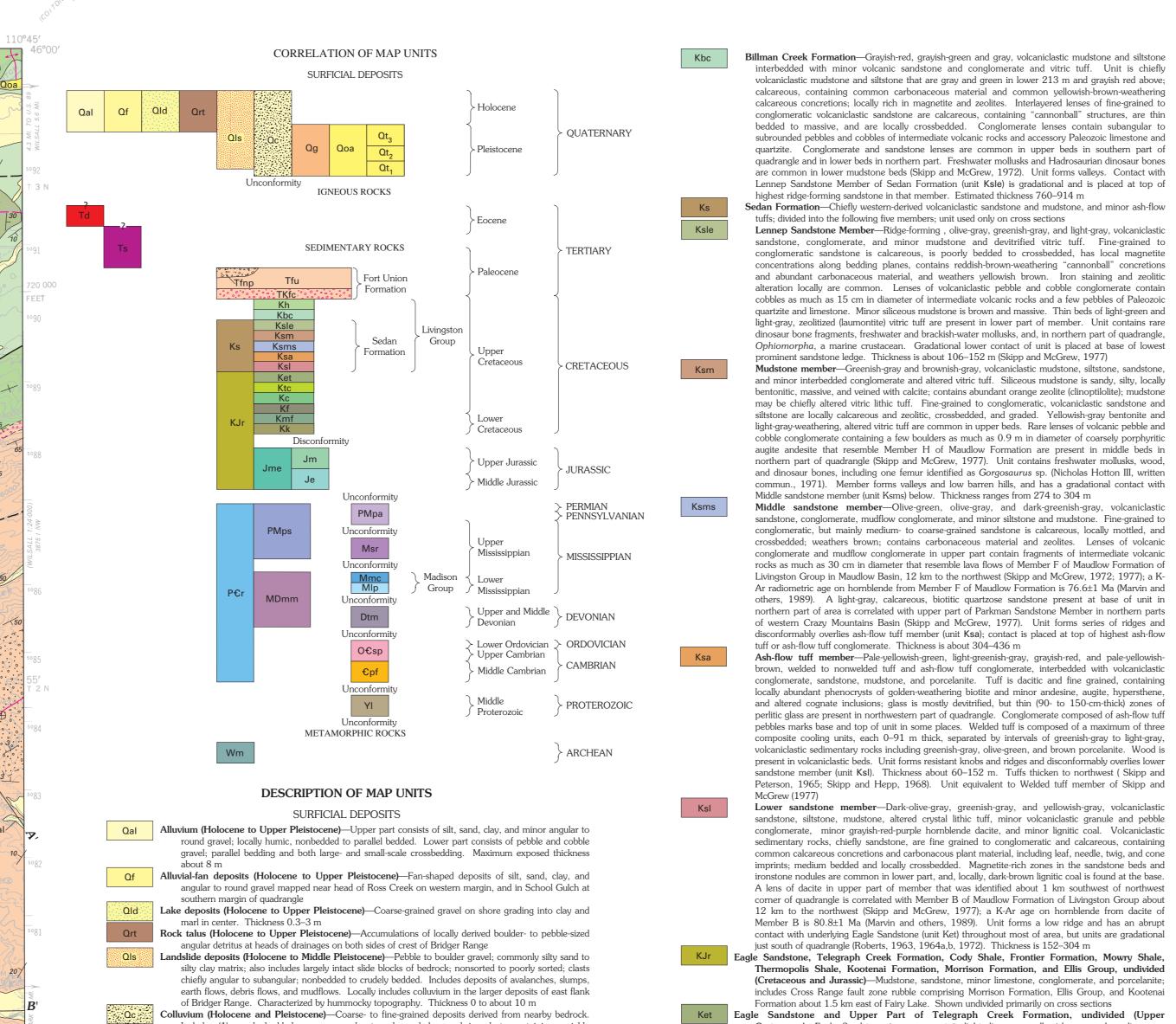
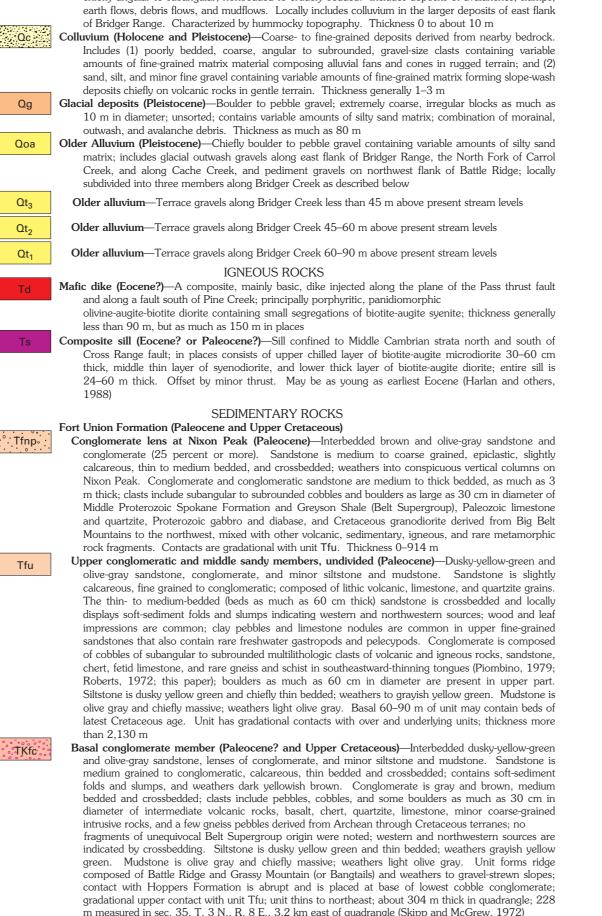
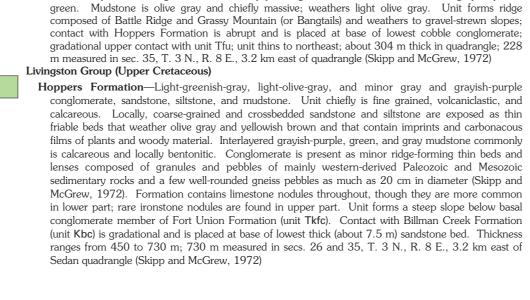


U.S. Geological Survey <sup>2</sup>Montana State University

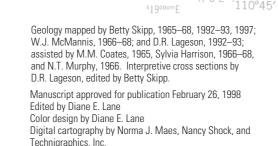


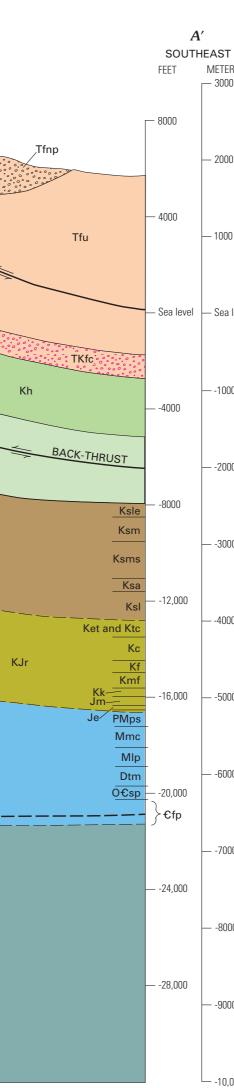


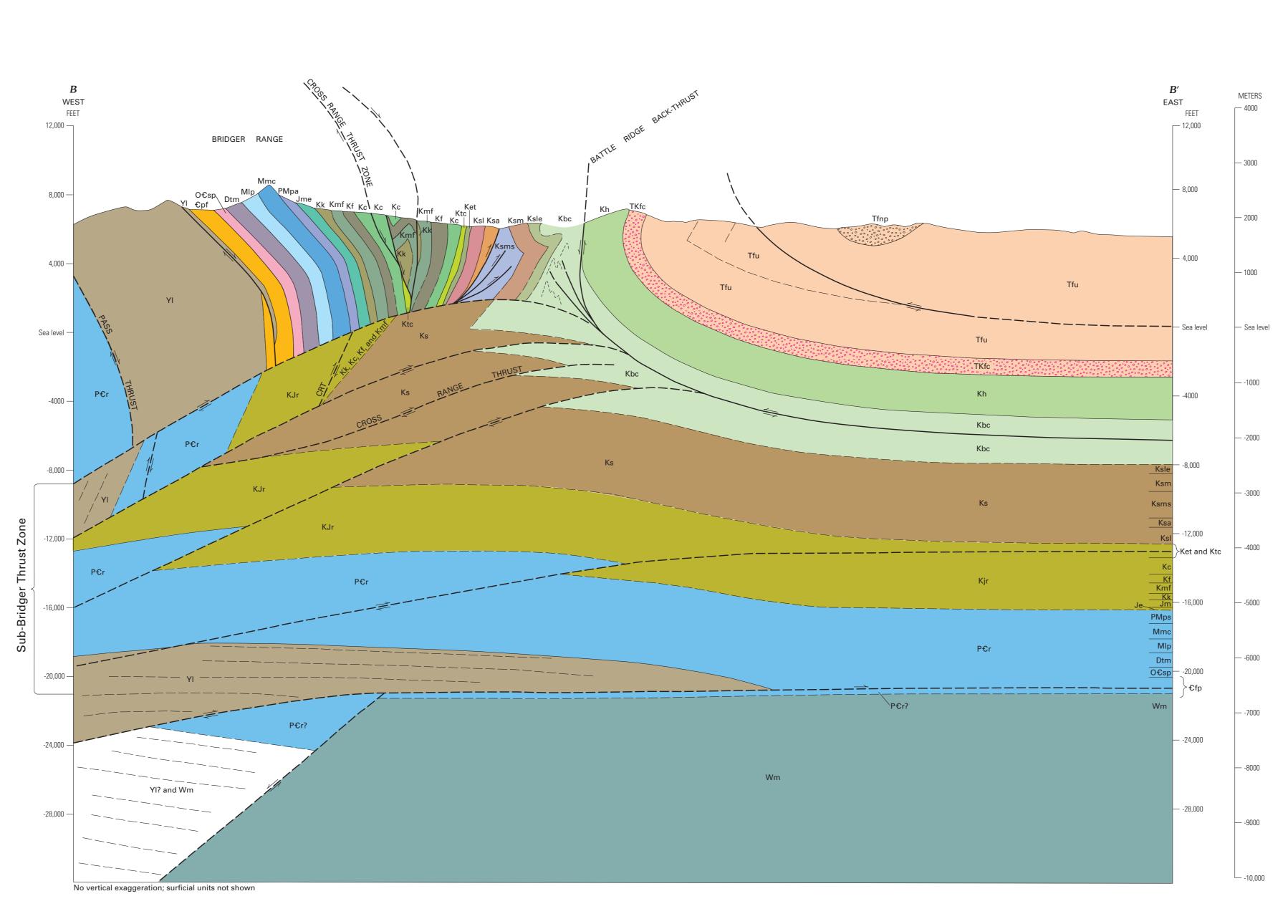




36 to 91 m





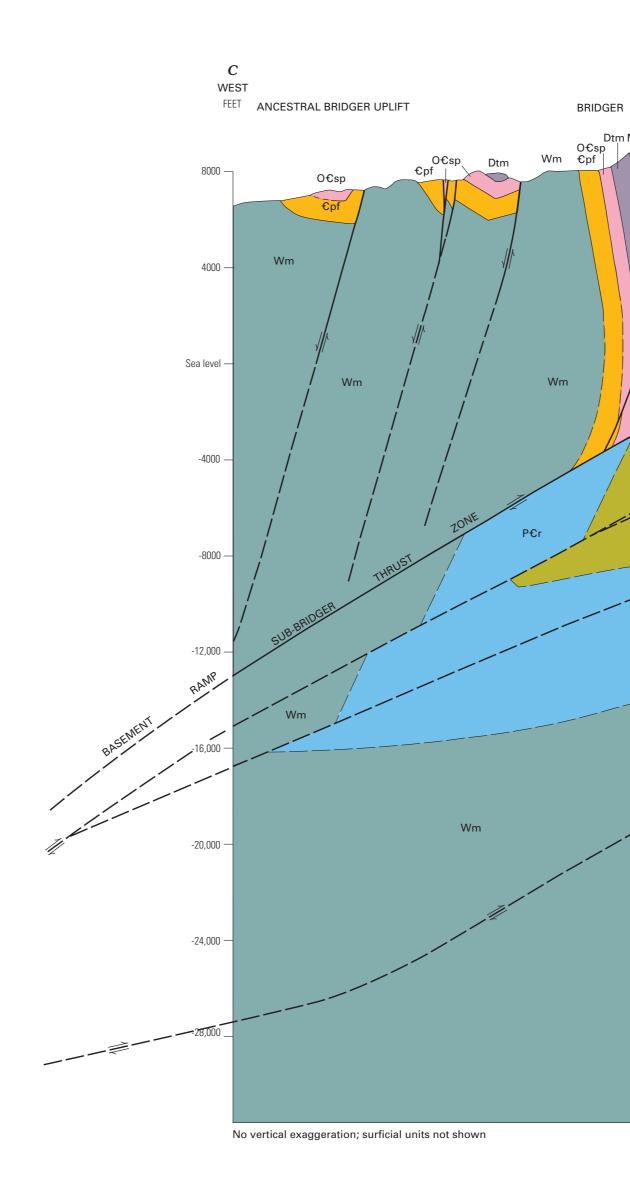


GEOLOGIC MAP OF THE SEDAN QUADRANGLE, GALLATIN AND PARK COUNTIES, MONTANA Betty Skipp,<sup>1</sup> D.R. Lageson,<sup>2</sup> and W.J. McMannis<sup>3</sup>



Strike and dip of beds in sedimentary rocks Horizontal

Inclined Vertical



region and a discussion of the main Quaternary and Tertiary tectonic events evident in the rocks and structures of the

Sedan quadrangle. The Cenozoic events are labeled  $D_1$  to  $D_3$  from oldest to youngest, and they all postdate formation

In the southern Bridger Range, Archean basement rocks are similar in degree of metamorphism and deformation

to those in the cores of other Laramide uplifts across southwestern Montana and Wyoming. Isotopic dates for these

of the Cordilleran plate margin.

## **GEOLOGIC INVESTIGATIONS SERIES I-2634** Version 2.1

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rocks generally fall in the range of 3.2–2.7 Ga. (James and Hedge, 1980; Mueller and others, 1985; Mogk and Henry,

1988; Wooden and others, 1988; Mogk and others, 1992), although zircons have been dated as old as 3.96 Ga from

quartzites in the Beartooth Mountains (Mueller and others, 1992). The metamorphic fabric of these basement rocks has

in some cases exerted a strong control on the geometry of subsequent Proterozoic and Phanerozoic structures,

particularly Laramide folds (Miller and Lageson, 1993). The important variable is the attitude of basement foliation with

respect to the basement-cover nonconformity; where foliation is subparallel to the nonconformity and overlying

stratigraphy, then the basement is folded concordantly with cover rocks; where foliation is sub-perpendicular to the

nonconformity, then passive-slip mechanisms of basement deformation prevail in the cores of Laramide folds as

Middle Proterozoic rocks in the central Bridger Range correlate with lower units of the Belt Supergroup to the

northwest (Winston, 1986a) and are known to be older than 1,449 Ma and younger than 1,468 Ma (Aleinikoff and

others, 1996). McMannis (1963) was the first to understand that the juxtaposition of Middle Proterozoic conglomerates

basin. As early as 1894, however, Iddings and Weed (Iddings and Weed, 1894) had mapped the general distribution of

containing Archean clasts and Archean rocks along the Pass fault marks the vicinity of the southern margin of the Belt

D<sub>1</sub>: Sevier Folding and Thrusting

Middle Paleocene Fort Union Formation (Roberts, 1972), were already in place before local Sevier fold-thrust

deformation began, probably in late Paleocene time (Skipp and McGrew, 1968; Harlan and others, 1988). An Eocene(?)

mafic dike intrudes the updip termination of the rotated Pass thrust fault (McMannis, 1955; this paper). Paleomagnetic

and isotopic dating of alkalic dikes and sills of compositions similar to this dike in the Crazy Mountains Basin about 50 km

to the northeast yielded post-deformational dates of 52–48 Ma, early middle Eocene (Harlan and others, 1988). Thus,

fold-thrust deformation in the Sedan area is bracketed as post-Middle Paleocene and pre-Middle Eocene. The Cross

Range and Pass thrust faults were active at this time, as was initial back-thrusting along the Battle Ridge shear zone.

D<sub>2</sub>: Laramide Deformation

A second phase of contractional deformation involved uplift of the ancestral Bridger Range anticlinorium

a basement-cored Laramide-style uplift (McMannis, 1955; Skipp and McGrew, 1968; Lageson, 1989). There is

approximately 7,600 m of structural relief on the Archean basement at the south end of the Bridger Range. No major

thrust faults crop out along the eastern flank of the Bridger Range to account for this relief. However, Sohio Oil

Company seismic and drilling data (Lageson, 1989) confirmed the existence of a west-dipping zone of thrust faults (sub-

Bridger thrust zone of Lageson, 1989) that bounds the east flank of the Bridger Range, producing a Laramide-style

"basement-overhang." As the sub-Bridger thrust zone translated up-section into the Livingston Group, it delaminated the

Hoppers Formations in the process. As the ancestral Bridger Range uplift rose, the Pass and Cross Range fault zones

were rotated into their present orientations and severe crowding developed between the sub-Bridger thrust zone and the

southwest end of Battle Ridge, producing a detachment fault in the lower sandstone member of the Sedan Formation (the

Ksl detachment) and disharmonic box folds north of Battle Ridge. The timing of Laramide uplift is bracketed by the

following: (1) The youngest rock deformed by uplift of the ancestral Bridger Range is the Late Cretaceous to Middle

Paleocene Fort Union Formation (Roberts, 1972); (2) directly south of the Bridger Range , the Absaroka-Gallatin volcanic

field blankets Laramide structures in the Gallatin Range with pronounced angular unconformity. Volcanism began around

53 Ma and continued to about 43 Ma, clearly postdating Laramide deformation (Chadwick, 1972). Thus, Laramide uplift

in the area is also bracketed as late Paleocene to Eocene. Structural relationships show, however, that Laramide uplift

deformed Sevier folds and thrusts, so that within the late Paleocene to Eocene time period, late Paleocene Sevier

deformation was closely followed by probable early Eocene Laramide thrusting and uplift of the Bridger Range. Late-

D<sub>3</sub>: Crustal Extension

Range. This fault is shown south of Ross Pass on the Sedan quadrangle, but it extends the full length of the range

beyond the western edge of the map area. The range-front normal fault has down-dropped the Gallatin River valley

along its segmented trace, but overall it appears that the valley collapsed along the axial surface of the ancestral Bridger

Range anticlinal uplift, leaving the east-dipping limb as a "perched basement wedge" (Lageson, 1989). Regionally, the

range-front normal fault is parallel to Winston's (1986b) "Townsend line," suggesting reactivation of a deeper, Middle

Proterozoic zone of weakness. Tertiary sedimentary rocks within the eastern Gallatin River valley dip 2°–35° E. toward

the normal fault, suggesting that the Gallatin River valley block has rotated clockwise (looking northward) during

deformation. On the basis of preliminary gravity modeling, Lageson (1989) reported that the Gallatin River valley is an

asymmetric half-graben having a maximum sediment thickness of about 2 km, with 2,200 m of throw on the adjacent

range-front fault. The gravity model casts strong doubt on the existence of pre-Tertiary Phanerozoic rocks of any

differences of the Eocene-Oligocene Renova and Miocene Sixmile Creek Formations, constituting the "Bozeman Group"

(Kuenzi and Fields, 1971; Fields and others, 1985). These two units are separated by the "mid-Tertiary unconformity,"

widely recognized throughout the region. The change from predominantly fine-grained fluvial and lacustrine sediments

(Renova) to predominantly coarse-grained volcaniclastic sandstone and conglomerate (Sixmile Creek) is often cited as

heralding the onset of modern Basin and Range extension in the Three Forks Basin (Lageson, 1989). However,

Thompson and others (1982) called upon four major changes in climate during the Tertiary to account for the differences

in sediment texture. Hanneman and Wideman (1991) used calcic paleosol zones to delimit five sequence stratigraphic

units within the Bozeman Group and correlated sequence 4 (Sixmile Creek) with "partially filled extensional basins." Ir

the Paradise Valley, Burbank and Barnosky (1990) reported that extension began at 17 Ma, immediately following the

surface in the Three Forks and other basins in southwestern Montana, coupled with prograding alluvial fans, entrenched

meandering rivers, and contemporary seismicity, suggests that this is an ongoing process that has become increasingly

wave" of the Yellowstone hot spot; the Bridger Range lies within Belt I, characterized by "new, small escarpments and

reactivated faults" that are in the waxing stage of activity. As the Yellowstone hot spot migrates farther northeast, it may

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mid-Tertiary unconformity. However, the presence of gently tilted Eocene through Miocene sedimentary rocks on the

The onset of post-Laramide crustal extension in southwestern Montana has historically been based on the textural

McMannis (1955) mapped a range-front normal fault at the break in slope along the western base of the Bridger

stage motion on the Battle Ridge–Bangtail back-thrust took place during the waning stages of the Laramide event.

Sedan Formation from superjacent strata to produce the Battle Ridge–Bangtail back-thrust and folded the Fort Union and

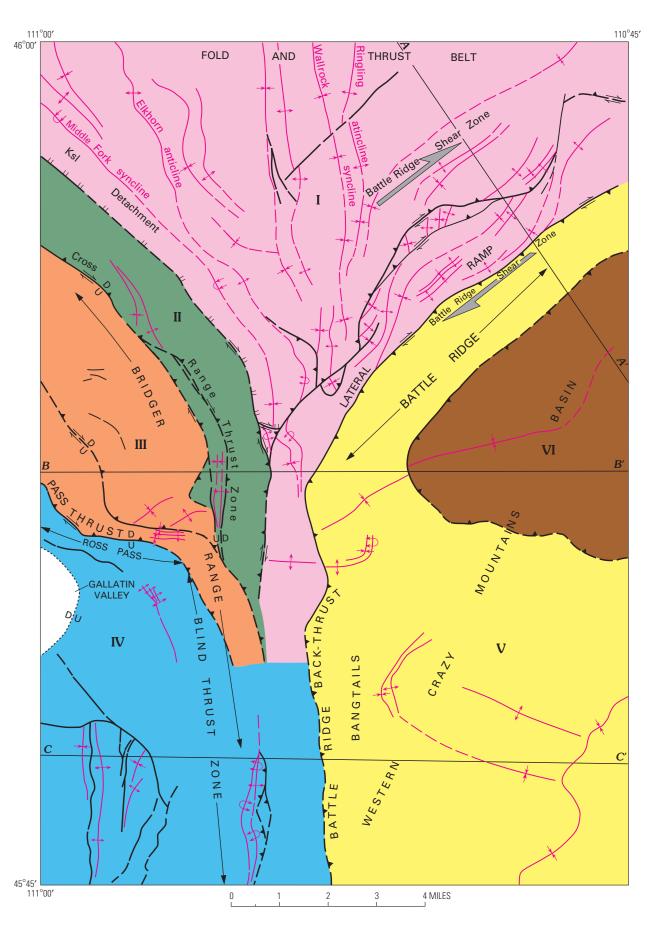
The youngest synorogenic rocks in the Sedan area, the Nixon Peak Conglomerate Lens of the Late Cretaceous to

exemplified in the southern Bridger Range (Miller and Lageson, 1993; cross section C-C').

Laramide uplift of the ancestral Bridger Range closely followed fold-thrust deformation.

Belt and pre-Belt rocks in the Bridger Range.

significant thickness at the bottom of the valley.



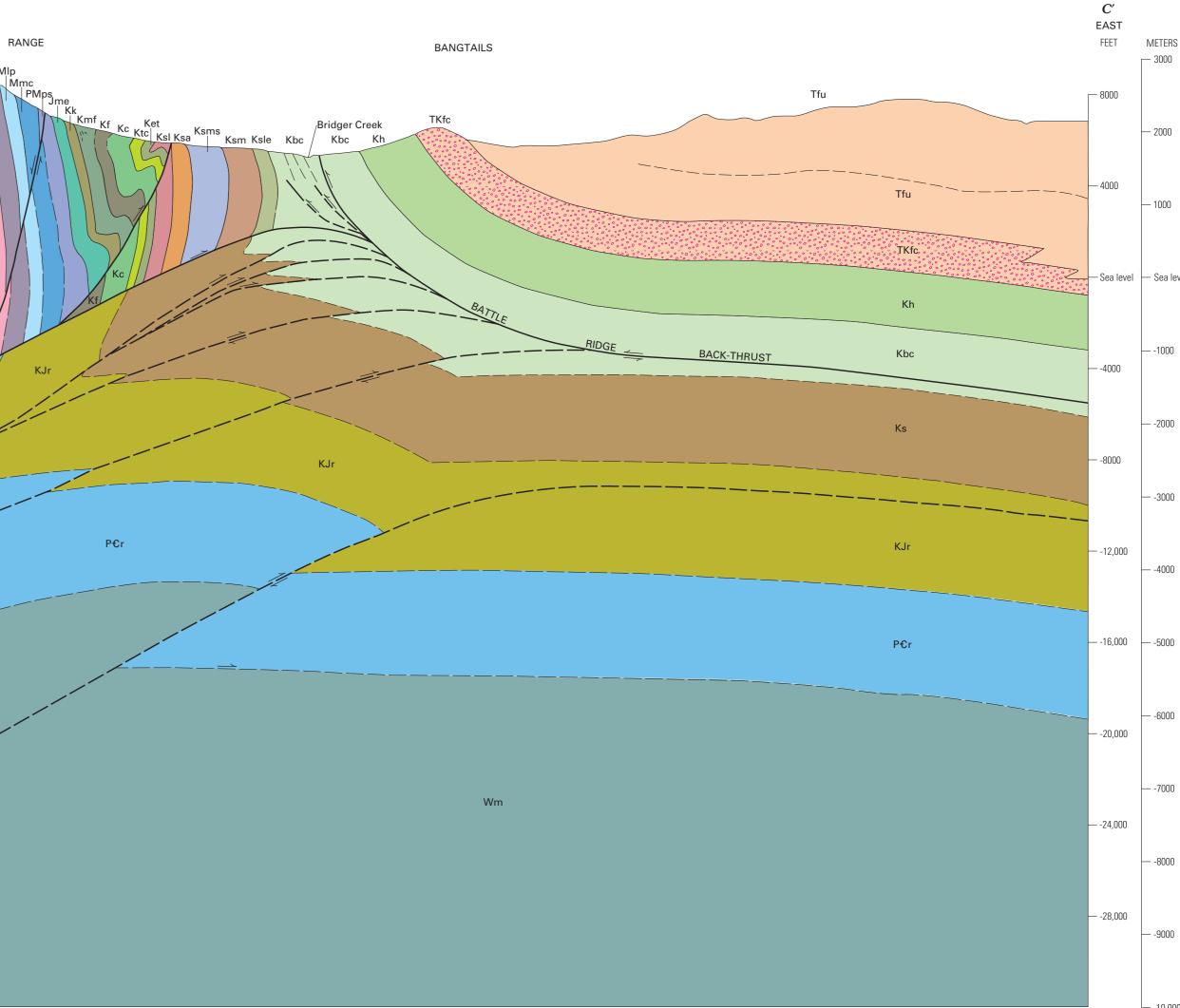
EXPLANATION

------- Fault—Dashed where approximately located or concealed <u>D</u> Normal or oblique slip—Arrows indicate sense of relative movement; U, upthrown side; D, downthrown side  $\rightarrow$  D Thrust—Sawteeth on upper plate; U, apparent upthrown side; D, apparent downthrown side; arrows indicate oblique slip **Detachment**—Double bars indicate upper deformed plate Anticline—Showing crestline. Dashed where approximately located or concealed Overturned anticline—Showing crestline and direction of dip of limbs. Dashed where approximately located o concealed mately located or concealed \_\_\_\_\_ Overturned syncline—Showing troughline and direction of dip of limbs. Dashed where approximately located

or concealed

Structural domains North-central area Cross Range thrust sheet Northern Bridger Range Southern Bridger Range Battle Ridge and the Bangtails Conglomerate of Nixon Peak

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