussing. Instead, the sign describes the effects of cattle eating and trampling the riparian vegetation, which destabilizes the stream banks and promotes meanders. The Forest Service built this fence to keep the cattle away from the streambank, presumably so the stream would not meander and undercut the road.

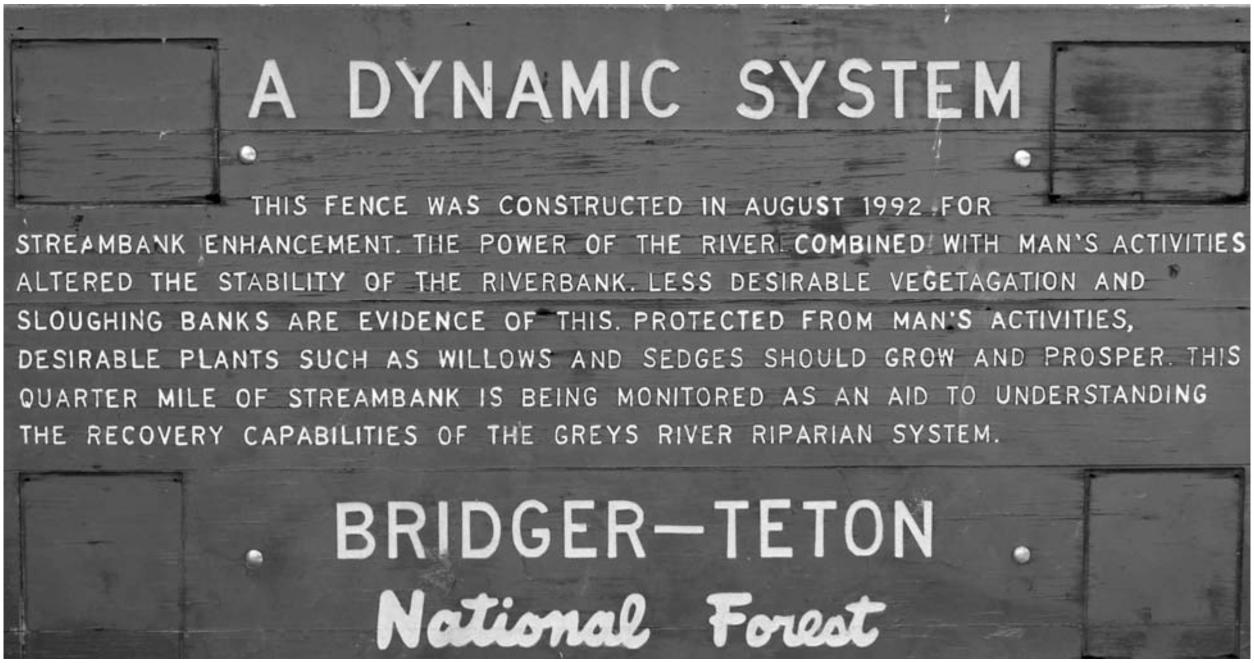


Fig. 48. The misleading sign……….

Mi. 24.0: Pullout [at 517647mE/4759772mN]. Upstream of Man Creek, the oxbow of the Greys River shown on the 1980 USGS topo map of the Man Peak quad (airphotos from 1973) has now been cut off and abandoned. In 1973, the channel here flowed on the far west side of the valley, in the distant trees.

Mi 25.7: Moose Flat Campground on right.

Mi 25.9: Pearson Creek; pinchoff formed by an age class 2 earthflow from the west; this has formed Moose Flat upstream (forested; older than other Flats??).

Mi 26.8: road curves through an age class 3 landslide toe.

Mi 28.3: junction with Deadman Creek Road. [522479mE/4756215mN]. Turn left (E).

Mi 29.4: the Deadman Creek moraine complex can be seen to the E, as a flat-topped forested hill; bench above road in N tributary here is Bull Lake outwash terrace.

Mi 29.7. STOP 2-4. (Al Jones). Turn right on small dirt track and park in small meadow at the base of the Bull Lake moraine. [523916mE/4757797mN]. Ascend to top of moraine via a small foot path.

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Return to Greys River Road (a 1.4 mi drive).

Mi. 31.1: junction of Deadman Creek Road and Greys River Road; turn left (S) and continue upvalley.

Mi 31.6: huge meadow called “The Elbow”; probably dammed by an earthflow from Anderson Creek.

Mi 31.9: Late Pinedale outwash terrace on left, about 6 m above modern stream level.

Mi. 32.2: junction with Blind Bull Creek Road; [522823mE/4754441mN]. turn left (E) atnd continue 2.0 miles to Pinedale terminal moraine and scarps of the Greys River fault.

Mi 34.2: STOP 2-5. Blind Bull moraines and fault scarps. (Al Jones).

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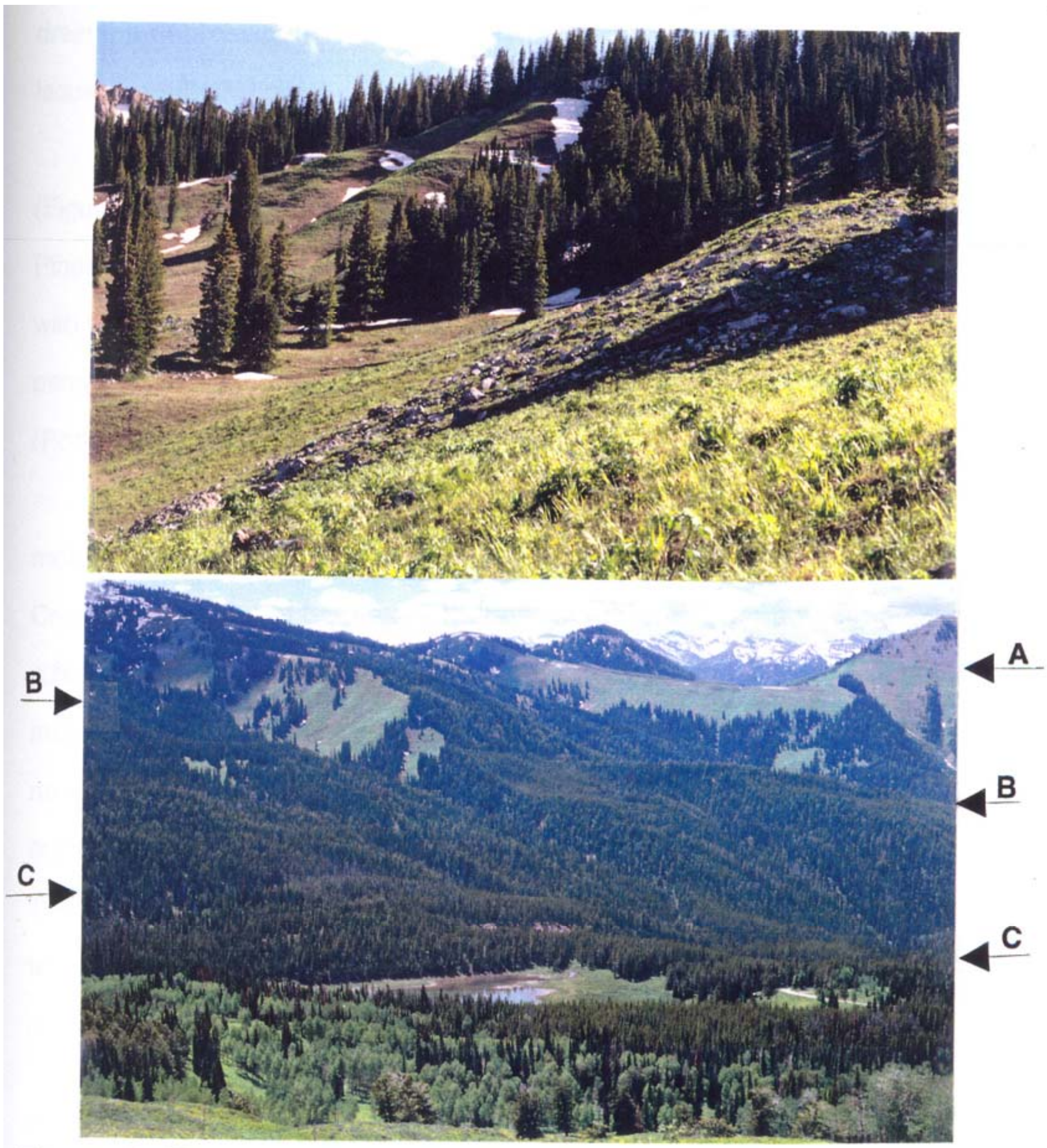

Figure 8. Photographs of Pinedale moraines. The top picture was taken from the upper cirque area of Blind Bull Creek looking south. The picture shows an early Pinedale moraine, composed of limestone clasts (older bedrock) derived from the hanging wall of the Darby Thrust, sitting on Cretaceous bedrock. The bottom picture was taken from the eastern drainage divide of Blind Bull Creek looking southwest. Arrows: A, marks the Darby Thrust; B, marks the early Pinedale moraine crests; C, marks the late Pinedale moraine crests surrounding a filled depression. The pine forested slopes are composed of moraine; the aspens in the foreground are growing in alluvial/colluvial deposits derived from Cretaceous bedrock.

Fig. 49.

Return to Greys River Road.

Mi 36.2: junction of Blind Bull Road and Greys River Road; turn left (S) and continue upvalley.

Mi 44.6: junction with Bear Creek Road; turn right (W) and cross bridge over Greys River; to the south is our first view of the Wyoming Range and the high pediment surface (QTf of Rubey, "fanglomerate"). Ascend onto +6 m terrace (LPa) and continue west.

Mi 49.7: cross creek. **STOP 2-6.** (Jim McCalpin). View up glaciated valley of Bear Creek; late Pleistocene glacier came nearly down to the Greys River. The glacial deposits of the eastern flank of the Salt River Range have never been studied.

Fig. 50. Oblique satellite view of the glaciated valley of Bear Creek (at center), looking SW. The Greys River Road and Greys River are visible at lower left. The downvalley extent of Late Pleistocene glaciers coincides with the widened valley floor with its meandering stream. The lowest ca. 1 km of the valley was not glaciated (at least in Pinedale time) and is flanked on both sides by hills of west-dipping bedrock. The road in this unglaciated section is lying on the Pinedale outwash terrace.

Return to Greys River Road.

Mi 47.2: junction of Bear Creek Road and Greys River Road; turn right (S) and continue upvalley.

Mi 47.5: junction with Sheep Creek Road on left; turn left (E).

Mi 49.7: STOP 2-7. Fault scarps of the Greys River fault. (Al Jones). [527023mE/4744435mN].

This impressive fault scarp was “rediscovered” in 1989 when geologists at Utah State University were studying Quaternary faulting in the Overthrust Belt. While examining W.W. Rubey’s map of the Afton-Big Piney area, made in the 1930s, we noticed that Rubey had drawn a solid line with hachures across the alluvium of Sheep Creek. His map legend said that line symbol indicated a “fault scarp.” So we hopped in a car, drove from Logan to Sheep Creek, and were mightily surprised to find a whopping fault scarp cutting the latest glacial outwash of Sheep Creek. This scarp could be traced up both valley sides to the base of the faceted spurs separating the high range front of the Wyoming Range, from the uplifted and dissected Quaternary-tertiary pediment surface.

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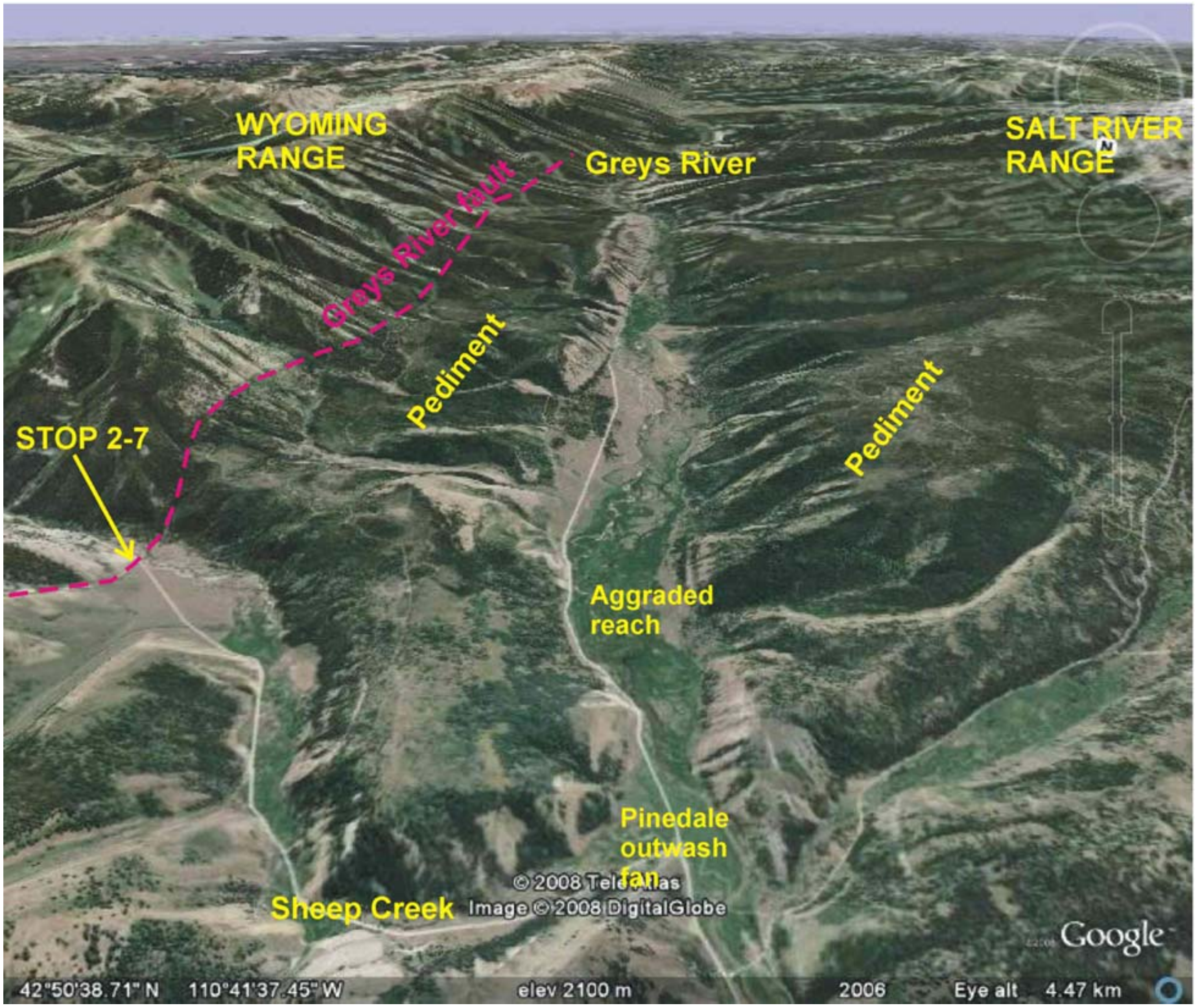


Fig. 51. Oblique satellite view of the high pediments flanking the Greys River, in the reach south of Sheep Creek. View is to the south. The pediment is separated from the Wyoming Range by the Greys River fault, which lies at the base of a faceted range front developed on Mesozoic rocks (particularly the Jurassic Nugget Sandstone). We will see Holocene scarps of this fault where they displace Pinedale outwash and post-glacial alluvium at Sheep Creek (STOP 2-7). Note how the Greys River has apparently been constricted and aggraded by the Pinedale outwash fan of Sheep Creek, rather than by a landslide toe. The "pediments" labeled on the west side of the Greys River are conjectural.

Fig. 52. Panoramic photo of the Holocene fault scarp of the Greys River fault at Sheep Creek; view is to the east. The scarp displaces presumed Pinedale outwash over most of its length, but at far right (right of the road) it displaces younger postglacial terraces by a smaller amount.

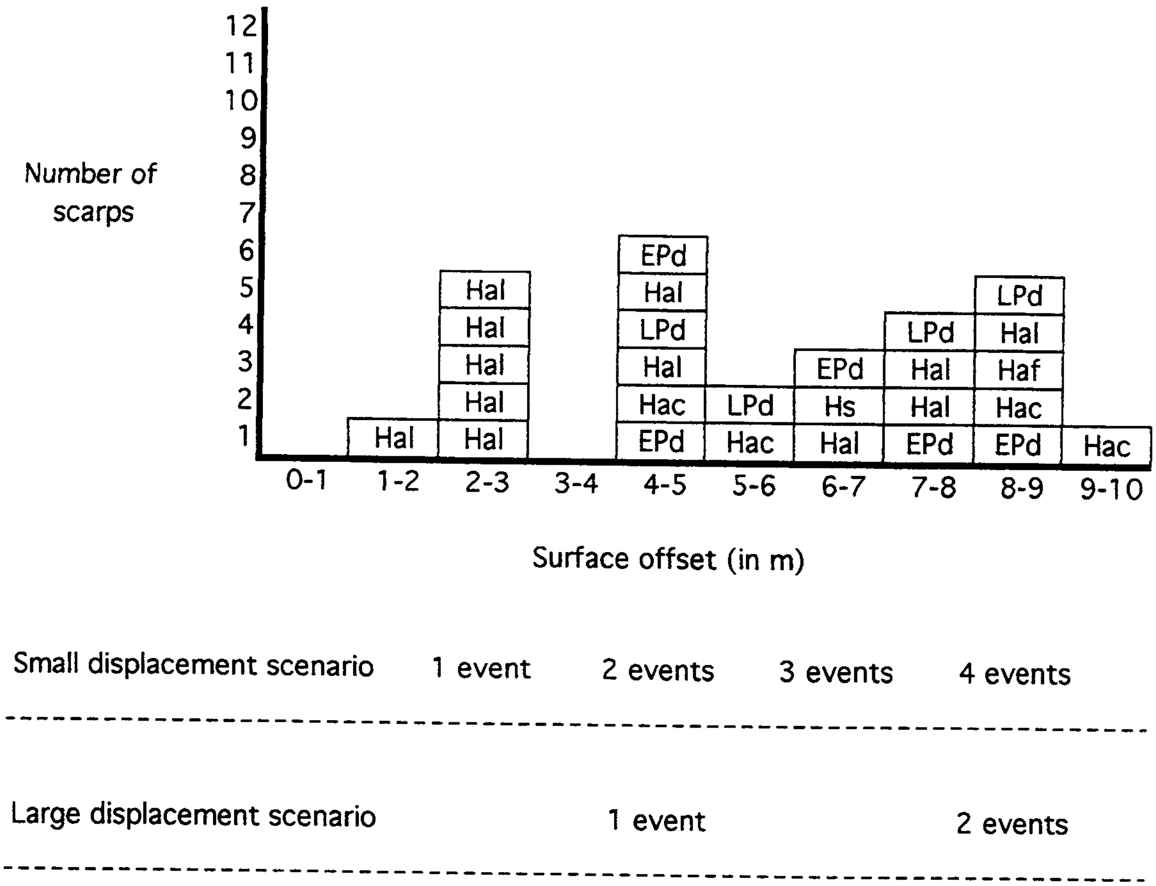


Figure 14. Histogram showing the distribution of offset along the Greys River fault. The small displacement scenario is derived from a unimodal interpretation of distribution of slip along the fault, which supports four faulting events with 2 m of offset during each event. The large displacement scenario is derived from a bimodal interpretation of the distribution of offset along the fault, which supports two faulting events with 4 m of offset during each event. Ages of faulted deposits are given: EPd = early Pinedale moraine, LPd = late Pinedale moraine, Hac = Holocene hill-slope deposits, Hal = Holocene alluvium.

Fig. 53.

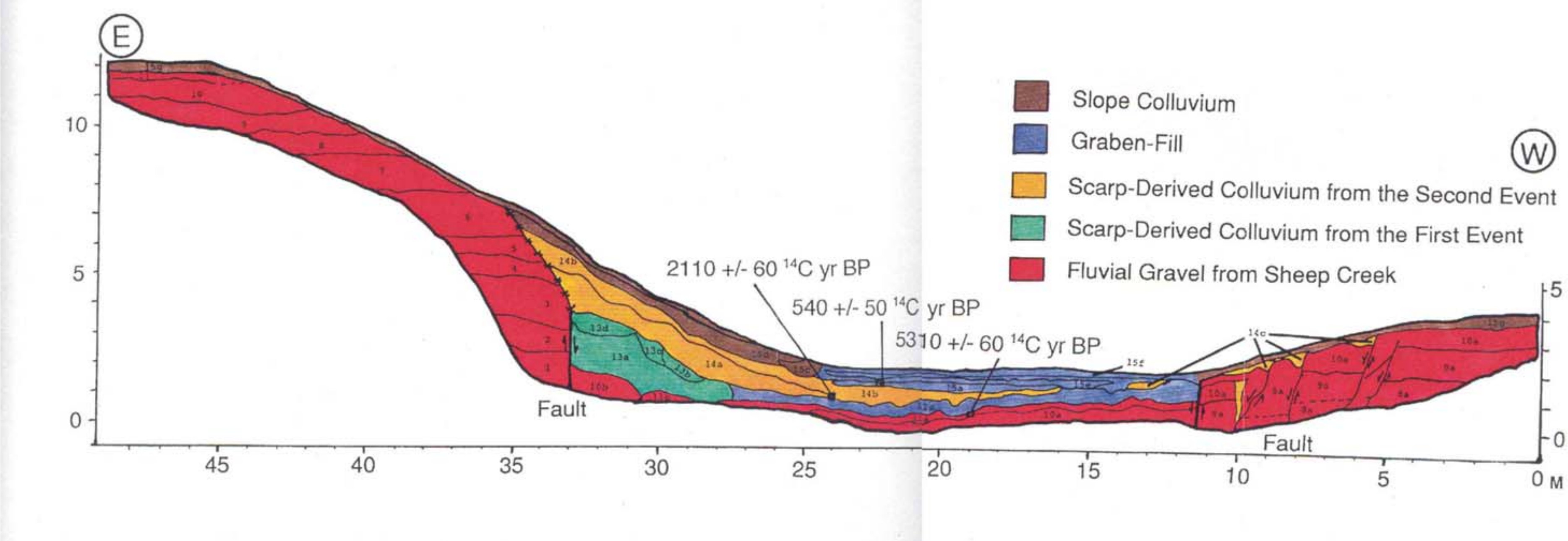


Figure 17. Simplified version of the log of the middle trench at Sheep Creek. Logged in July of 1991, by L.C. Allen Jones, James McCalpin, Witold Zuchiewicz and Kelly Davis.

Fig. 54

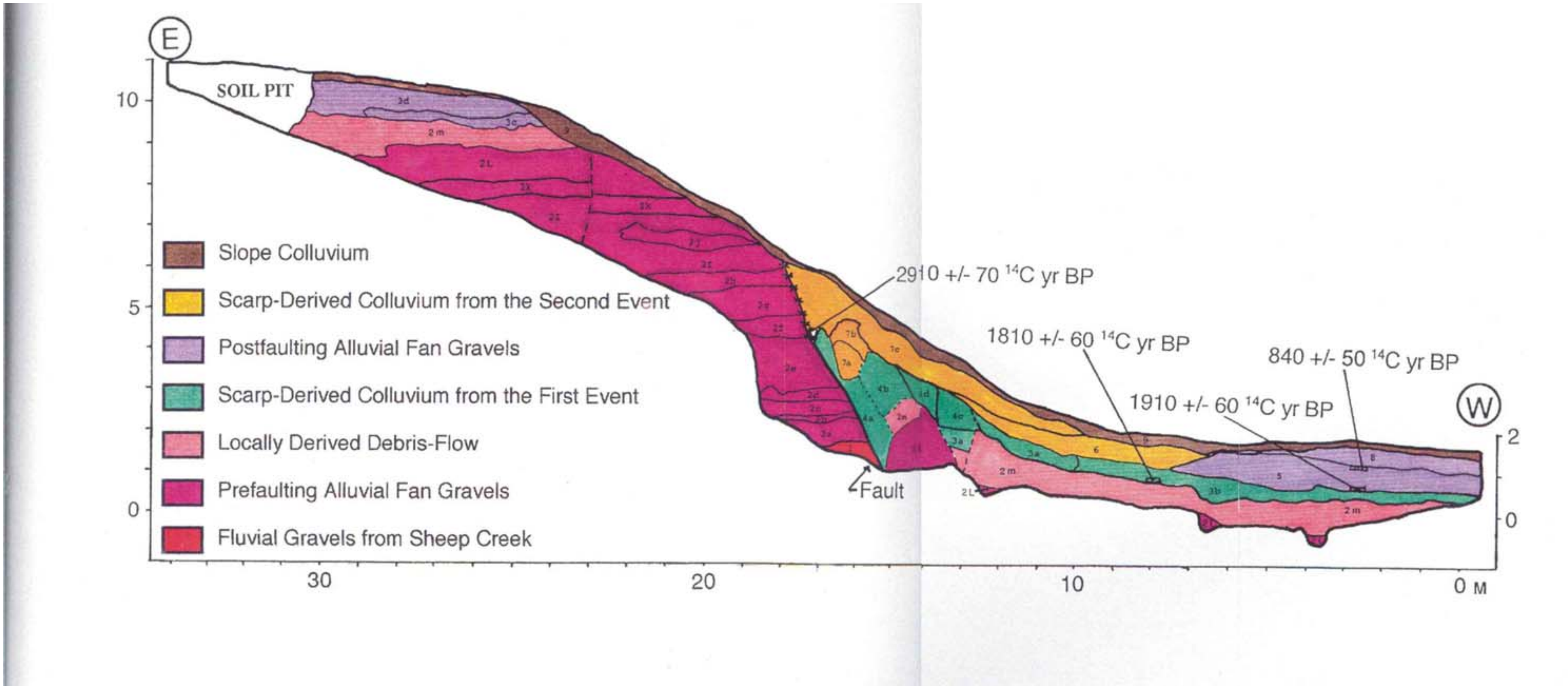
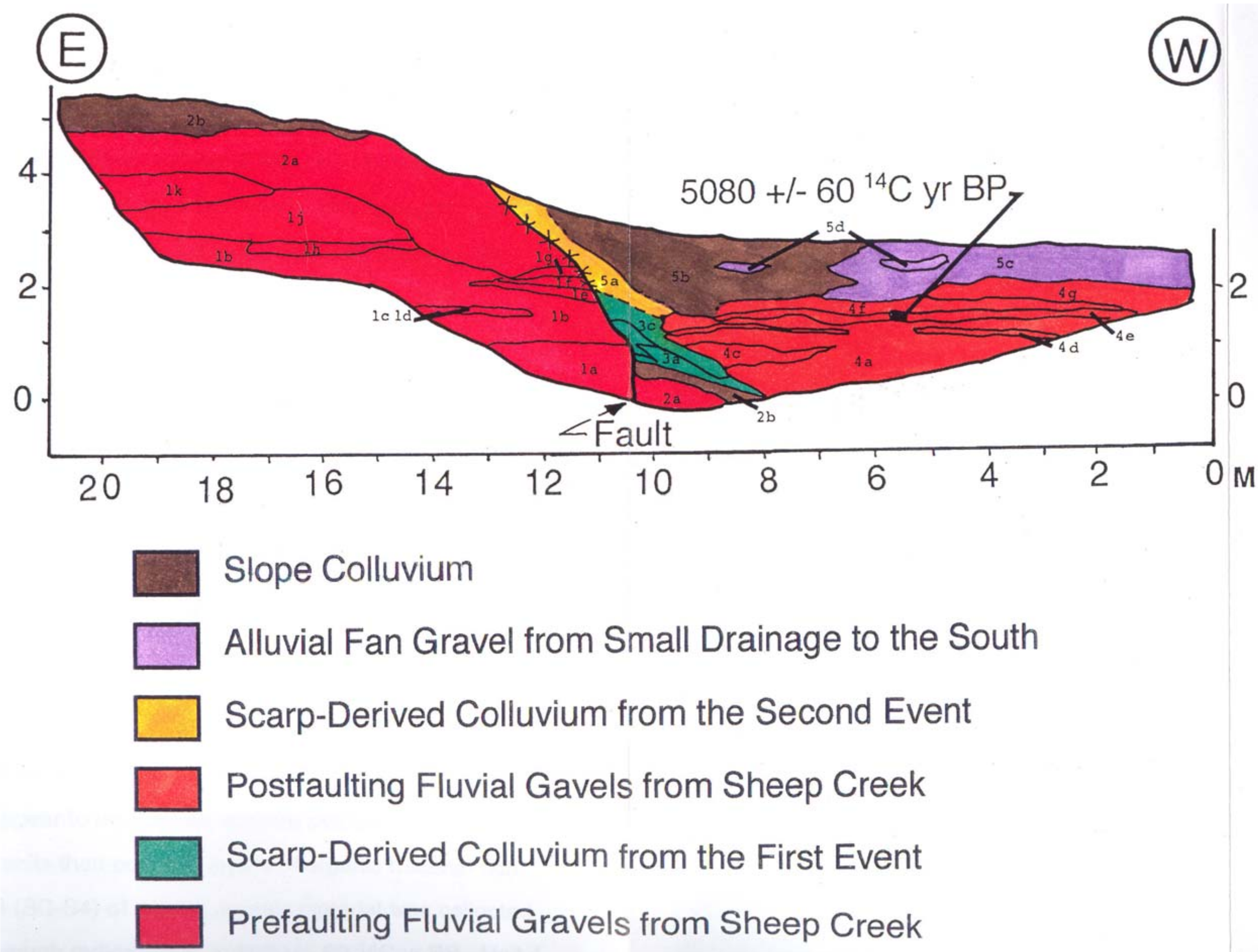


Figure 18. Simplified version of the log of the north trench at Sheep Creek. Logged in July of 1991, by L.C. Allen Jones, James McCalpin and Matthew Novak.

Fig. 55.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Slope Colluvium
Alluvial Fan Gravel from Small Drainage to the South
Scarp-Derived Colluvium from the Second Event
Postfaulting Fluvial Gavels from Sheep Creek
Scarp-Derived Colluvium from the First Event
Prefaulting Fluvial Gravels from Sheep Creek

Fig. 56.

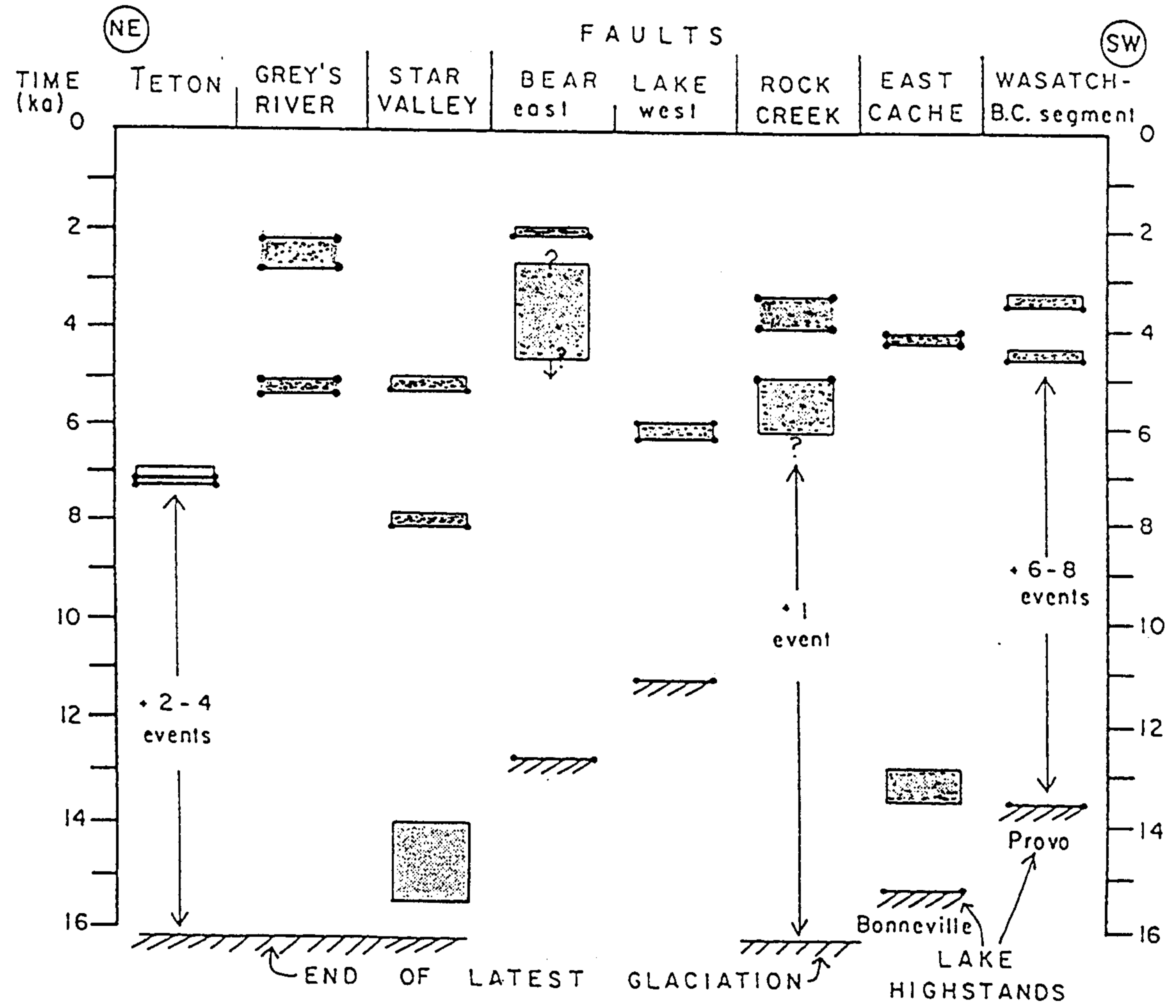


Figure 19. Temporal distribution of paleoseismic events in the northeast Basin and Range Province. Shaded boxes show inferred time periods for paleoearthquakes as bracketed by radiocarbon dates (black dots). Horizontal lines with hatchers indicates oldest Quaternary stratigraphic unit investigated. The timing for the paleoseismic events come from: Teton fault (Byrd and Smith, 1990); Greys River fault (Jones and McCalpin, 1992); Star Valley fault (Warren, 1992); Bear Lake faults (McCalpin and others, 1990b); Rock Creek fault (McCalpin and Warren, 1992); East Cache fault (McCalpin and Forman, 1991); Wasatch fault, Brigham City segment (Personius, 1991). (Adapted from McCalpin, 1993).

Fig. 57.

Continue E up Sheep Creek Road.

Mi 54.1: STOP 2-8. Darby Thrust exposure. (Jim McCalpin) [532976mE/4742737mN].

Possible exposure of the Darby Thrust in roadcuts to the N. Pull off road carefully. The Darby Thrust is one of the major east-verging, west-dipping thrust faults of the Overthrust Belt. It is probable that the Greys River normal fault developed atop a ramp in the Darby Thrust, as Tertiary extension developed in the late Oligocene-early Miocene. See sequence of conceptual drawings by West (198x).

Fig. 58 (next 4 pages). A series of schematic cross-sections showing how a thrust belt terrain can be tectonically inverted by succeeding tectonic extension. This example from West (1989, 1992, 1993) was based on his observations in the southern Overthrust Belt, south of Evanston, WY (the Bear River fault zone).

Step 1, geometry at the end of Sevier orogeny compression.

Step 2, beginning of Neogene east-west extension.

Step 3, normal slip (backsliding) begins on the low-angle detachment.

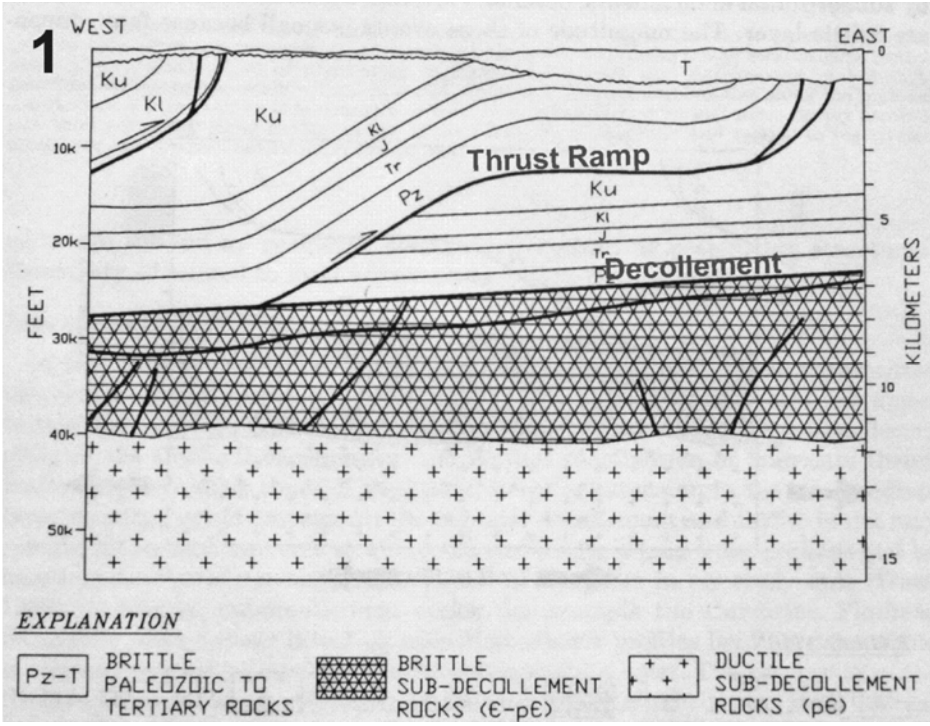
Step 4, normal slip (backsliding) begins on the thrust ramp.

Step 5, early Tertiary basins begins to form above the tip of the inverted thrust ramp; the normal ramp fault begins to grow up toward the surface.

Step 6, the normal ramp fault breaks through to the surface and begins to form a middle Tertiary basin; the inverted thrust ramp is tectonically beheaded, and becomes inactive. The detachment beneath the thrust ramp also ceases to slip.

Step 7, continued growth of the middle-late Tertiary extensional basin; planar faults in the crystalline basement beneath the detachment grow upward, displacing the detachment.

Step 8, planar fault breaks through to the surface, and begins to form a late Tertiary to Quaternary basin there. The normal ramp fault is beheaded and becomes inactive. This is the present geometry, based on patterns of instrumental seismicity and surface ruptures such as the Hebgen Lake (1959) and Borah Peak (1983) earthquakes.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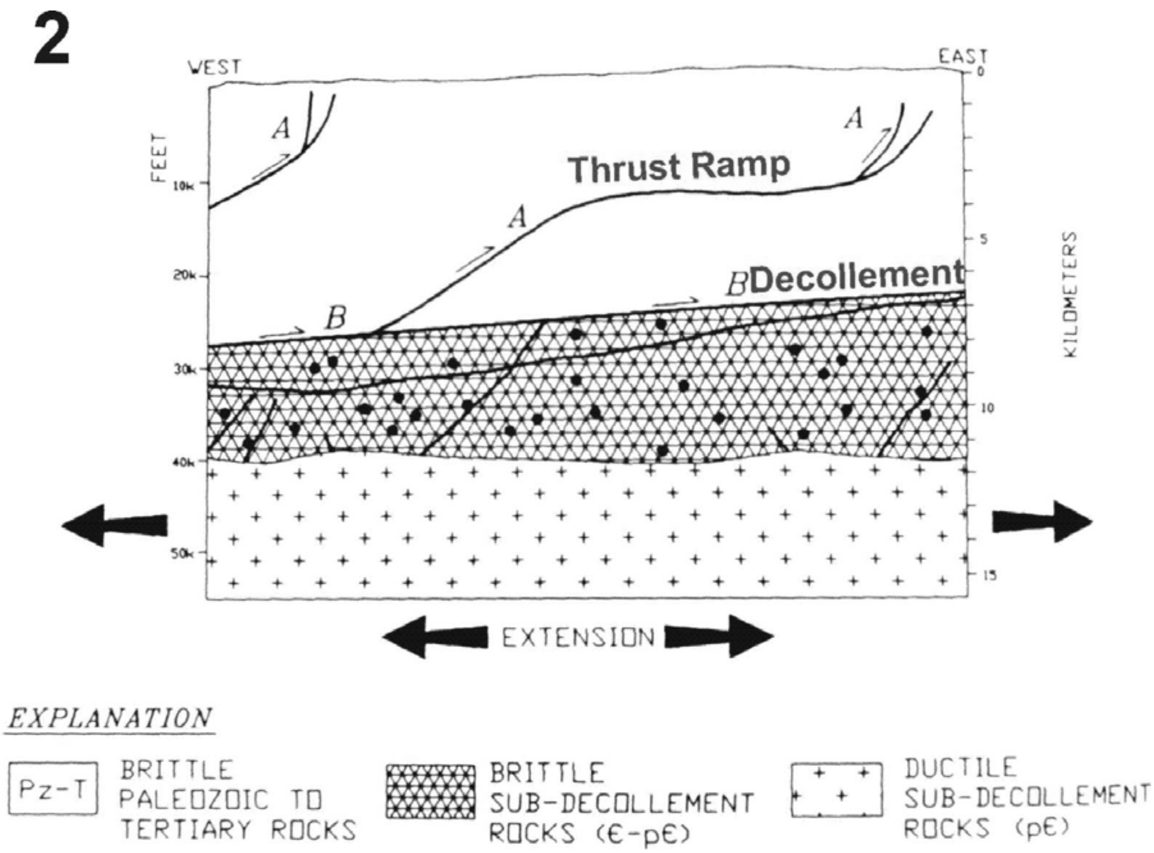
BRITTLE SUB-DECOLLEMENT ROCKS (Є-pЄ)
DUCTILE SUB-DECOLLEMENT ROCKS (pЄ)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KILOMETERS
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5
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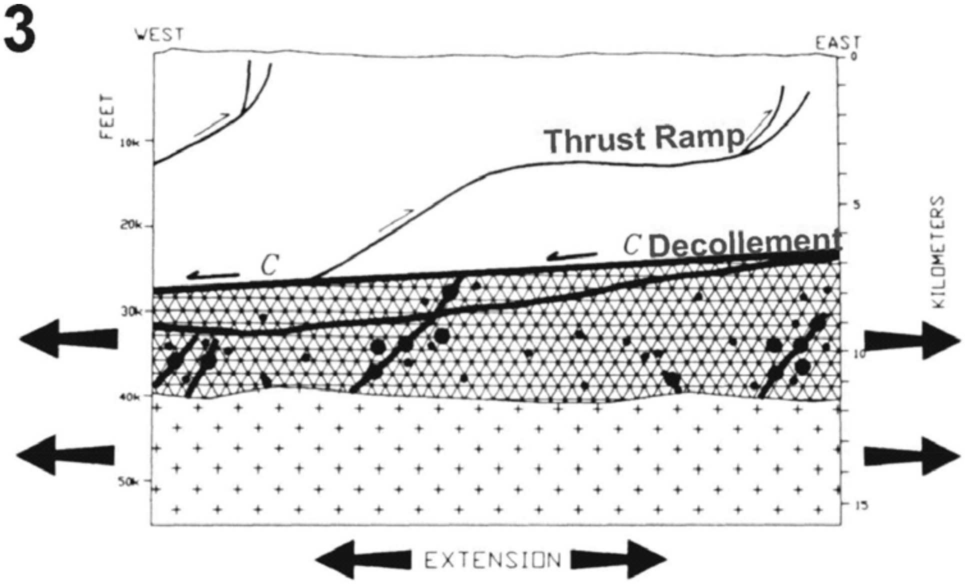
15
EXTENSION
EXPLANATION
Pz-T
BRITTLE PALEOZOIC TO TERTIARY ROCKS
BRITTLE SUB-DECOLLEMENT ROCKS (Є-pЄ)
DUCTILE SUB-DECOLLEMENT ROCKS (pЄ)

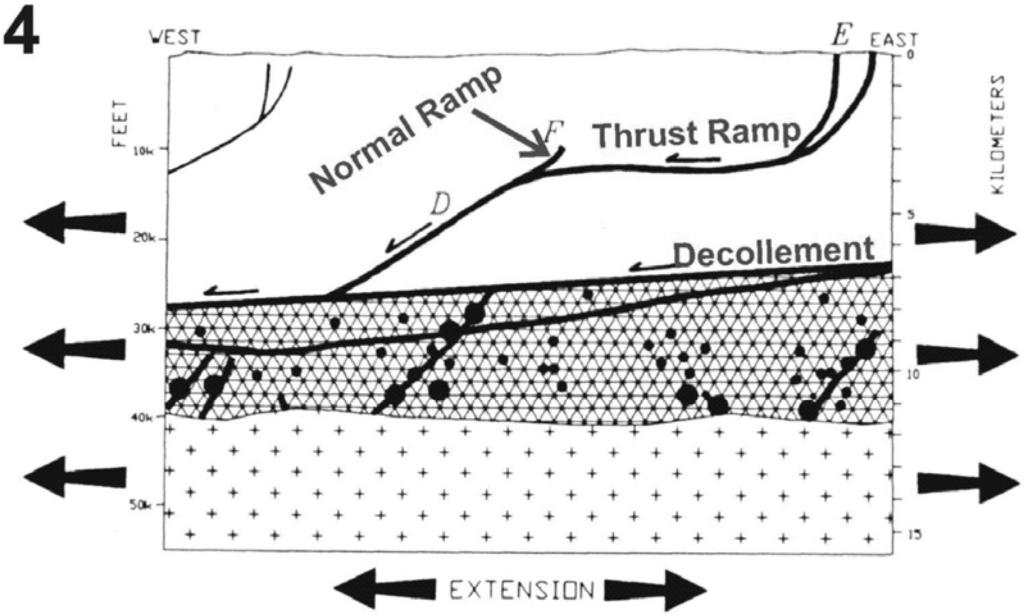
3



EXPLANATION

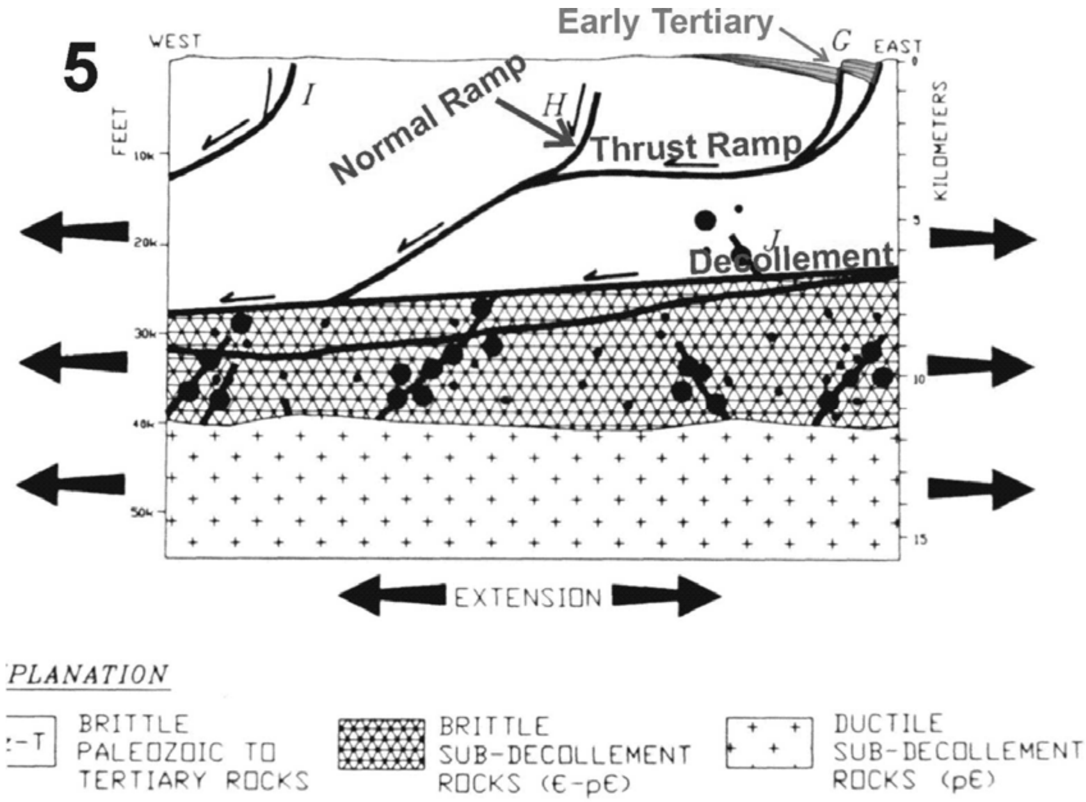
Pz-T — BRITTLE PALEOZOIC TO TERTIARY ROCKS	BRITTLE SUB-DECOLLEMENT ROCKS (Є-pЄ)	DUCTILE SUB-DECOLLEMENT ROCKS (pЄ)

4



(PLANATION

z-T — BRITTLE PALEOZOIC TO TERTIARY ROCKS	BRITTLE SUB-DECOLLEMENT ROCKS (Є-pЄ)	DUCTILE SUB-DECOLLEMENT ROCKS (pЄ)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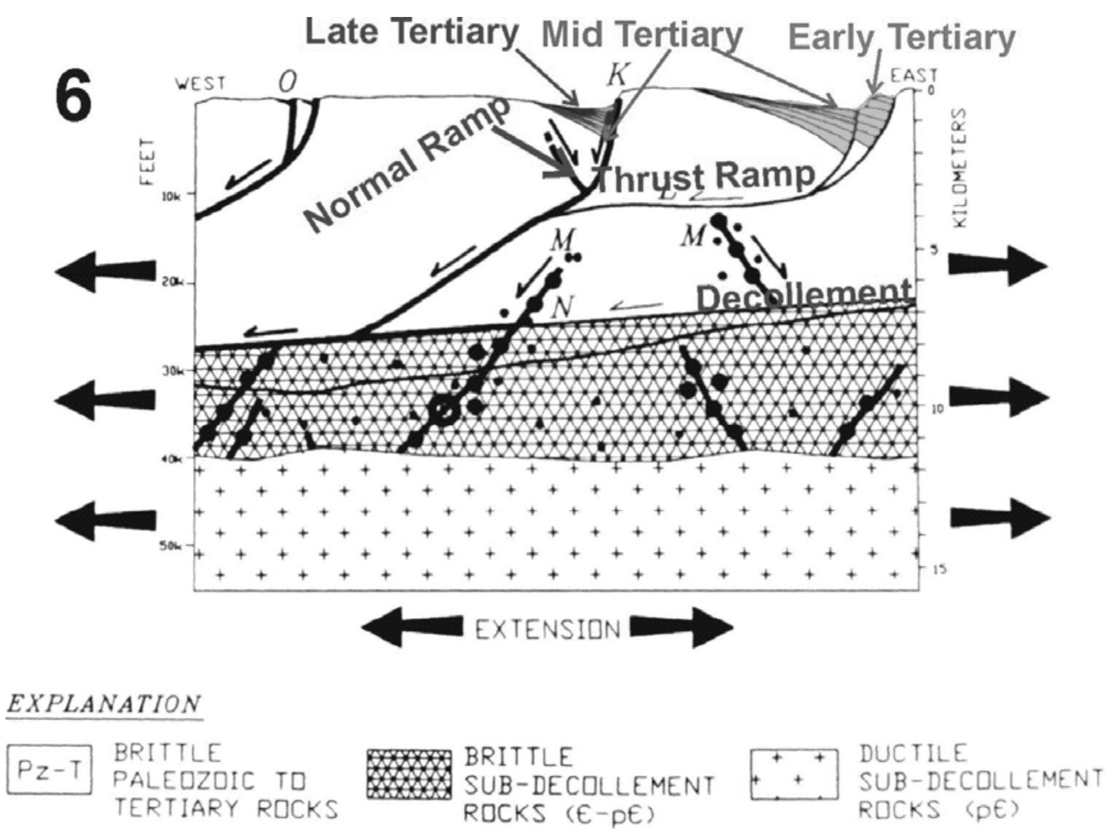
BRITTLE PALEOZOIC TO TERTIARY ROCKS
BRITTLE SUB-DECOLLEMENT ROCKS (Є-pЄ)
DUCTILE SUB-DECOLLEMENT ROCKS (pЄ)


6
WEST
EAST
Late Tertiary
Mid Tertiary
Early Tertiary
O
K
Normal Ramp
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L
M
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N
Decollement
FEET
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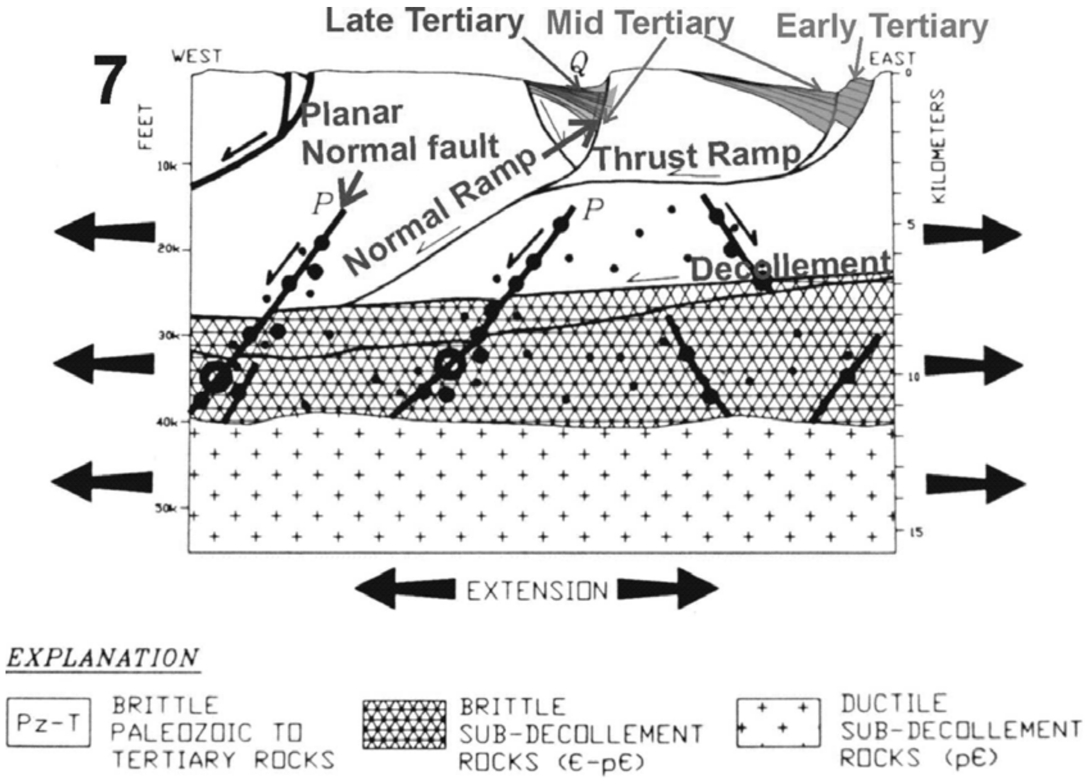
EXTENSION
EXPLANATION
Pz-T
BRITTLE PALEOZOIC TO TERTIARY ROCKS
BRITTLE SUB-DECOLLEMENT ROCKS (Є-pЄ)
DUCTILE SUB-DECOLLEMENT ROCKS (pЄ)


7
Late Tertiary
Mid Tertiary
Early Tertiary
WEST
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Q
FEET
KILOMETERS
Planar
Normal fault
Normal Ramp
Thrust Ramp
Decollement
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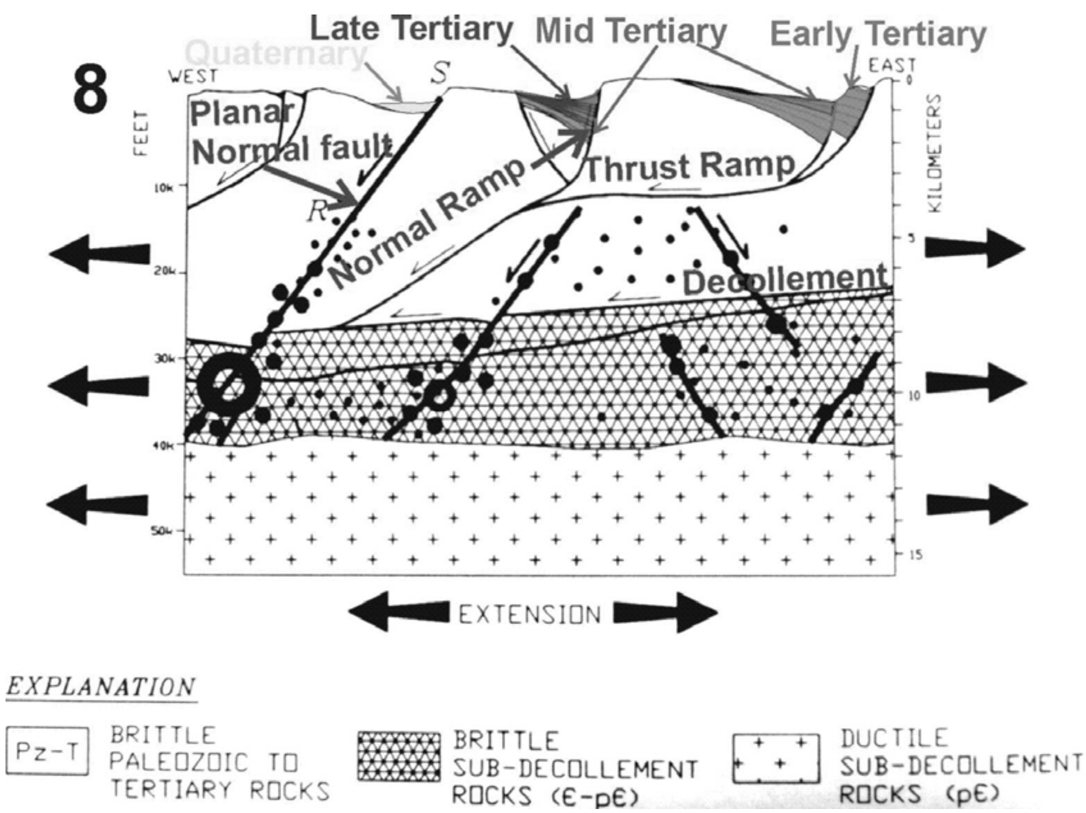
EXTENSION
EXPLANATION
Pz-T
BRITTLE PALEOZOIC TO TERTIARY ROCKS
BRITTLE SUB-DECOLLEMENT ROCKS (Є-pЄ)
DUCTILE SUB-DECOLLEMENT ROCKS (pЄ)


8
Late Tertiary
Mid Tertiary
Early Tertiary
Quaternary
WEST
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Planar
Normal fault
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EXTENSION
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BRITTLE PALEOZOIC TO TERTIARY ROCKS
BRITTLE SUB-DECOLLEMENT ROCKS (Є-pЄ)
DUCTILE SUB-DECOLLEMENT ROCKS (pЄ)

Continue upvalley on Sheep Creek Road.

Mi 56.0: STOP 2-9. (Al Jones)Roadcuts on left (N) side of road expose red conglomerates, probably Eocene Wasatch Formation (Tw). But Rubey maps this area only as containing QTf (Quaternary-Tertiary fanglomerate, the same unit mapped on the Greys River pediment surfaces). If the latter is true, we could use this QTf unit as a datum from which to measure the post-pediment vertical displacement across the Greys River fault.

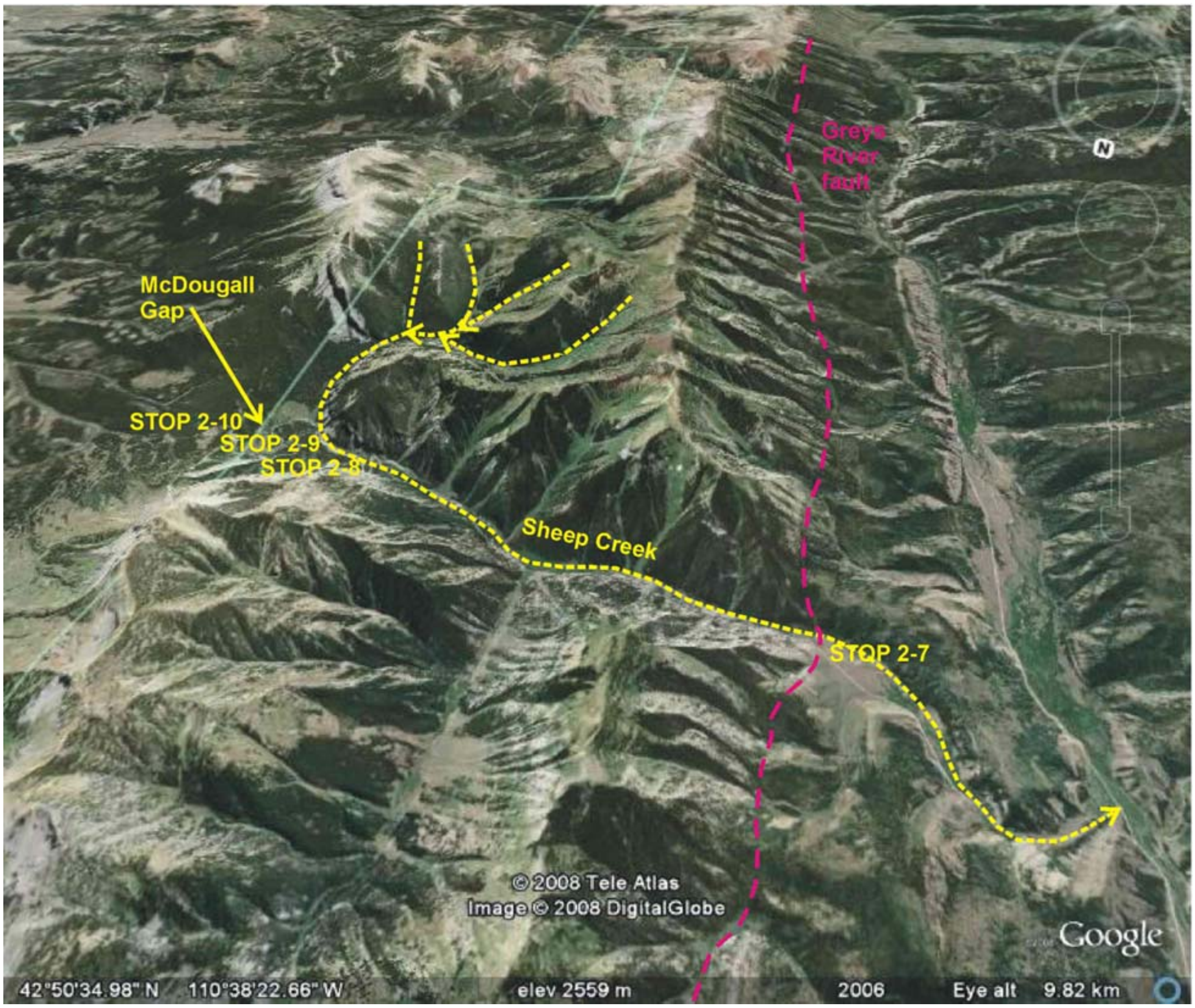

Fig. 59. Oblique satellite image of the course of Sheep Creek (yellow dashed line) as it cuts through the Wyoming Range; view is to the south.

Mi 56.0: STOP 2-10. McDougall Gap (Jim McCalpin). This is not a true "wind gap", because it contains the channel of Sheep Creek. However, drainages on the eastern flank of the Wyoming Range, like Sheep Creek, should drain eastward toward Big Piney. Presumably, Sheep Creek did just that at some time in the late Tertiary or early Quaternary.

Turn around and descend Sheep Creek Road to the west.

Mi 59.1: probable Pinedale terminal moraine of Sheep Creek, poorly preserved [531928mE/ 4743045mN].

Mi 64.9: junction of Sheep Creek Road with greys River Road; turn left (S)

Mi 67.6: Forest Park Campground (USFS); turn left (E) into campground. CAMPSITE FOR SUNDAY NIGHT.

ROAD LOG
Day 3
Reset trip meters to Zero!!

Mi 0.0: From Forest Park Campground, walk up jeep road to East which ascends to the pediment surface.

OPTIONAL STOP 3-1; pediment above Forest Park CG. (Jim McCalpin)

Depending on the condition of the road and the weather, we will try to drive up or walk up the old jeep road that leads from just north of the Forest Park CG, up to the surface of the high pediment surface of the Greys River Valley (unit QTf of Rubey, 1973). Our previous visits to the pediment surface in other locations have not shown very good exposures of the QTf “fanglomerate”, due to a lack of exposures on the pediments. However, if we can find a clearing near the edge, there will be great views of the Greys River Valley and the Salt River Range to the west.

An unanswered question is: what caused the incision of the pediment surface, and when did it happen? Was the incision caused by stream capture and base-level lowering from the lower Greys River (Snake River tributary) eroding headward into the upper Greys River? If so, where was the capture point? And where did the upper Greys River flow prior to the capture? Can the pediment be dated by cosmogenics??

Walk back to Forest Park CG. Drive out of the Campground and turn left (S) onto Greys River Road; proceed south.

Mi. 12.0: STOP 3-2. Box Canyon moraines and fault scarps (Al Jones).
-- INSERT BLURB HERE--

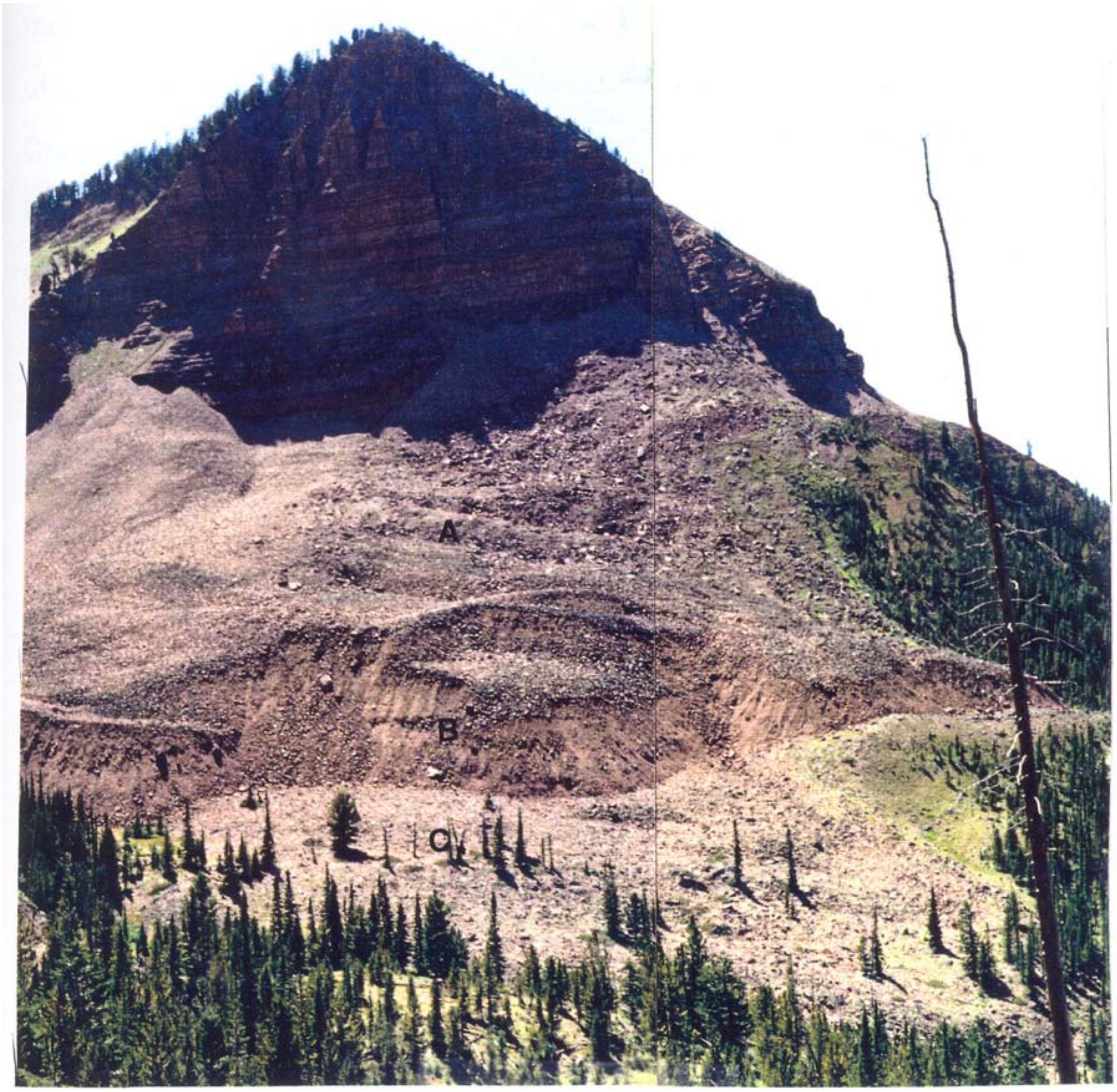

Figure 10. Photograph of a rock glacier in the Box Canyon Drainage. The picture was taken from the eastern headwall looking west. The rock glacier, moving toward the photographer, is protected from the sun by the unnamed peak in the center of the picture. The weathered upper-surface, the fresh leading edge, and the weathered lower-surface are indicated A, B, and C respectively.

Fig. 60.

Continue south on Greys River Road to junction with Smiths Fork Road at Poison Meadows. For those heading home to the SE, one travel option is to continue south from here on the LaBarge Road, rather than driving the Smiths Fork Road. For those heading home to the SW, W, or N, and for those who dropped off their cars 3 days ago, take the Smiths Fork Road over Commissary Ridge.

Mi 42.0: USFS kiosk on the Smiths Fork Road; pick up vehicles and disperse.

REFERENCES (major sources of this Guidebook in bold)

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Rubey, W.W., 1973, Geologic map of the Afton Quadrangle and part of the Big Piney Quadrangle, Lincoln and Sublette counties, Wyoming: USGS Map I-686, 1:62,500.

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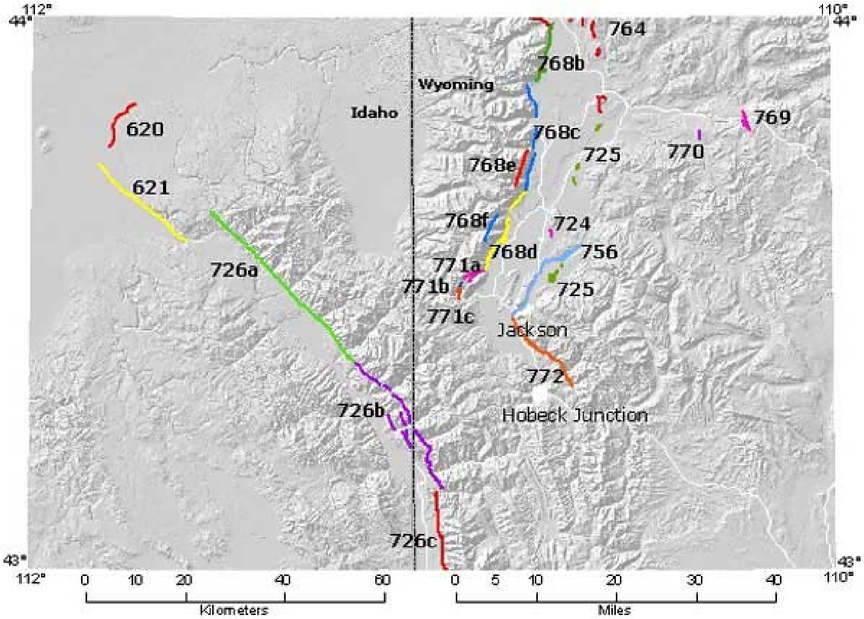
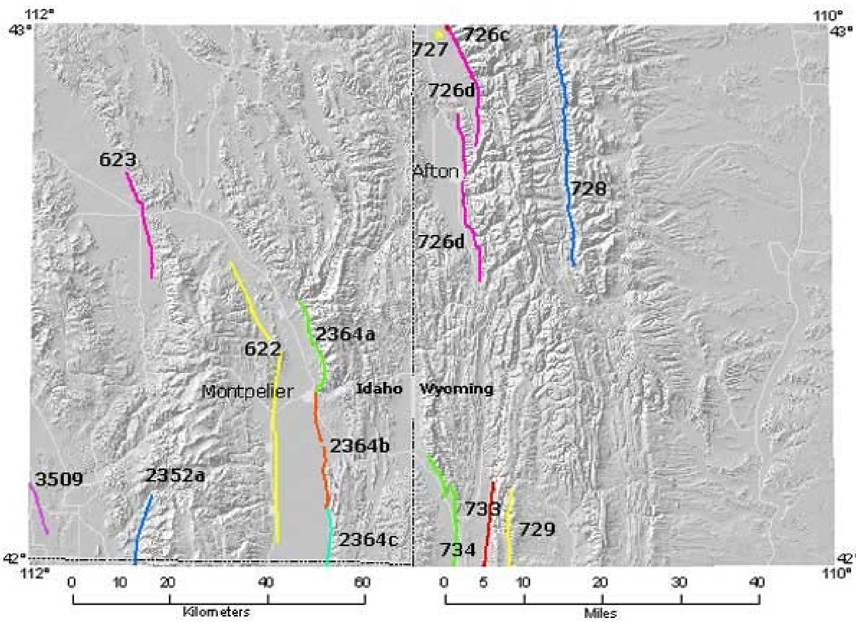
Zuchiewicz, W. and McCalpin, J.P., 2000, Geometry of faceted spurs on an active normal fault; case study of the central Wasatch fault, Utah, USA: Annales Societatis Geologorum Poloniae, v. 70, p. 231-249.

Appendix 1. Maps of faults from the USGS Quaternary Fault and Fold database (http://earthquake.usgs.gov/regional/qfaults/wy/drg.html





http://earthquake.usgs.gov/regional/qfaults/wy/prs.html

Fault Colors	Age of Latest Movement	
	Geologic Period	Numerical Age
red	Holocene and post-glacial	<15 ka
purple	late Quaternary	<150 ka
green	middle to late Quaternary	<500 ka
blue	Quaternary	< 1.5 Ma
yellow	late Cenozoic	<20 Ma

APPENDIX 2: USGS reports on Quaternary faults

Complete Report for Grand Valley fault, Star Valley section (Class A) No. 726d

Brief Report ||Partial Report

citation for this record: McCalpin, J.P., Machette, M.N., and Haller, K.M., compilers, 1994, Fault number 726d, Grand Valley fault, Star Valley section, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/regional/qfaults, accessed 08/17/2008 02:51 PM.

Synopsis	**General:** This long fault extends from Idaho into Wyoming along the western base of the Snake and Salt River Ranges. **Sections:** This fault has 4 sections. Detailed mapping and limited trenching suggest that the fault has four segments and an additional poorly characterized part of the fault that suggest different rates of Quaternary displacement and apparently different paleoseismic histories. Those segments are herein considered as informerally named sections in accordance with this compilation. From north to south they are the Swan Valley section [726a], the Grand Valley section [726b], the Prater Mountain section [726c], and the Star Valley section [726d]. The southernmost, the youngest and most active, records recurrent Holocene movement. The northern part of the fault is outside the Intermountain Seismic Belt and the southern part is within this active belt; furthermore, faulting on the northern part is clearly older and less frequent than to the south.
Name comments	**General:** Name of fault and its sections are modified from Piety and others (1992 #538). Earlier workers in the area restricted the use of "Grand Valley fault" to the part of the structure in Idaho, the southern extension in Wyoming was known as the "Star Valley fault." Preference for the single name as used by Piety and others (1992 #538) is given here. The Grand Valley fault extends from about 26 km southeast of Pocatello, Idaho, south to about 22 km south of Afton, Wyoming. **Section:** The section was defined by Piety and others (1992 #538) as extending from Prater Canyon south to 1 km north of the Salt River (as shown by Warren, 1992 #837). This part of the fault bounds two distinct structural and physiographic basins of approximately equal size (Piety and others, 1986 #55). Furthermore, the topographic high separating these two basins near

	"The Narrows" is coincident with a 4-km right step in the trace of the fault. The Star Valley section includes both parts of the Star Valley fault of Witkind (1975 #819) in Wyoming. Piety and others (1986 #55) suggested that the southern 27 km of the Grand Valley fault is characterized by similar faulting histories on either side of the echelon step. **Fault ID Comments:** Refers to number 22 (Grand Valley fault, Idaho) of Witkind (1975 #320) and numbers 20 and 21 (Star Valley fault, Wyoming) of Witkind (1975 #819).
County(s) and State(s)	LINCOLN COUNTY COUNTY, WYOMING
AMS sheet(s)	Preston
Physiographic province(s)	MIDDLE ROCKY MOUNTAINS
Reliability of location	Good Compiled at 1:250,000 scale. *Comments:* Fault location taken from 1:24,000-scale maps of Warren (1992 #837) and 1:275,000-scale map of Piety and others (1992 #538).
Geologic setting	Down-to-west range-front normal fault that extends from near the Snake River Plain southward along the western base of the Snake and Salt River Ranges. Basin fill is estimated to be 2 to 3 km thick based on seismic reflection data (Royse and others, 1975 #4391; Dixon, 1982 #4382).
Length (km)	This section is 52 km of a total fault length of 136 km.
Average strike	N8°W (for section) versus N22°W (for whole fault)
Sense of movement	Normal *Comments:* (Piety and others, 1986 #55; Piety and others, 1992 #538)
Dip	10°-70° W. *Comments:* According to cross-section 1 of Webel (1987 #815), the fault dips 70° near the surface, but progressively flattens and merges with the Absaroka thrust fault (dip 10° W.) at a depth of about 12 km.
Paleoseismology studies	[726-1] Warren (1992 #837) trenched an 11-m-high scarp 0.8 km south of Swift Creek (the Afton trench site). The exposed stratigraphy suggests that three latest Quaternary earthquakes occurred at about 5,540±70 14C yr BP (3 m of slip), 8,090±80 14C yr BP (4 m of slip), and about 12-15 ka (4 m slip). McCalpin (1993 #796) reported that the earliest (third) event at the site occurred between 14 and 15.5 ka.
Geomorphic expression	Isolated fault scarps are present on late Quaternary alluvial fans at the mouths of major valleys (Piety and others, 1992 #538). These scarps tend

	to fall into to one of two size classes: 5-6 m high and 11-15 m high suggesting multiple times of movement on different age landscapes. Elsewhere, the fault is at the abrupt alluvial bedrock contact and few scarps exist beyond the mouths of the narrow channel valleys.
Age of faulted surficial deposits	Holocene and late Pleistocene alluvial fans along the eastern margin of Star Valley.
Historic earthquake	
Most recent prehistoric deformation	Latest Quaternary (<15 ka) *Comments:* Warren (1992 #837) dated the most recent paleoearthquake as mid-Holocene at about 5540±70 14C yr BP; these data are reiterated by McCalpin (1993 #796).
Recurrence interval	>5.5 k.y. (<5.5 ka); 2.4-2.7 k.y. (5.5-8 ka); 4-7 k.y. (8 to 14.5-15 ka) *Comments:* Warren (1992 #837) documented two recurrence intervals from his three dated events. The most recent recurrence interval was 2,400-2,700 14C yr, preceded by a less well constrained interval of about 4-7 k.y. However, since most recent event occurred at about 5,540±70 14C yr BP, the present interval of quiescent suggests that recurrence intervals can be longer than 5.5 k.y., which appears to be the criteria used by Mason (1992 #463) to suggest that the repeat time between earthquakes on this section is 5±2.4 k.y. based on data presented by Piety and others (1986 #55).
Slip-rate category	Between 0.2 and 1.0 mm/yr *Comments:* Warren (1992 #837) reported a late Quaternary slip rate of 0.73-0.91 mm/yr. This rate must be derived from the cumulative slip of the two most recent events (7 m) and the time interval between about 5.5 ka and 12-15 ka. Earlier, Piety and others (1986 #55; 1992 #538) and then Anders and others (1990 #409) suggested that the latest Quaternary (<15 ka) slip rate for the Star Valley section is 0.6-1.1 mm/yr based on 8.3-11.6 m high scarps on 11-15 ka deposits. Interestingly the slip rate on this part of the fault is comparable to that on the Swan Valley section during the interval from 2.0-4.4 Ma. Wong and others (2000 #4484) suggested fault slip rates ranging from 0.026 to 2.3 mm/yr, with maximum weighting of 60% on a value of 1.1 mm/yr. These reported slip rates are based on a combination of data from Anders and others (1990 #409), Piety and others (1986 #55; 1992 #538), and McCalpin (1993 #796). The late Quaternary characteristics of this fault (overall geomorphic expression, continuity of scarps, age of faulted deposits, etc.) suggest the slip rate during this period is probably less than the 1.1 mm/yr that Wong and others (2000 #4484) favored. Because most of the reported slip rates are less than 1 mm/yr (especially the younger ones), we assign the 0.2-1 mm/yr slip-rate category to this section of the Grand Valley fault.
Date and	1994

Compiler(s)	James P. McCalpin, GEO-HAZ Consulting, Inc. Michael N. Machette, U.S. Geological Survey Kathleen M. Haller, U.S. Geological Survey
References	#409 Anders, M.H., Rodgers, D.W., McCalpin, J.P., and Haller, K.M., 1990, Late Tertiary and Quaternary faulting north and south of the eastern Snake River Plain, in Roberts, S., ed., Geologic field tours of western Wyoming: Geological Survey of Wyoming Public Information Circular 29, p. 1-38. #4382 Dixon, J.S., 1982, Regional structural synthesis, Wyoming salient of Western Overthrust belt: American Association of Petroleum Geologists Bulletin, v. 66, p. 1560-1580. #463 Mason, D.B., 1992, Earthquake magnitude potential of active faults in the Intermountain seismic belt from surface parameter scaling: Salt Lake City, University of Utah, unpublished M.S. thesis, 110 p. #796 McCalpin, J.P., 1993, Neotectonics of the northeastern Basin and Range margin, western USA: Zeitschrift fuer Geomorphologie N. Folge, v. 94, p. 137-157. #538 Piety, L.A., Sullivan, J.T., and Anders, M.H., 1992, Segmentation and paleoseismicity of the Grand Valley fault, southeastern Idaho and western Wyoming, in Link, P.K., Kuntz, M.A., and Platt, L.B., eds., Regional geology of eastern Idaho and western Wyoming: Geological Society of America Memoir 179, p. 155-182. #55 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: Bureau of Reclamation Seismotectonic Report 86-3, 198 p., 2 pls. #4391 Royse, F.J., Warner, M.A., and Reese, D.L., 1975, Thrust belt structural geometry and related stratigraphic problems Wyoming-Idaho-northern Utah, in Bolyard, D.W., ed., Deep drilling frontiers of the central Rocky Mountains: Denver, Colorado, Rocky Mountain Association of Geologists--1975 Symposium, p. 41-54. #837 Warren, G.A., 1992, Quaternary geology and neotectonics of southern Star Valley and the southwest flank of the Salt River Range, western Wyoming: Logan, Utah State University, unpublished M.S. thesis, 96 p., 3 pls., scale 1:24,000. #815 Webel, S., 1987, Significance of backthrusting in the Rocky Mountain thrust belt, in Miller, W.R., ed., The thrust belt revisited: Wyoming Geological Association, 38th Annual Field Conference, Jackson

	Hole, Wyoming, September 8-11, 1987, Guidebook, p. 37-53. #819 Witkind, I.J., 1975, Preliminary map showing known and suspected active faults in Wyoming: U.S. Geological Survey Open-File Report 75-279, 35 p. pamphlet, 1 sheet, scale 1:500,000. #320 Witkind, I.J., 1975, Preliminary map showing known and suspected active faults in Idaho: U.S. Geological Survey Open-File Report 75-278, 71 p. pamphlet, 1 sheet, scale 1:500,000. #4484 Wong, I., Olig, S., and Dober, M., 2000, Preliminary probabilistic seismic hazard analyses--Island Park, Grassy Lake, Jackson Lake, Palisades, and Ririe Dams: U.S. Department of the Interior, Bureau of Reclamation Technical Memorandum D8330-2000-17.

Complete Report for Grand Valley fault, Prater Mountain section (Class A) No. 726c

Brief Report ||Partial Report

citation for this record: **McCalpin, J.P., Machette, M.N., and Haller, K.M., compilers, 1994, Fault number 726c, Grand Valley fault, Prater Mountain section, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/regional/qfaults, accessed 08/17/2008 02:49 PM.**

Synopsis	**General:** This long fault extends from Idaho into Wyoming along the western base of the Snake and Salt River Ranges. **Sections:** This fault has 4 sections. Detailed mapping and limited trenching suggest that the fault has four segments and an additional poorly characterized part of the fault that suggest different rates of Quaternary displacement and apparently different paleoseismic histories. Those segments are herein considered as informerally named sections in accordance with this compilation. From north to south they are the Swan Valley section [726a], the Grand Valley section [726b], the Prater Mountain section [726c], and the Star Valley section [726d]. The southernmost, the youngest and most active, records recurrent Holocene movement. The northern part of the fault is outside the Intermountain Seismic Belt and the southern part is within this active belt; furthermore, faulting on the northern part is clearly older and less frequent than to the south.
Name comments	**General:** Name of fault and its sections are modified from Piety and others (1992

	#538). Earlier workers in the area restricted the use of "Grand Valley fault" to the part of the structure in Idaho, the southern extension in Wyoming was known as the "Star Valley fault." Preference for the single name as used by Piety and others (1992 #538) is given here. The Grand Valley fault extends from about 26 km southeast of Pocatello, Idaho, south to about 22 km south of Afton, Wyoming. **Section:** Piety and others (1992 #538) do not name this part of the fault or include it in discussions of other segments (sections). They suggested that this part of the fault may have not ruptured with adjacent segments and thus has a unique faulting history. This informally named section as shown herein extends from Greys River (location of northern boundary explained in section 726b) south to Prater Canyon, and is located near Prater Mountain. **Fault ID Comments:** Refers to number 22 (Grand Valley fault, Idaho) of Witkind (1975 #320) and numbers 20 and 21 (Star Valley fault, Wyoming) of Witkind (1975 #819).
County(s) and State(s)	LINCOLN COUNTY COUNTY, WYOMING
AMS sheet(s)	Driggs Preston
Physiographic province(s)	MIDDLE ROCKY MOUNTAINS
Reliability of location	Poor Compiled at 1:250,000 scale. *Comments:* Location of fault poorly located (concealed) on 1:200,000-scale map without topography of Piety and others (1992 #538, fig. 5).
Geologic setting	Down-to-west range-front normal fault that extends from near the Snake River Plain southward along the western base of the Snake and Salt River Ranges. Basin fill is estimated to be 2 to 3 km thick based on seismic reflection data (Royse and others, 1975 #4391; Dixon, 1982 #4382).
Length (km)	This section is 17 km of a total fault length of 136 km.
Average strike	N7°W (for section) versus N22°W (for whole fault)
Sense of movement	Normal *Comments:* (Piety and others, 1992 #538)
Dip	
Paleoseismology studies	

Geomorphic expression	
Age of faulted surficial deposits	Piety and others (1992 #538) stated that loess-covered alluvial surfaces of about 70 ka age at the range front are not displaced. However, between Prater Canyon and Dry Creek, loess-covered alluvial fans of about 70-130 ka age at the range front are displaced.
Historic earthquake	
Most recent prehistoric deformation	Late Quaternary (<130 ka) *Comments:* Age assignment based on data presented by Piety and others (1992 #538) that suggest that at least part of this section has ruptured since 130 ka.
Recurrence interval	40±30 k.y. *Comments:* Mason (1992 #463) suggested a repeat time between earthquakes of 40±30 k.y. on this section. This was based on data presented by Anders and others (1989 #408) that indicated the most recent event occurred between 10 k.y. and 70 k.y. This recurrence interval is not constrained on the young side and may not be a representative of an earthquake cycle. In addition, based on the time of most recent movement indicated by Piety and others (1992 #538), the above stated recurrence interval is too short and does not realistically represent the interval since the last event.
Slip-rate category	Less than 0.2 mm/yr *Comments:* Low slip-rate category assigned based on the absence of scarps on 70 ka deposits (Piety and others, (1992 #538).
Date and Compiler(s)	1994 James P. McCalpin, GEO-HAZ Consulting, Inc. Michael N. Machette, U.S. Geological Survey Kathleen M. Haller, U.S. Geological Survey
References	#408 Anders, M.H., Geissman, J.W., Piety, L.A., and Sullivan, J.T., 1989, Parabolic distribution of circumeastern 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. #4382 Dixon, J.S., 1982, Regional structural synthesis, Wyoming salient of Western Overthrust belt: American Association of Petroleum Geologists Bulletin, v. 66, p. 1560-1580. #463 Mason, D.B., 1992, Earthquake magnitude potential of active faults in the Intermountain seismic belt from surface parameter scaling: Salt Lake City, University of Utah, unpublished M.S. thesis, 110 p.

	#538 Piety, L.A., Sullivan, J.T., and Anders, M.H., 1992, Segmentation and paleoseismicity of the Grand Valley fault, southeastern Idaho and western Wyoming, in Link, P.K., Kuntz, M.A., and Platt, L.B., eds., Regional geology of eastern Idaho and western Wyoming: Geological Society of America Memoir 179, p. 155-182. #4391 Royse, F.J., Warner, M.A., and Reese, D.L., 1975, Thrust belt structural geometry and related stratigraphic problems Wyoming-Idaho-northern Utah, in Bolyard, D.W., ed., Deep drilling frontiers of the central Rocky Mountains: Denver, Colorado, Rocky Mountain Association of Geologists--1975 Symposium, p. 41-54. #160 Smith, R.B., and Sbar, M.L., 1974, Contemporary tectonics and seismicity of the Western United States with emphasis on the Intermountain seismic belt: Geological Society of America Bulletin, v. 85, p. 1205-1218. #320 Witkind, I.J., 1975, Preliminary map showing known and suspected active faults in Idaho: U.S. Geological Survey Open-File Report 75-278, 71 p. pamphlet, 1 sheet, scale 1:500,000. #819 Witkind, I.J., 1975, Preliminary map showing known and suspected active faults in Wyoming: U.S. Geological Survey Open-File Report 75-279, 35 p. pamphlet, 1 sheet, scale 1:500,000.

Complete Report for Greys River fault (Class A) No. 728

Brief Report ||Partial Report

***citation for this record:* McCalpin, J.P., compiler, 1994, Fault number 728, Greys River fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/regional/qfaults, accessed 08/17/2008 02:46 PM.**

Synopsis	Complex fault scarps in densely-forested terrain at the base of a steep range front. Data from three trenches at one location indicate that similar amounts of slip have characterized the past two faulting events; however, the history of faulting suggests highly variable recurrence intervals during the late

	Quaternary.
Name comments	Originally mapped but unnamed by Rubey (1973 #822). Name first used by Jones and McCalpin (1992 #813) and informally introduced by McCalpin (1993 #796). Fault extends from about 1 km south of Blind Trail Creek south to the East Fork of the Greys River as shown by Rubey (1973 #822) and Jones (1995 #3910). **Fault ID Comments:** Not shown on any previous compilation.
County(s) and State(s)	LINCOLN COUNTY COUNTY, WYOMING
AMS sheet(s)	Preston
Physiographic province(s)	MIDDLE ROCKY MOUNTAINS
Reliability of location	Good Compiled at 1:250,000 scale. *Comments:* Fault location from 1:62,500-scale mapping of Rubey (1973 #822), supplemented by unpublished 1:24,000-scale mapping that was recompiled at 1:48,000 scale by Jones (1995 #3910). Although Rubey's mapping stopped at 43° N, the study by Jones (1995 #3910) supports a northern termination of the Quaternary fault at this same latitude. Fault traces were recompiled at 1:250,00 scale on a topographic base map.
Geologic setting	This high-angle down-to-west normal fault bounds the west side of the Wyoming Range. Fault probably soles into the Laramide-age Darby thrust fault. McCalpin (1993 #796) indicated that the throw of the fault may be 300-1000 m based on cross sections of Rubey (1973 #822).
Length (km)	50 km.
Average strike	N3°W
Sense of movement	Normal *Comments:* Normal movement indicated by Rubey (1973 #822).
Dip	10°-70° W. *Comments:* According to cross section 1 (fig. 14) of Webel (1987 #815), the fault dips 70° at the surface and joins the Laramide-age Darby thrust at depth of about 2 km, the latter of which flattens progressively to less than 10° at depth of 8.2 km.
Paleoseismology studies	Site 728-1. Jones and McCalpin (1992 #813) excavated three trenches across fault scarps on upper Pleistocene outwash deposits at Sheep Creek, a tributary to the Grey's River. The trenches revealed evidence of one late and one middle Holocene earthquake; their timing is constrained by eight

	radiocarbon ages. No stratigraphic evidence for earlier earthquakes was present, even though the trenched deposits are thought to be about 15 ka. The most recent faulting event resulted in about 5 m of slip and the earlier event about 4.3 m of slip.
Geomorphic expression	Fault scarps generally are 3- to 11-m high (Jones and McCalpin, 1992 #813); along most of the range front, complex step faults are present in bedrock-cored colluvium.
Age of faulted surficial deposits	Upper Triassic and Jurassic bedrock is in fault contact with Permian-Pennsylvanian or lower Triassic bedrock along most of the length of the fault; locally Triassic bedrock is faulted as mapped by Rubey (1973 #822).
Historic earthquake	
Most recent prehistoric deformation	Latest Quaternary (<15 ka) *Comments:* The most recent event is late Holocene: it is bracketed by radiocarbon ages of 1,910±60 14C yr BP and 2,110±60 14C yr BP (Jones and McCalpin, 1992 #813; McCalpin, 1993 #796).
Recurrence interval	2,970-3,400 14C yr (about 2.0-5.2 ka) *Comments:* Recurrence interval from Jones and McCalpin (1992 #813) based on dated paleoearthquakes at 1,910-2,110 14C yr BP and 5,080-, 14C yr BP. This short recurrence interval suggests an earthquake cluster (two closely spaced events) that may not be characteristic of the longer late Quaternary history of the fault. However, no displacement occurred between about 5 ka and 15 ka. This 10-k.y. interval of quiescence implies considerable variability in recurrence times (McCalpin, 1993 #796).
Slip-rate category	Between 0.2 and 1.0 mm/yr *Comments:* No slip rate is published, but the most recent displacement of 5 m occurred after an interval of 2970-3400 14C yrs suggests moderately high slip rates. This short recurrence interval suggests an earthquake cluster (two closely spaced events) that may not be characteristic of the longer late Quaternary slip rate of the fault. In fact, inferred late Quaternary slip rates are much lower because of the variability in the recurrence intervals. The previous 4.3 m of slip occurred over an interval of more than 10 k.y., which results in much lower possible slip rate that are consistent with the assigned slip-rate category. Wong and others (2000 #4484) suggested fault slip rates ranging from 0.04-1.9 mm/yr, each with separate weighting. These reported slip rates are based on data of McCalpin (1992 #813). They place a 60% weighting on a rate of 0.7 mm.yr, which we consider to be a maximum rate for the late Quaternary. Considering the above discussion and the evidence for an earthquake cluster in the middle Holocene, we categorize the Greys River fault in the 0.2-1.0 mm/yr bracket and recognize that it may have considerably faster slip rates over short intervals of geologic time (several thousand years). A similar treatment was afforded the nearby Rock Creek

	fault [729].
Date and Compiler(s)	1994 James P. McCalpin, GEO-HAZ Consulting, Inc.
References	#3910 Jones, L.C.A., 1995, The Quaternary geology of the eastern side of the Greys River Valley and the neotectonics of the Greys River fault in western Wyoming: Logan, Utah State University, unpublished M.S. thesis, 116 p., 7 pls., scale 1:48,000. #813 Jones, L.C.A., and McCalpin, J.P., 1992, Quaternary faulting on the Grey's River fault, a listric normal fault in the overthrust belt of Wyoming: Geological Society of America Abstracts with Programs, v. 24, no. 6, p. 20. #796 McCalpin, J.P., 1993, Neotectonics of the northeastern Basin and Range margin, western USA: Zeitschrift fuer Geomorphologie N. Folge, v. 94, p. 137-157. #822 Rubey, W.W., 1973, Geologic map of the Afton quadrangle and part of the Big Piney quadrangle, Lincoln and Sublette Counties, Wyoming: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-686, 2 sheets, scale 1:62,500. #815 Webel, S., 1987, Significance of backthrusting in the Rocky Mountain thrust belt, in Miller, W.R., ed., The thrust belt revisited: Wyoming Geological Association, 38th Annual Field Conference, Jackson Hole, Wyoming, September 8-11, 1987, Guidebook, p. 37-53.