HKT 2019 – Tectonic Tour of the Region Surrounding Yellowstone and Grand Teton National Parks

HKT 2019 (Bozeman): Post-Conference Field Trip Guide

Tectonic Tour of the Region Surrounding Yellowstone and Grand Teton National Parks

Field trip leaders:
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Background:
Bozeman lies at the complex tectonic intersection of three major North American Phanerozoic tectonic provinces—the Sevier fold-thrust belt, Laramide province, and Basin and Range. These provinces overlap Precambrian basement, including the Mesoproterozoic Belt Basin and a Paleoproterozoic collisional suture zone involving Archean cratons. The **post-conference field trip** will focus on the world-class volcano-tectonic geology of Yellowstone National Park and the overlap of Basin and Range extension with the Laramide and fold-thrust provinces of western Wyoming near Jackson Hole and Grand Teton National Park.

Field trip safety rules:

1. Wear seatbelts at all times in the vehicles.
2. Listen to all instructions from your drivers before exiting the vehicles.
3. Please do not stand on or near active roadways with traffic; follow your field trip leaders and stay well away from roads.
4. If we do have to cross a road, please do so quickly and never stand or linger in the road, and be aware of cars/trucks at all times.
5. Some stops will involve short hikes; please walk carefully and do not stray from the group very far.
6. If you are examining rocks on a slope, watch your footing. Avoid climbing up slopes with loose rocks that can roll or fall on people below.
7. Please listen to and follow all instructions from your field trip leaders.
8. Please respect the environment and do not litter or disturb plants and animals. There may be rattlesnakes at some stops, so follow instructions of your field trip leaders.
9. Please – no alcohol or smoking in the vehicles or during the field trip (evenings are excluded).
10. We will conduct a “head count” for each vehicle before departing from a stop.
11. **SAFETY FIRST – at all times**

Day #1 – Saturday, June 8, 2019 ⇨ Bozeman to Ennis, Madison Valley, Quake Lake, Raynolds Pass, Island Park, Island Park volcanic caldera, Victor, Driggs, Teton Pass, Jackson Hole, Hoback River Canyon, University of Michigan field camp

Day #2 – Sunday, June 9, 2019 ⇨ Jackson Hole and Grand Teton National Park, South Entrance to YNP, Old Faithful, Madison River caldera rim, West Yellowstone, Gallatin River Canyon, Bozeman

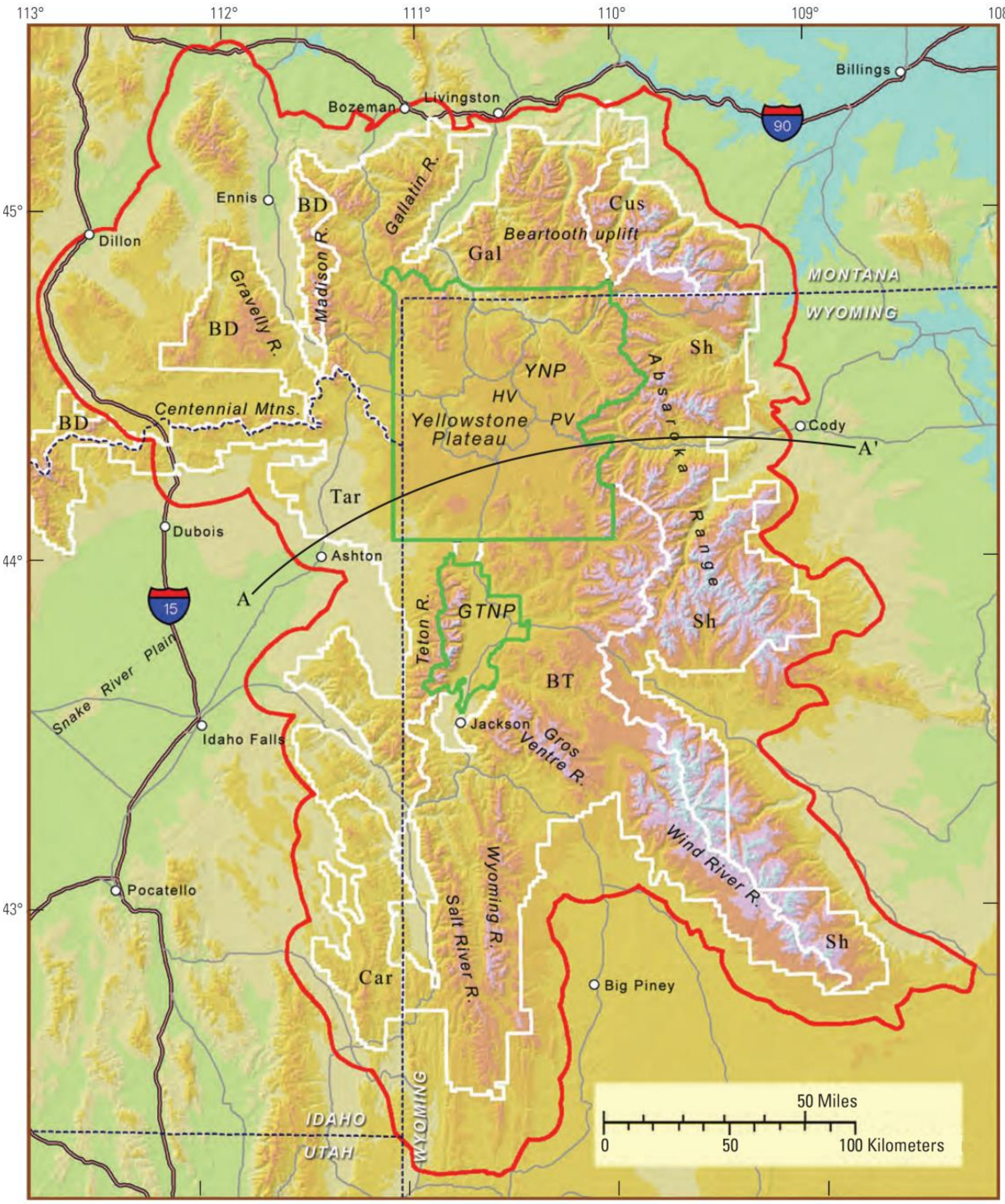
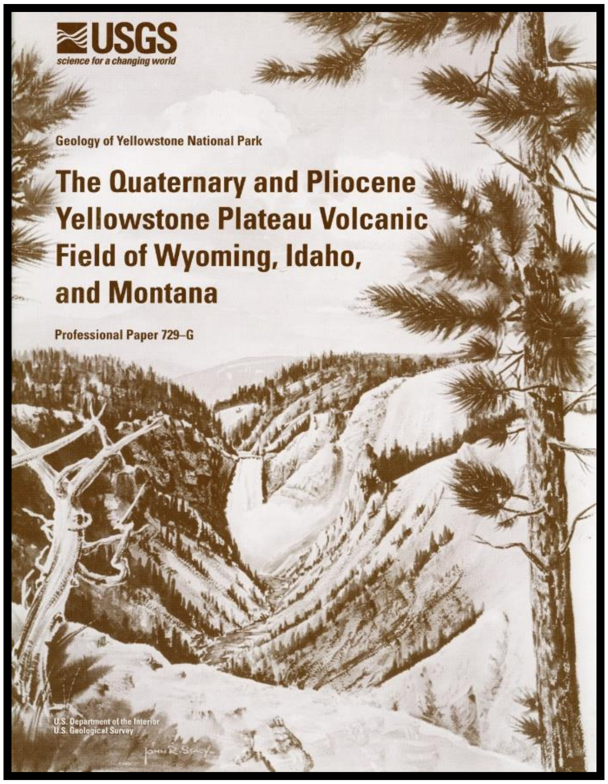
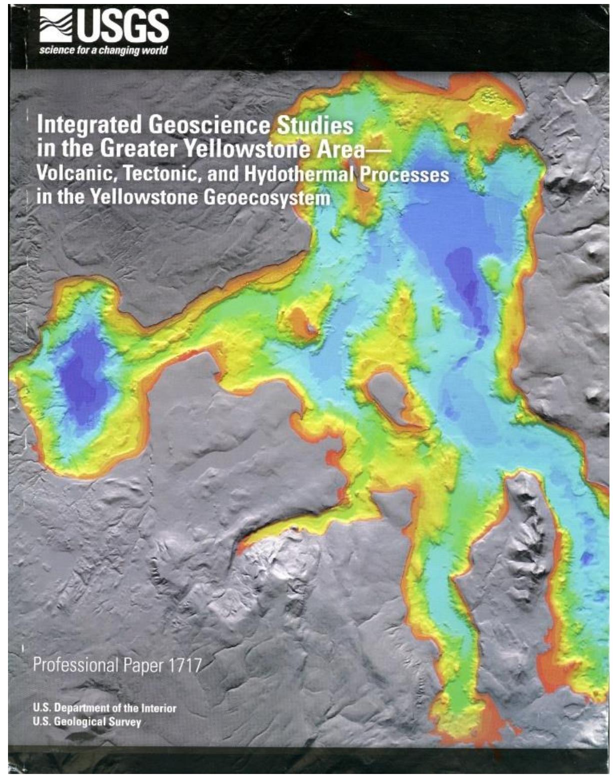
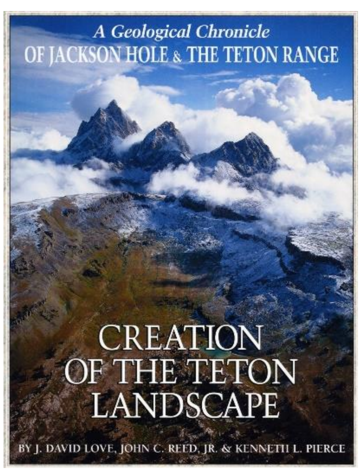


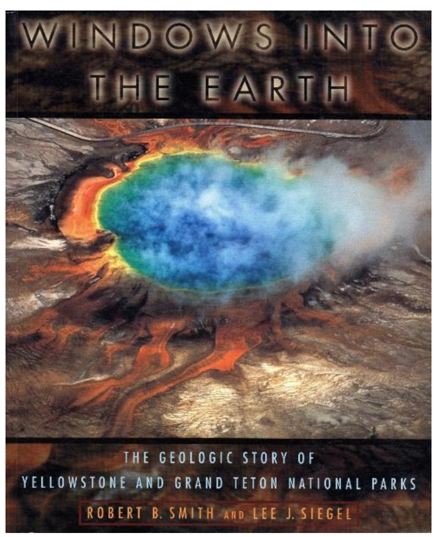
Figure 1. Shaded-relief map of the greater Yellowstone ecosystem (GYE, red line). The GYE incorporates Yellowstone and Grand Teton National Parks (YNP, GTNP outlined by green lines), 7 national forests (outlined in white), 3 States, and 21 counties (not shown). Roads are shown as thin gray lines. Designations of seven national forests: BD, Beaverhead-Deerlodge; Gal, Gallatin; Cus, Custer; Sh, Shoshone; BT, Bridger-Teton; Car, Caribou; and Tar, Targhee. Also designated, HV, Hayden Valley; PV, Pelican Valley. Map from Lisa Landenburger (written commun., 2004). A–A' line of section for figure 14.

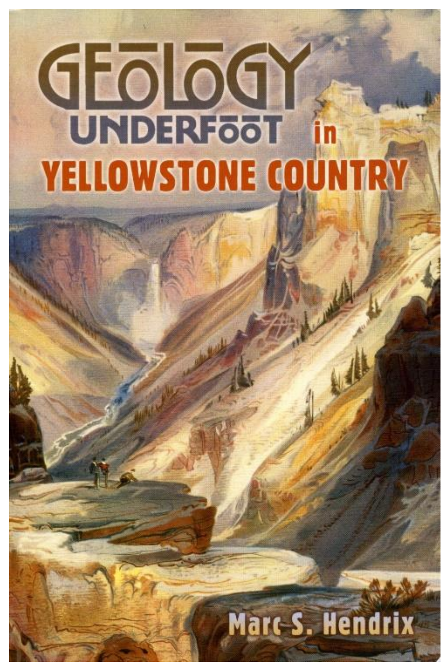
(Pierce, K.L., Despain, D.G., Morgan, L.A., and Good, J.M., The Yellowstone Hotspot, Greater Yellowstone Ecosystem, and Human Geography: U.S. Geological Survey Professional Paper 1717, Chapter A)


USGS
science for a changing world
Geology of Yellowstone National Park
The Quaternary and Pliocene Yellowstone Plateau Volcanic Field of Wyoming, Idaho, and Montana
Professional Paper 729–G
U.S. Department of the Interior
U.S. Geological Survey


USGS
science for a changing world
Integrated Geoscience Studies in the Greater Yellowstone Area—
Volcanic, Tectonic, and Hydothermal Processes in the Yellowstone Geoecosystem
Professional Paper 1717
U.S. Department of the Interior
U.S. Geological Survey

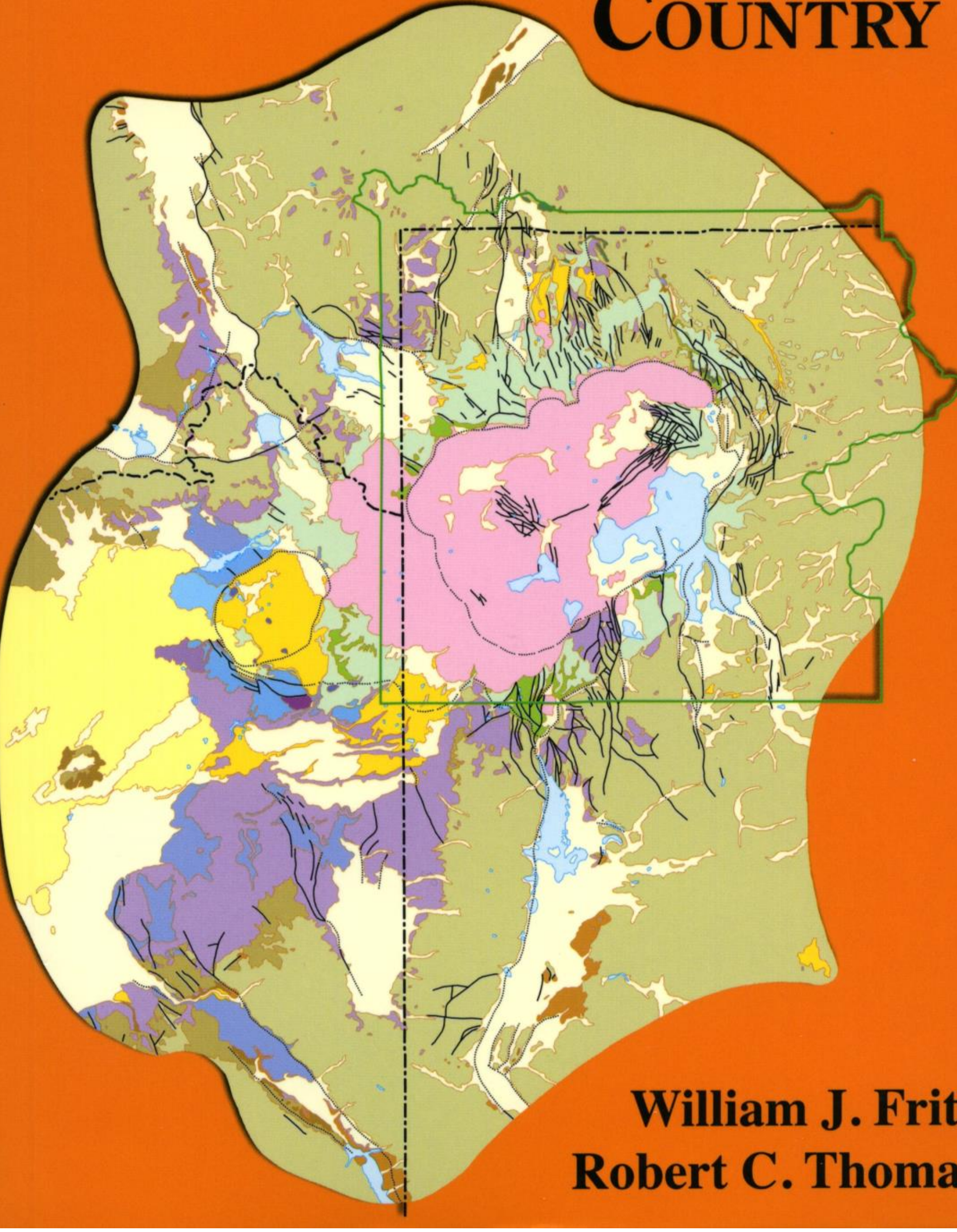

A Geological Chronicle
OF JACKSON HOLE & THE TETON RANGE
CREATION OF THE TETON LANDSCAPE
BY J. DAVID LOVE, JOHN C. REED, JR. & KENNETH L. PIERCE


WINDOWS INTO THE EARTH
THE GEOLOGIC STORY OF
YELLOWSTONE AND GRAND TETON NATIONAL PARKS
ROBERT B. SMITH AND LEE J. SIEGEL

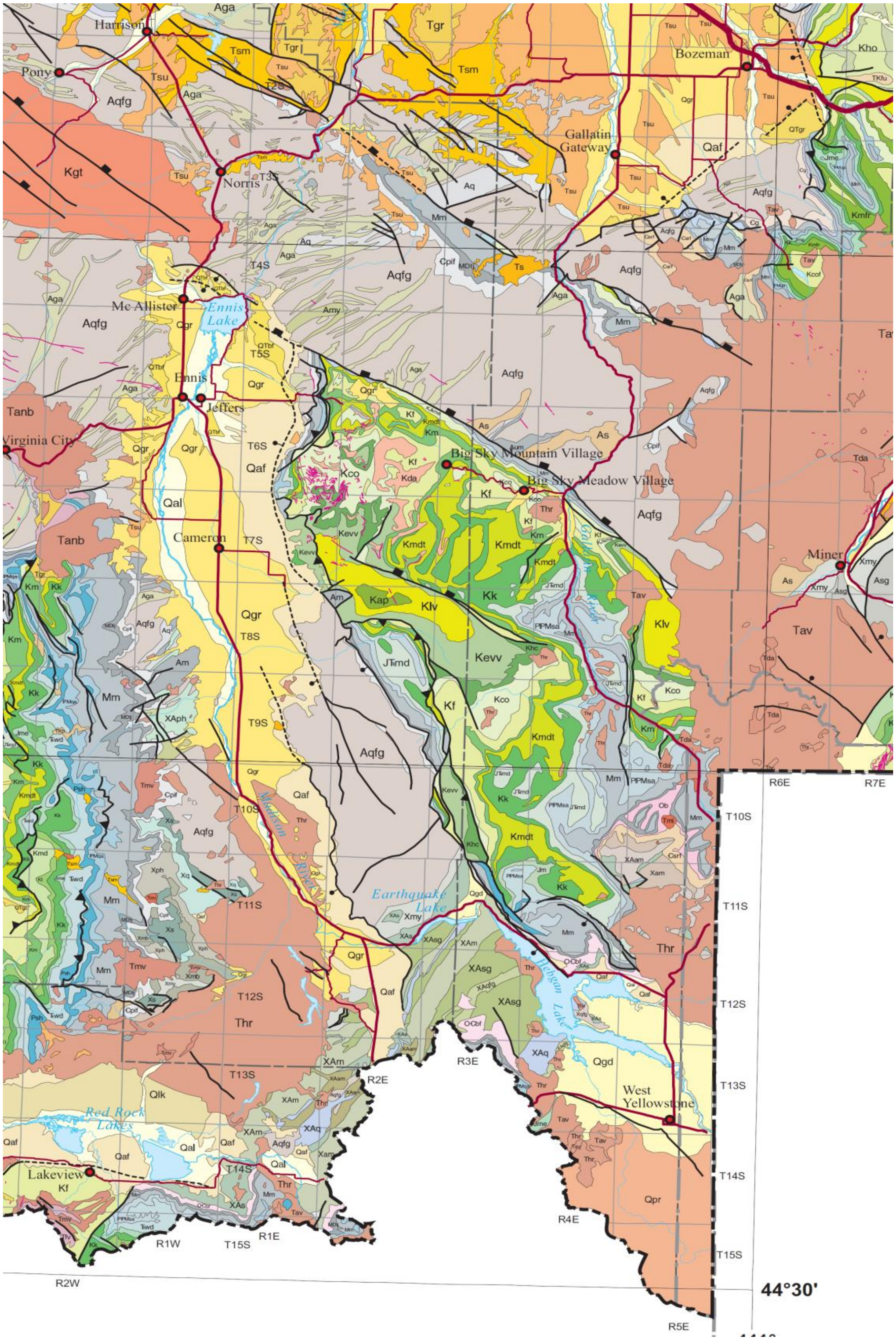

GEOLOGY UNDERFOOT in
YELLOWSTONE COUNTRY
Marc S. Hendrix

SECOND EDITION

ROADSIDE GEOLOGY OF YELLOWSTONE COUNTRY



William J. Fritz
Robert C. Thomas



(MBMG Geologic Map of Montana; 1:500,000)

(Two figures below from: Kellogg, Schmidt & Young, 1995, AAPG Bull., v. 79, no. 8, p. 1117-1137)

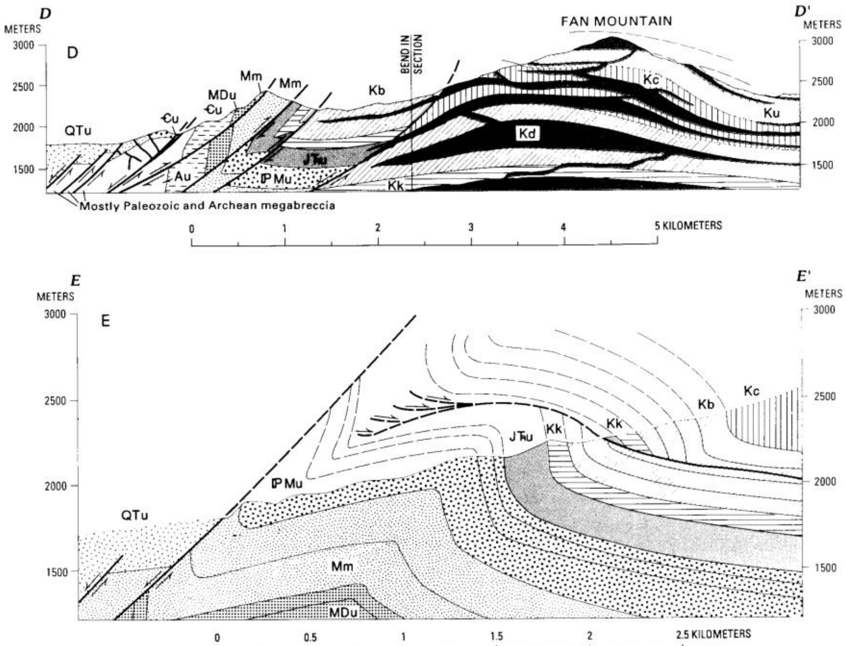


Figure 3—Continued. (D) Cross section DD′; (E) cross section EE′ through Shell Creek. Scale of 3E is twice that of Figure 3A–D.

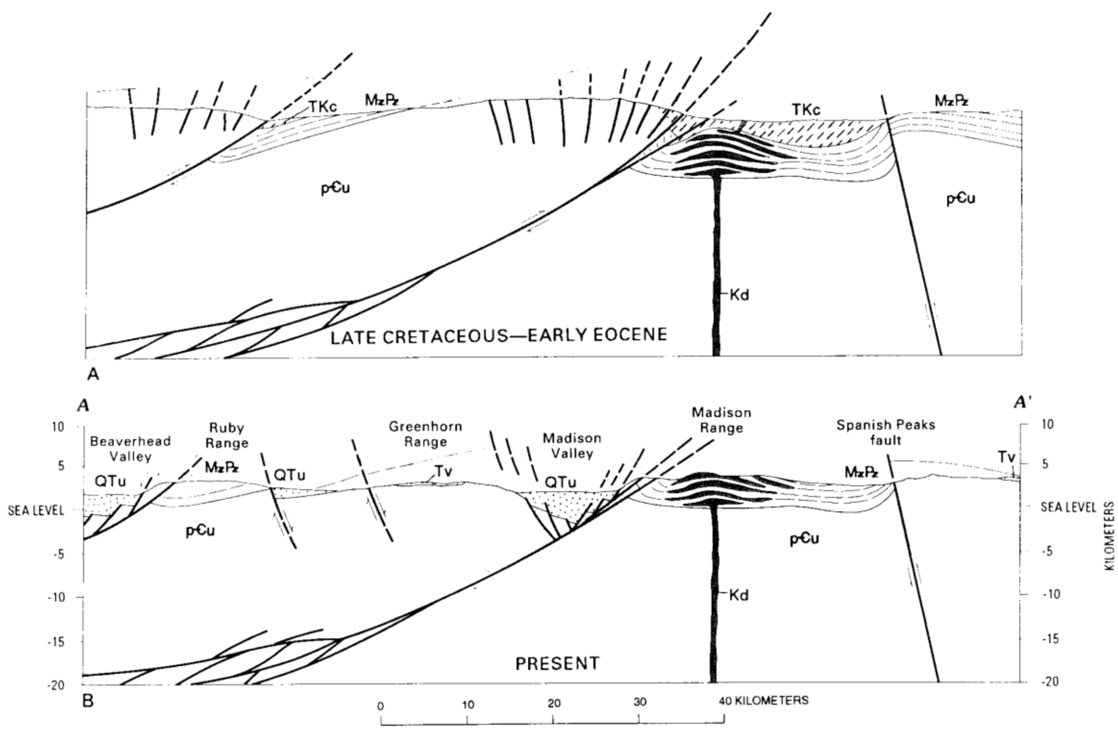
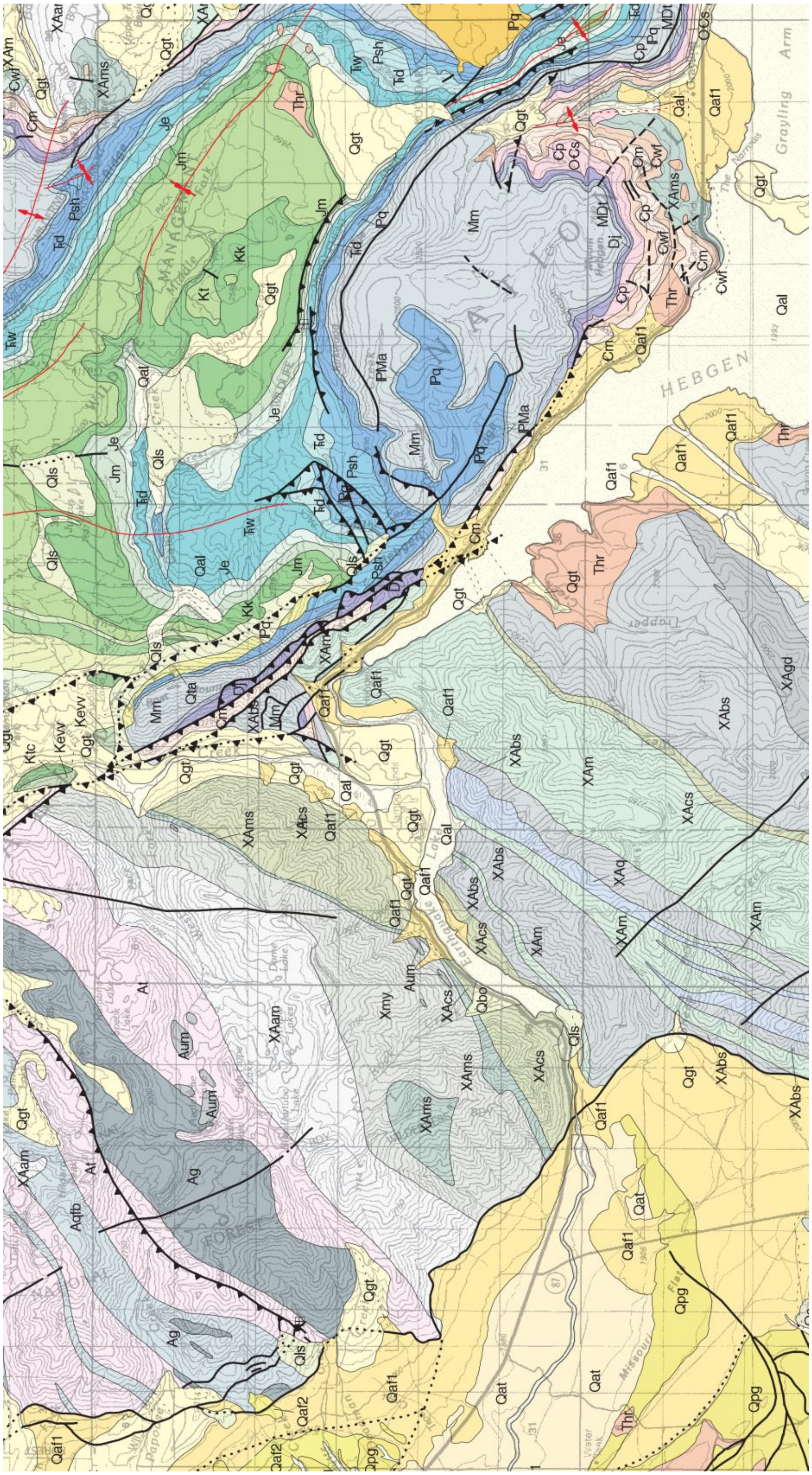


Figure 11—East-west cross sections across a portion of southwestern Montana showing major tectonic elements for (A) the close of Laramide deformation, and (B) the present. The location of cross section AA′ (Figure 9B) and unit symbols are given in Figure 1. Adapted, in part, from Schmidt et al. (1984, 1993b), Sheedlo (1984), Sharry et al. (1986), and Guthrie et al. (1989).



(MBMG Geologic Map of Hebgen Lake quadrangle, 1:100,000)






(Quake Lake photos by D. Lageson photos)

(**Next page:** historic U.S. Geological Survey fault scarp photos from 1959)

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Paleoseismology of Hebgen Lake Normal Fault at Cabin Creek, MT: Preliminary Report of the Hebgen Lake Paleoseismology Working Group

Kenneth Pierce (USGS[1]), David Lageson (MSU[2]), Cal Ruleman (MSU), Rain Hintz (MSU) and other members of the Hebgen Lake Paleoseismology Working Group, 2000
[1]U.S. Geological Survey, NRMSC, Montana State University, Bozeman, MT 59717-3492 (kpierce@usgs.gov)
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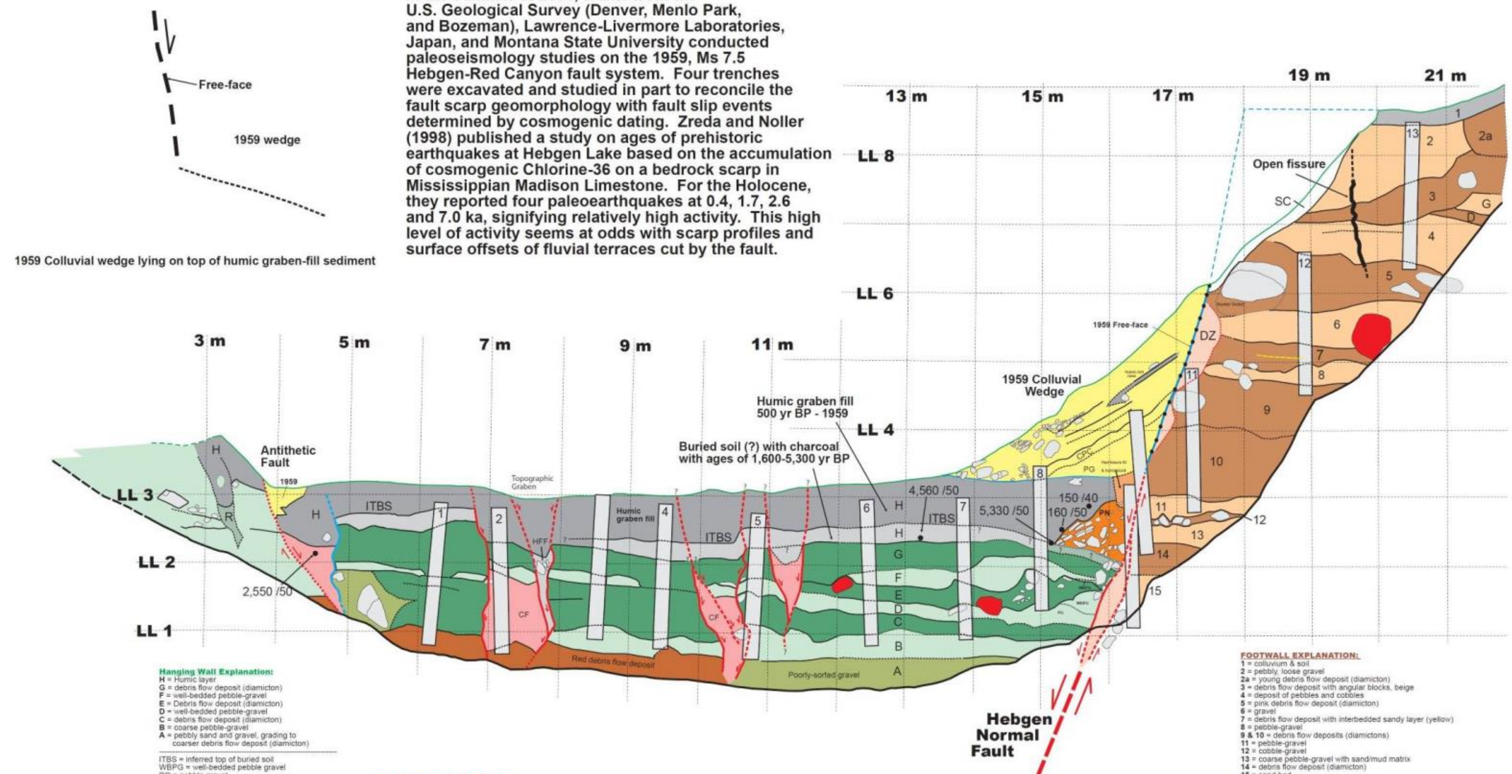
ABSTRACT:
In the summer of 2000, teams from the U.S. Geological Survey (Denver, Menlo Park, and Bozeman), Lawrence-Livermore Laboratories, Japan, and Montana State University conducted paleoseismology studies on the 1959, Ms 7.5 Hebgen-Red Canyon fault system. Four trenches were excavated and studied in part to reconcile the fault scarp geomorphology with fault slip events determined by cosmogenic dating. Zreda and Noller (1998) published a study on ages of prehistoric earthquakes at Hebgen Lake based on the accumulation of cosmogenic Chlorine-36 on a bedrock scarp in Mississippian Madison Limestone. For the Holocene, they reported four paleoearthquakes at 0.4, 1.7, 2.6 and 7.0 ka, signifying relatively high activity. This high level of activity seems at odds with scarp profiles and surface offsets of fluvial terraces cut by the fault.



Hanging Wall Explanation:
H = Humic layer
G = debris flow deposit (diamicton)
F = well-bedded pebble-gravel
E = Debris flow deposit (diamicton)
D = well-bedded pebble-gravel
C = debris flow deposit (diamicton)
B = coarse pebble-gravel
A = pebbly sand and gravel, grading to coarser debris flow deposit (diamicton)

ITBS = inferred top of buried soil
WBPG = well-bedded pebble gravel
PG = pebble gravel
PN = Penultimate colluvial wedge
CF= chaotic fissure fill, stratigraphy uncertain
R = root cast (?) with humic fill
HFF = humic fissure fill
2,550 /50 = ^{14}C age, yr BP (uncorrected), with error (+/-) after slash

FOOTWALL EXPLANATION:
1 = colluvium & soil
2 = pebbly, loose gravel
2a = young debris flow deposit (diamicton)
3 = debris flow deposit with angular blocks, beige
4 = deposit of pebbles and cobbles
5 = pink debris flow deposit (diamicton)
6 = gravel
7 = debris flow deposit with interbedded sandy layer (yellow)
8 = pebble-gravel
9 & 10 = debris flow deposits (diamictons)
11 = pebble-gravel
12 = cobble-gravel
13 = coarse pebble-gravel with sand/mud matrix
14 = debris flow deposit (diamicton)
15 = sand bed
RED cobbles from Triassic Woodside Formation
SC = scarp colluvium
PG = pebble-gravel
CPC = coarse pebble-cobble layer, 10-15 cm thick
DZ = fault deformation zone
Gray cobbles & boulders = mapped for reference

CONCLUSIONS:

For two terraces at Cabin Creek, located at the northwest end of the 1959 surface rupture, the lower terrace has 3.1 m of surface offset from the 1959 event, whereas the upper terrace has 5.3 m, indicating the higher terrace experienced an additional 2.2 m of offset since deposition. Our trench across the faulted upper terrace revealed only the 1959 colluvial wedge (height 2.7 m = ca. 5.2 m vertical throw on the main fault [Tm]) and a penultimate wedge (height 1.1 m = ca. 2.2 m Tm), totaling 7.4 m Tm, consistent with 7.7 m Tm of the original terrace top. Following the penultimate event, one meter of fine-grained humic sediment containing charcoal accumulated over the last few hundred years in the penultimate graben and eventually buried the penultimate colluvial wedge. Thus, there appears to be only one pre-1959 event during the Holocene at Cabin Creek, consistent with surficial geology, which we provisionally date as late Holocene, but older than 1,000 years, based on preliminary radiocarbon ages and new cosmogenic data collected by other members of the research team.

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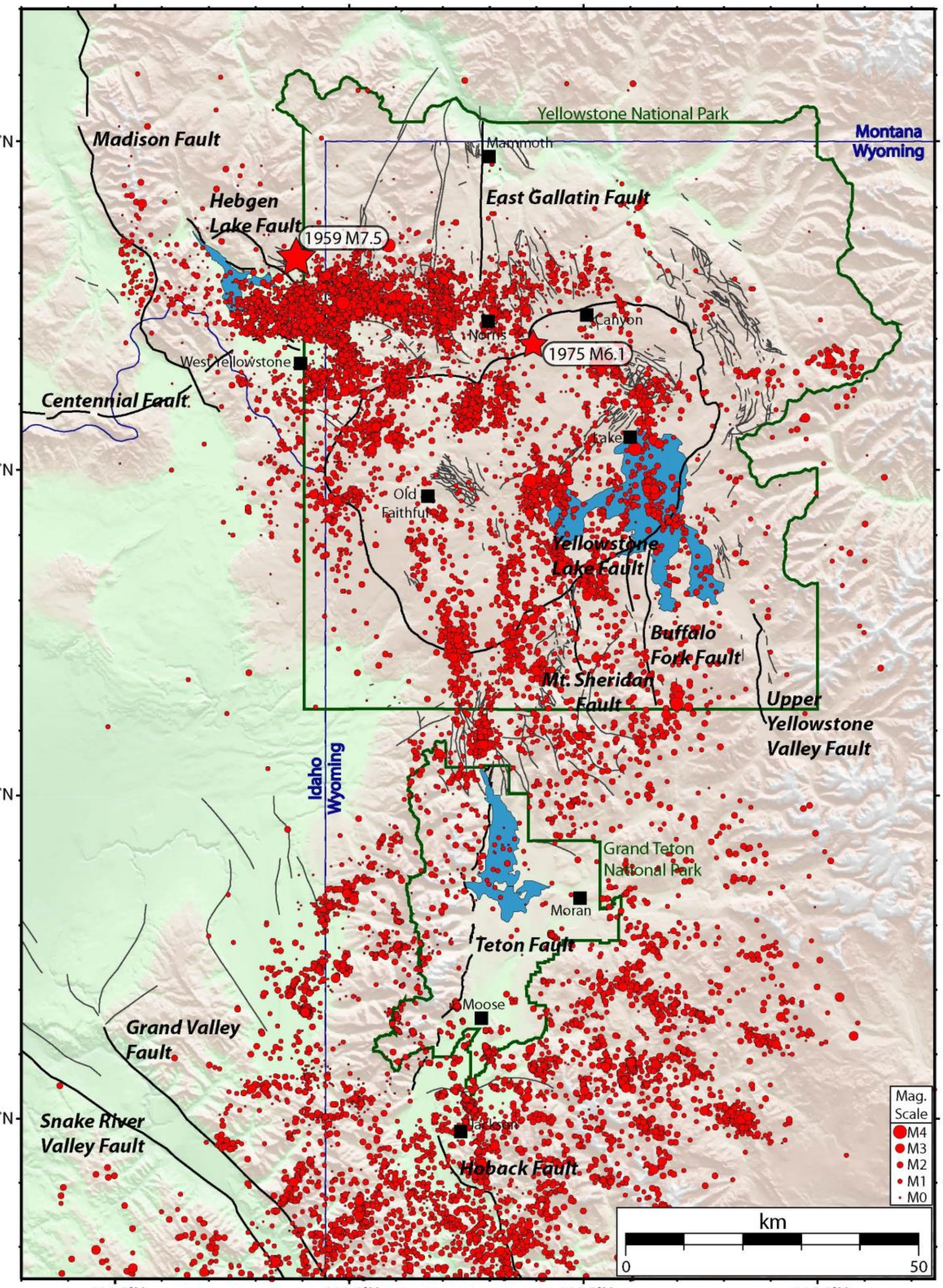
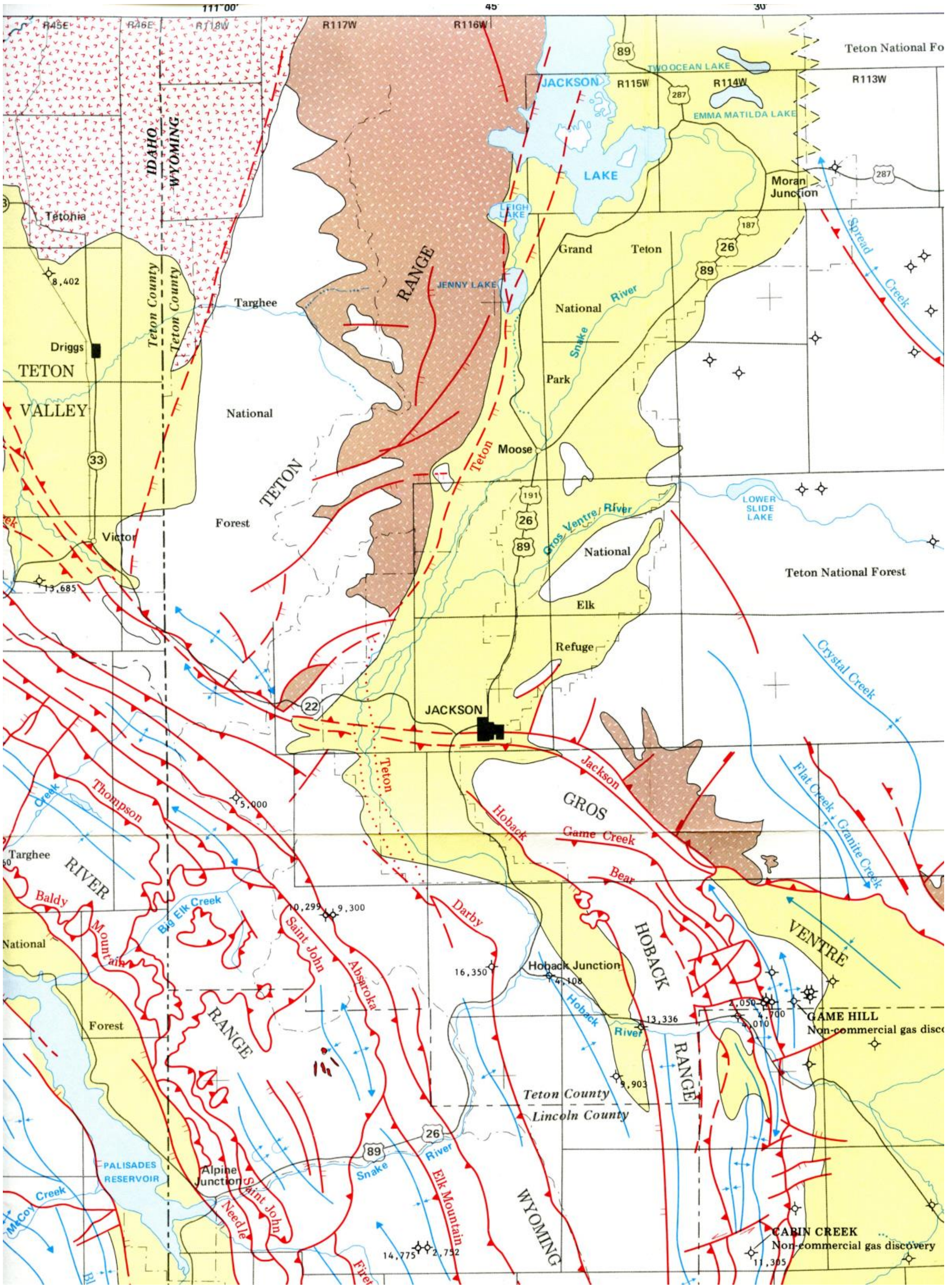
Earthquake Hazards Program



(Source: Dr. Robert [Bob] Smith – University of Utah)

Topographic relief map showing terrain created by the tectonic intersection of the Idaho-Wyoming salient of the fold-and-thrust belt, Laramide (basement-involved) foreland, easternmost Basin-and-Range Province, and track of the Yellowstone melting anomaly ("hotspot")

Source: Yellowstone Ecological Research Center (2008) – The Greater Yellowstone Ecosystem (1:500,000)



(The Geological Survey of Wyoming, Map Series 23 – Tectonic Map of the Overthrust Belt, 1987, by D.L. Blackstone, Jr., and R.H. DeBruin)

Source for the following five illustrations: **Yonkee, W.A., and Weil, A.B., 2015, Tectonic evolution of the Sevier and Laramide belts within the North American Cordillera orogenic system: Earth-Science Reviews, 150, p. 531-593.**

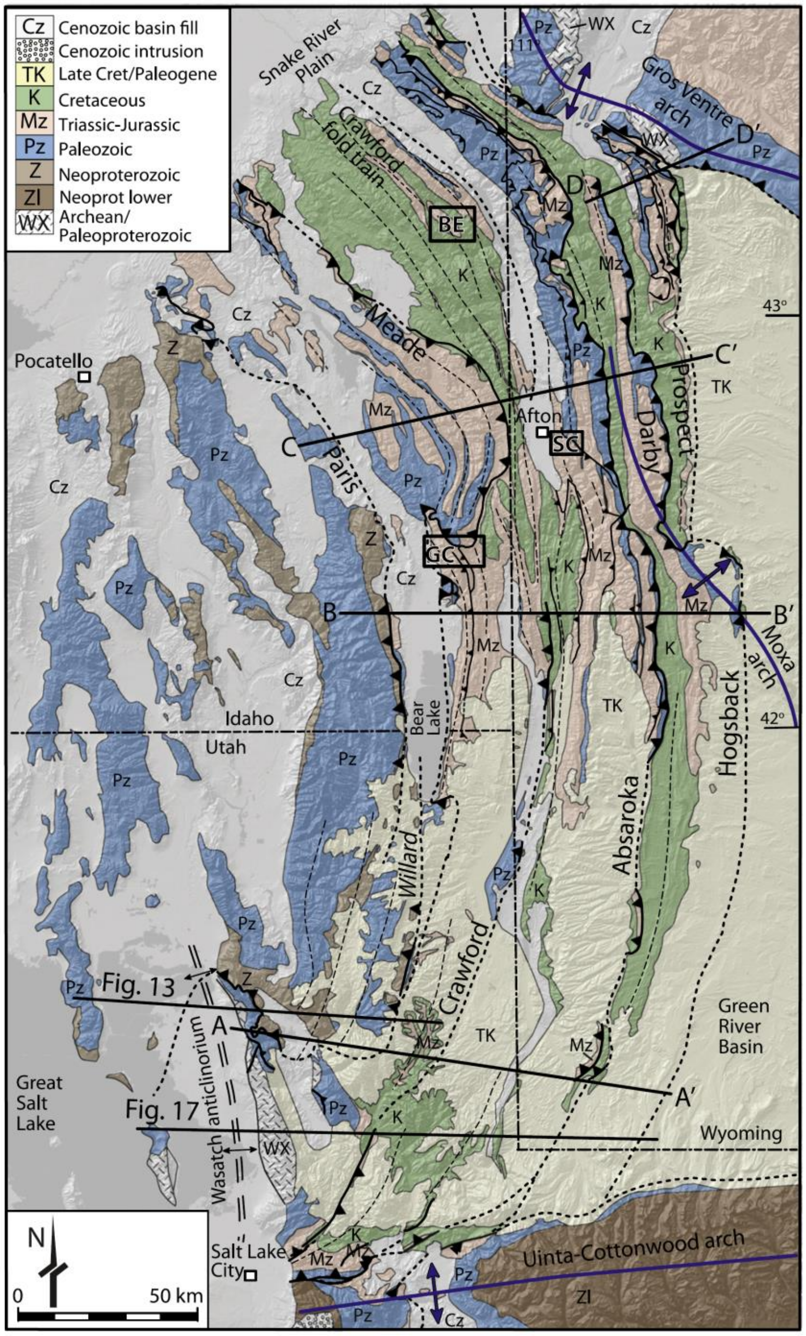


Fig. 10. Geologic and shaded relief map of the Wyoming salient of the Sevier fold-thrust belt. Major thrusts (Willard, Paris, Meade, Crawford, Absaroka, Hogsback, Darby, Prospect) and associated folds display systematic curvature from NW trends in the north part to NE trends in the south part of the salient. Locations of cross sections A–A′, B–B′, C–C′, and D–D′ in Fig. 11 indicated. Locations of section lines for Figs. 13 and 17 and BE — Big Elk, GC — Georgetown Canyon, and SC — Swift Creek areas for Fig. 20 also indicated.
Modified from Coogan (1992) and Yonkee and Weil (2010).

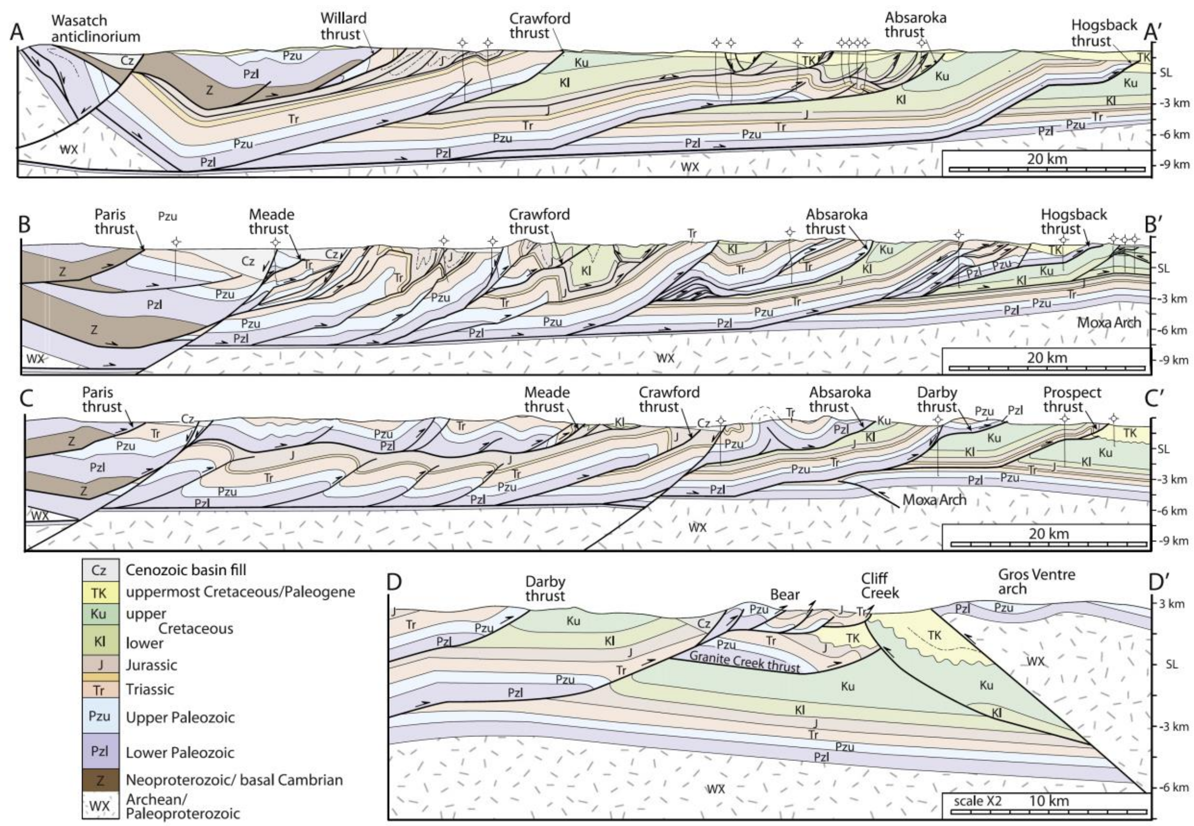


Fig. 11. Cross sections A–A′, B–B′, and C–C′ across southern, central, and north-central parts of the Wyoming salient illustrate typical thin-skin structural style. Fold-thrust shortening is greater in the central part of the salient. Section D–D′ illustrates interaction of frontal thrusts with the Laramide foreland Gros Ventre arch.
Sections modified from Hunter (1988), Coogan (1992), Royse (1993), Peyton et al. (2011), and Yonkee and Weil (2010).

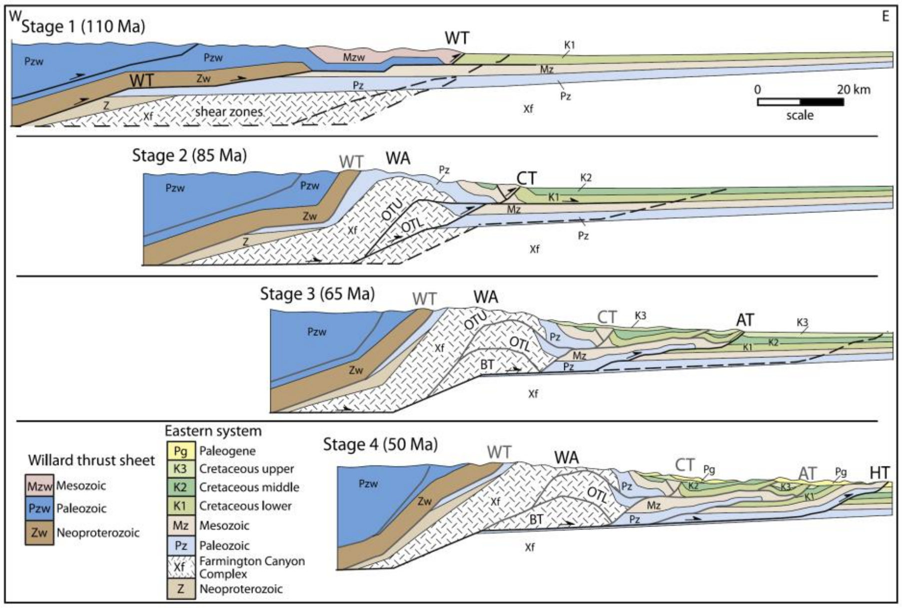
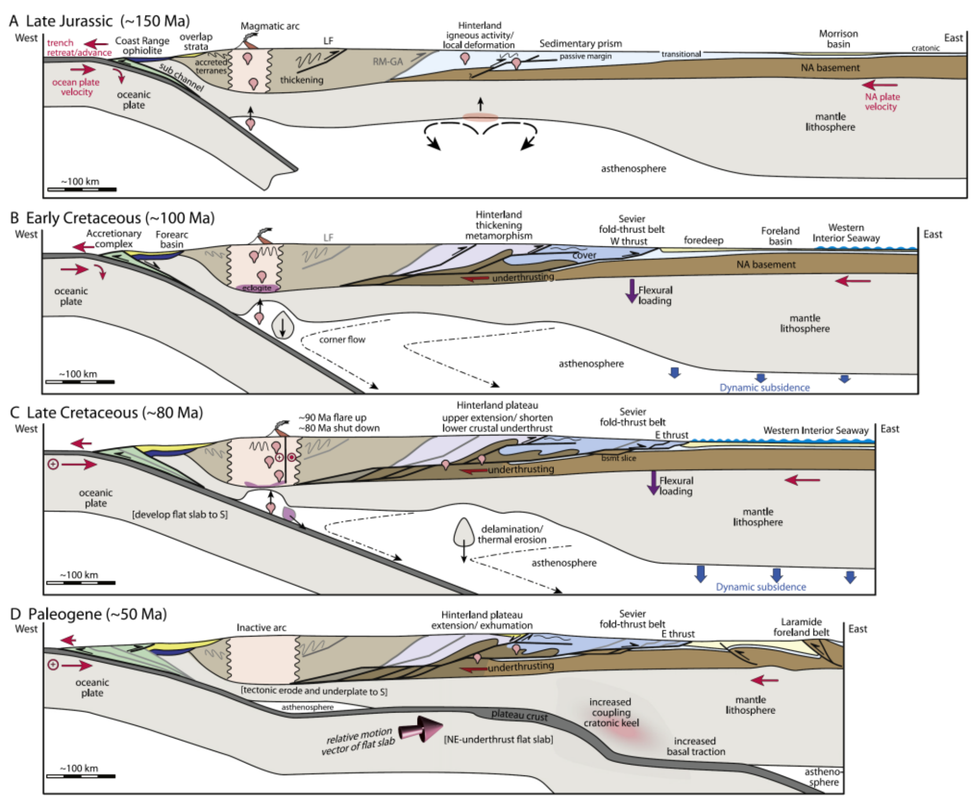
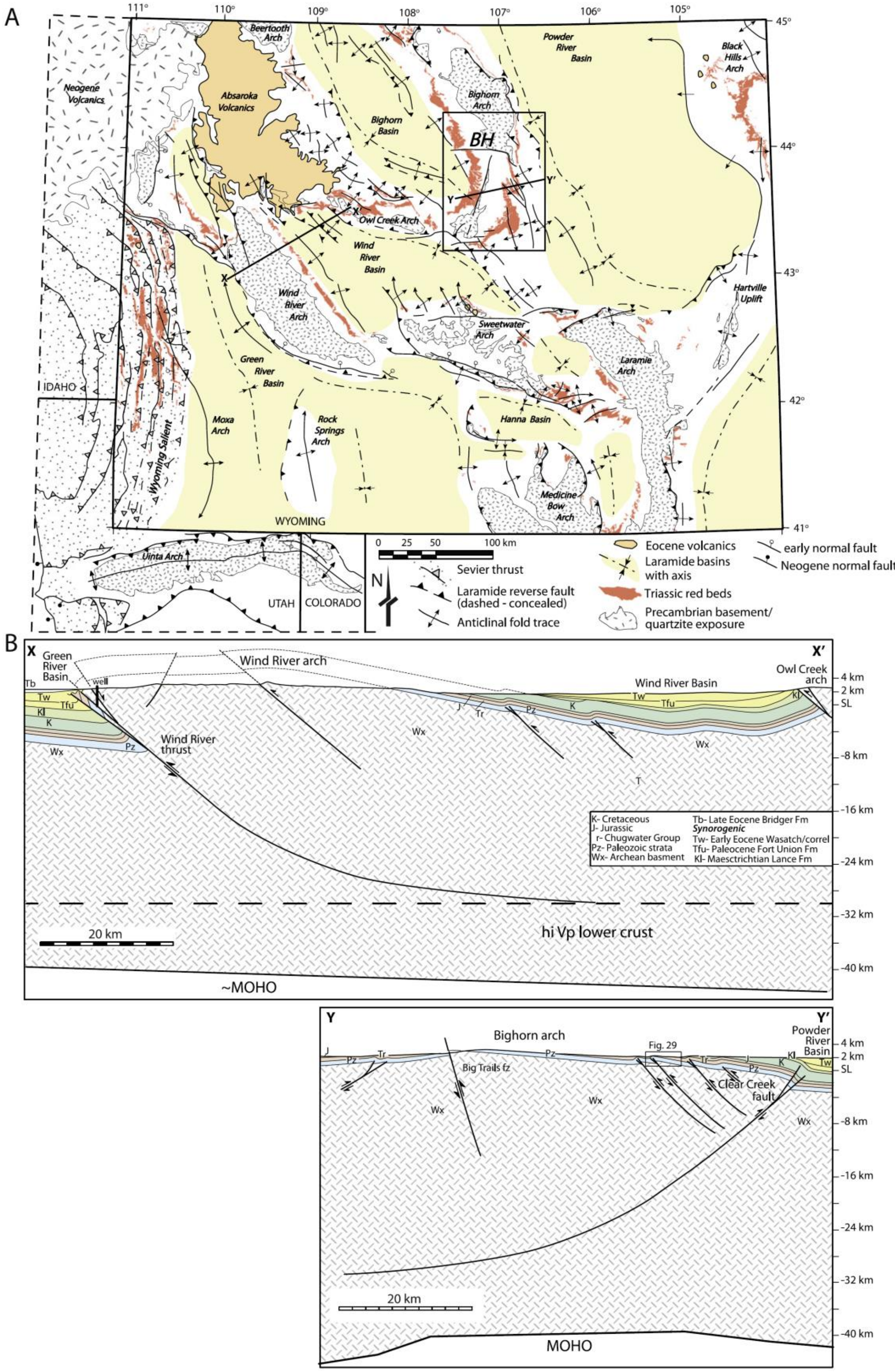


Fig. 17. Structural model for sequential development of the Wasatch anticlinorium and eastern thrust system in the southern Wyoming salient. Major thrusts are labeled from west to east: WT — Willard thrust, OTU and OTL — upper and lower branches of Ogden thrust system, BT — basal thrust, CT — Crawford thrust, AT — Absaroka thrust, and HT — Hogsback thrust. Synorogenic deposits for each thrust correspond to those given in Fig. 12. Future thrusts are dashed, active thrusts in black, and inactive thrusts shown in gray. Modified from Yonkee (1992) and DeCelles (1994).




A
B
111°
110°
109°
108°
107°
106°
105°
45°
44°
43°
42°
41°
Beartooth Arch
Absaroka Volcanics
Neogene Volcanics
Powder River Basin
Black Hills Arch
Bighorn Arch
Bighorn Basin
BH
Owl Creek Arch
Wind River Basin
Wind River Arch
Sweetwater Arch
Hartville Uplift
Laramie Arch
Green River Basin
Moxa Arch
Rock Springs Arch
Hanna Basin
Medicine Bow Arch
Wyoming Salient
IDAHO
WYOMING
UTAH
COLORADO
Uinta Arch
X
X'
Y
Y'
0 25 50 100 km
N
Sevier thrust
Laramide reverse fault (dashed - concealed)
Anticlinal fold trace
Eocene volcanics
Laramide basins with axis
Triassic red beds
Precambrian basement/ quartzite exposure
early normal fault
Neogene normal fault
Green River Basin
Wind River arch
Wind River Basin
Owl Creek arch
well
Wind River thrust
4 km
2 km
SL
-8 km
-16 km
-24 km
-32 km
-40 km
K- Cretaceous
J- Jurassic
r- Chugwater Group
Pz- Paleozoic strata
Wx- Archean basment
Tb- Late Eocene Bridger Fm
Synorogenic
Tw- Early Eocene Wasatch/correl
Tfu- Paleocene Fort Union Fm
Kl- Maesctrichtian Lance Fm
20 km
hi Vp lower crust
~MOHO
Bighorn arch
Big Trails fz
Fig. 29
Clear Creek fault
Powder River Basin
20 km
MOHO

Source for the following <u>three</u> maps: **Pierce, K.L., Despain, D.G., Morgan, L.A., and Good, J.M., The Yellowstone Hotspot, Greater Yellowstone Ecosystem, and Human Geography: U.S. Geological Survey Professional Paper 1717 (Chapter A).**

The Yellowstone Hotspot, Greater Yellowstone Ecosystem, and Human Geography

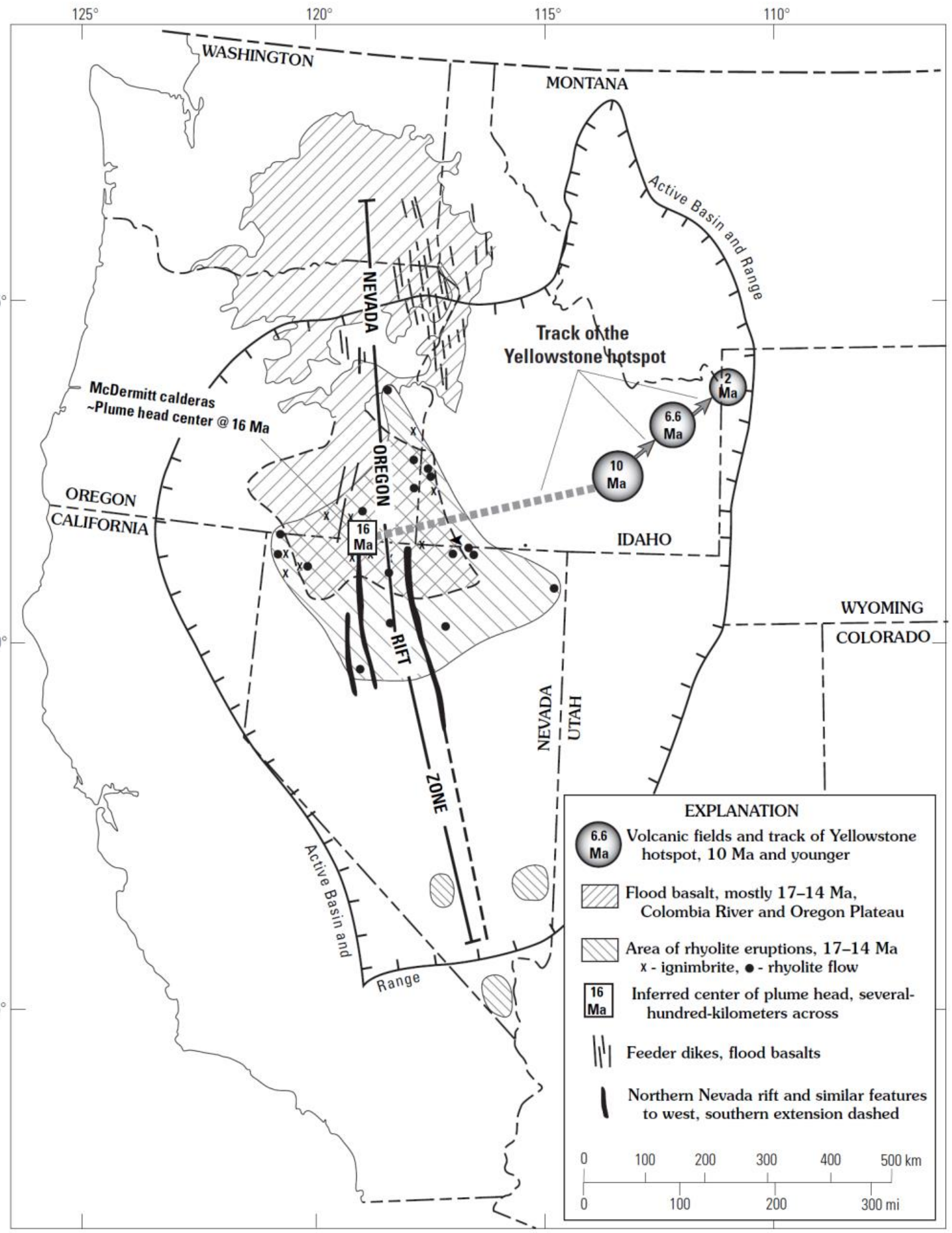
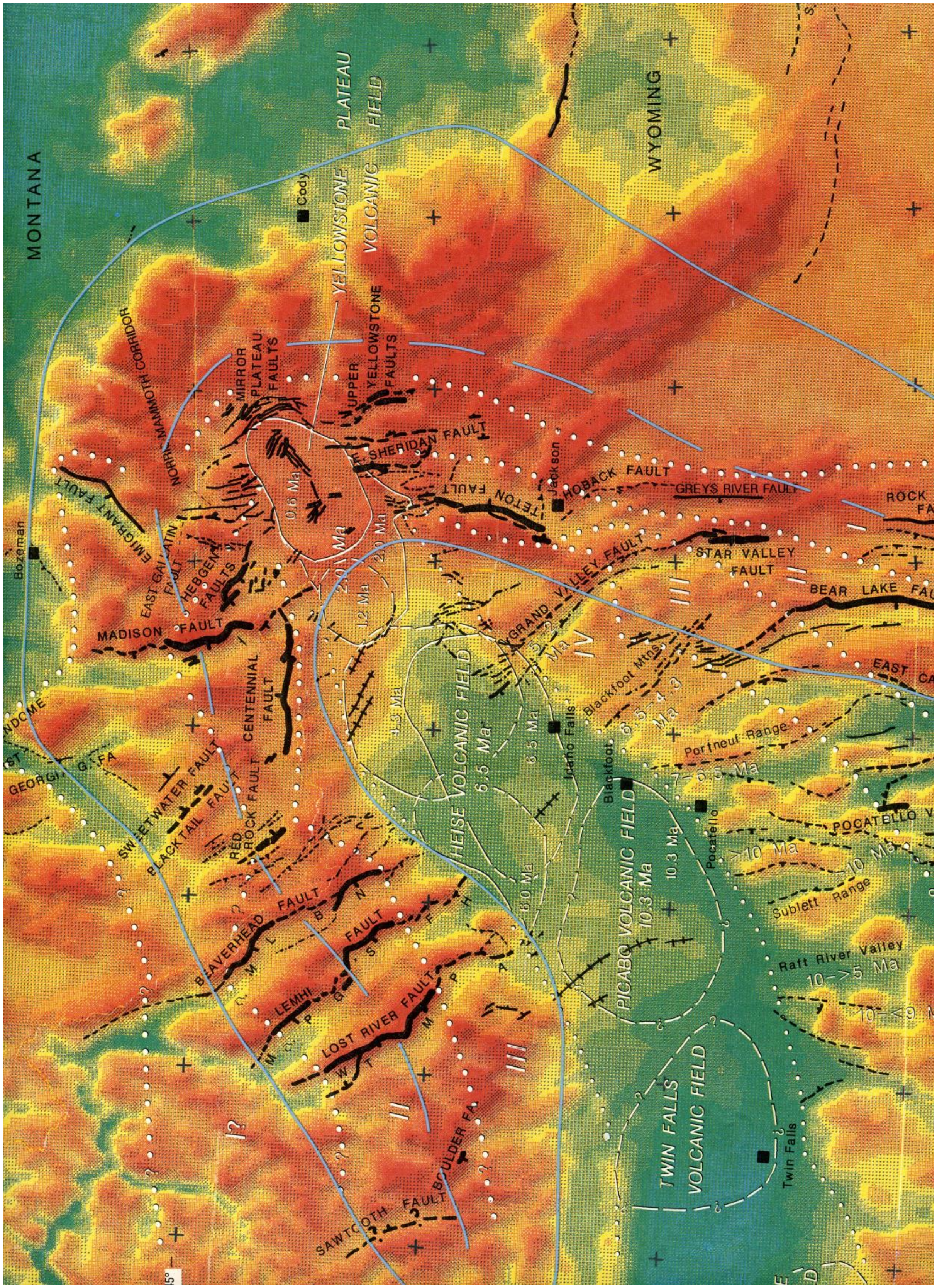


Figure 3. Map of the Western United States showing the track of the Yellowstone hotspot. Geologic evidence suggests that the hotspot originated about 16 million years ago when a postulated hot mantle-plume head about 400 km (250 mi) in diameter, pushed into the base of the North American plate. This plume head centered on the symbol labeled 16 Ma near the Nevada-Oregon border and produced both the flood basalts and rhyolite eruptions (indicated by the two directions of cross-hatching). From 10 to 2 million years ago, the hotspot track became more systematic and left in its wake the trench of the eastern Snake River Plain. The hotspot arrived in the greater Yellowstone area about 2 million years ago. The ages shown for individual volcanic fields refer to time of inception of volcanism.



Tectonic parabola ("bow wave") surrounding Greater Yellowstone (original from Pierce & Morgan, 1992, GSA Memoir 179)

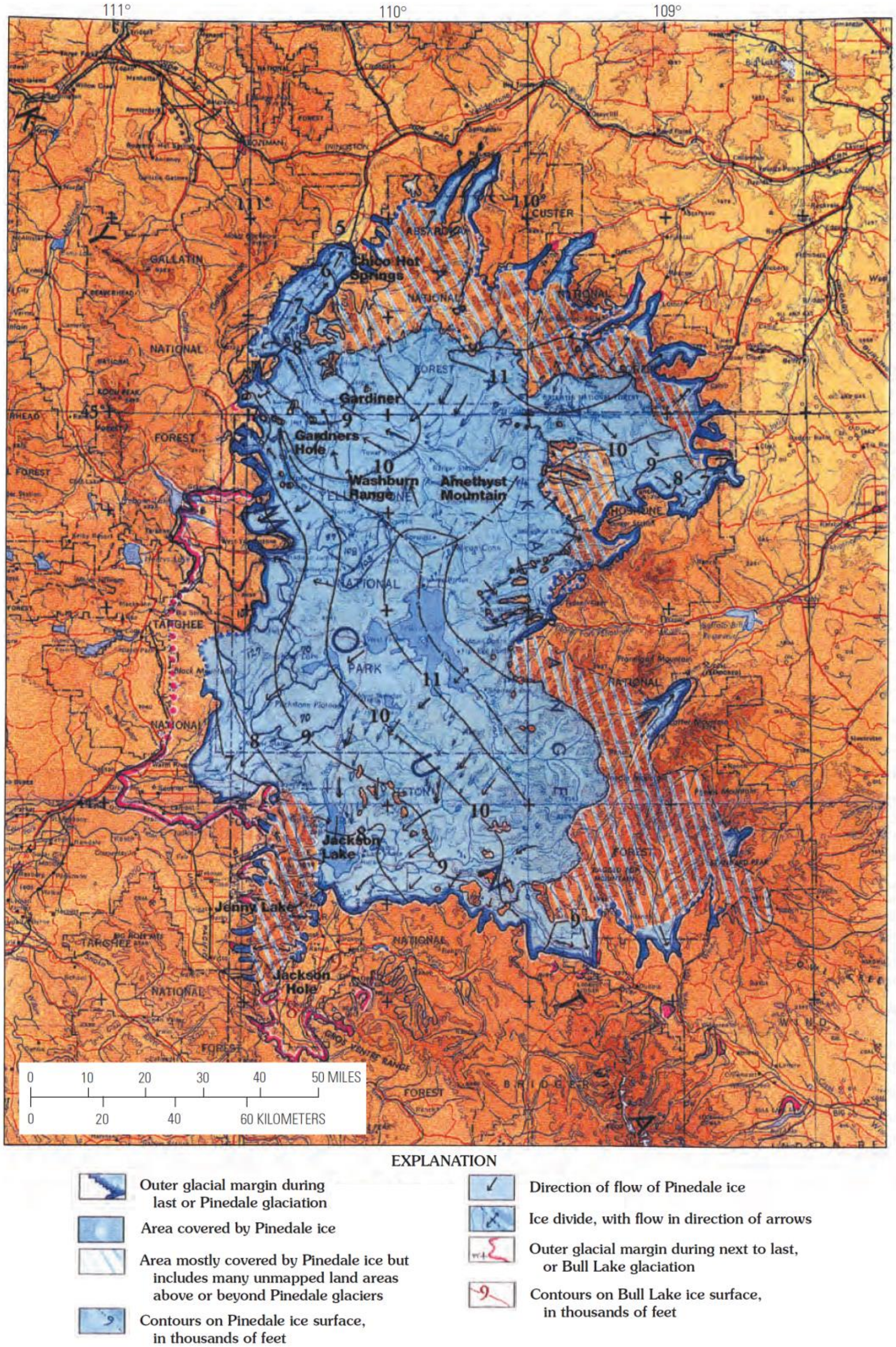


Figure 16. Map showing extensive glacial cover of the Yellowstone area about 17,000 years ago. Only the glaciers that were contiguous with those in Yellowstone are shown. Nearly all of Yellowstone Park was covered with glacial ice that was enhanced by three hotspot-related features: (1) the storm conduit of the eastern Snake River Plain, (2) the buildup of rhyolite to form Yellowstone Plateau, and (3) uplift to form the Yellowstone crescent of high terrain.

Dedication to my field assistant – a strong mountain horse:
Doing solo-field work in the backcountry of the Wyoming fold-and-thrust belt in the 1970s (D. Lageson)