# Non-marine Deposition in the Cordillera

Devonian to present
(but mostly Cenozoic)
Jerry Smith lecture - November 13, 2002

## Non-marine Depositional Systems

- Previously we have focused on marine and marine/non-marine interface environments with regard to sequence stratigraphy.
- Prior to the Cenozoic, non-marine environments tend to be located east of the orogenic zones close to the North American craton.

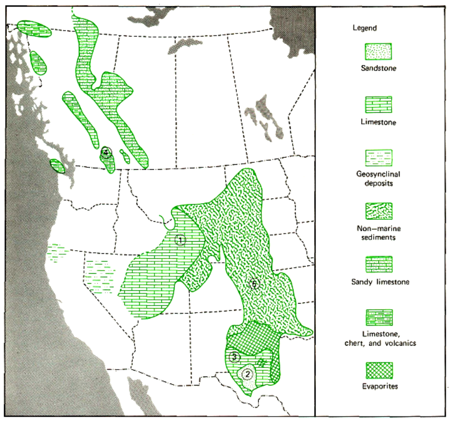


*FIGURE 14–14* **Facies of the Middle Permian Guadalupean Series in western North America. Note the many areas of limestone in the Cordilleran geosyncline. 1. Phosphoria Formation. 2. Delaware Basin. 3. Carlsbad Limestone. 4. Cache Creek Group. 5. Lykins Formation.**

## Depositional Environments

- Eolian
  - – Generally not close to the source area
- Alluvial
- Fluvial
- Lacustrine
  - – The three environments above all grade into one another depending on the climate, drainage and stream equilibrium.

## Eolian

- Wind transported clastic sediments – generally produce sand to silt size particles.
- Typically quartz grains as the mechanical working is too harsh for other minerals
- 2nd generation or higher sediments
- Colors are typically white-yellow: iron staining only on cements.

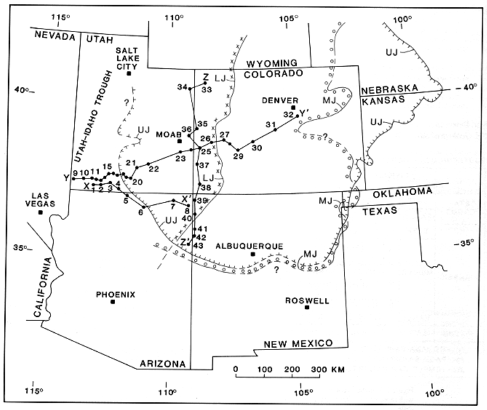


Figure 2. Distribution of the Lower (LJ), Middle (MJ), and Upper (UJ) Jurassic Series in the Southern Rocky Mountains region; each series is present on the side of the line with the symbol; after Peterson (1972), Pipiringos and O'Sullivan (1978), and F. Peterson (unpublished data). Also shown are lines of stratigraphic sections in Figures 3, 4, and 5.

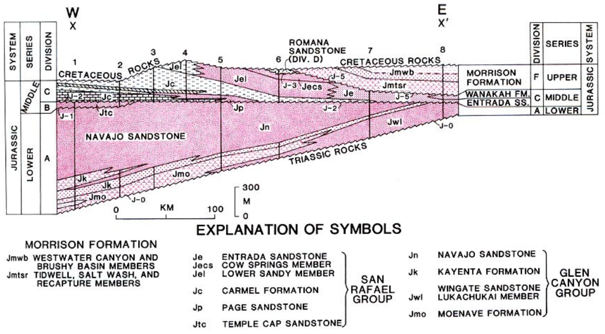
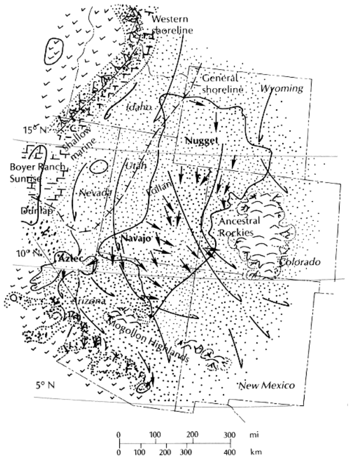
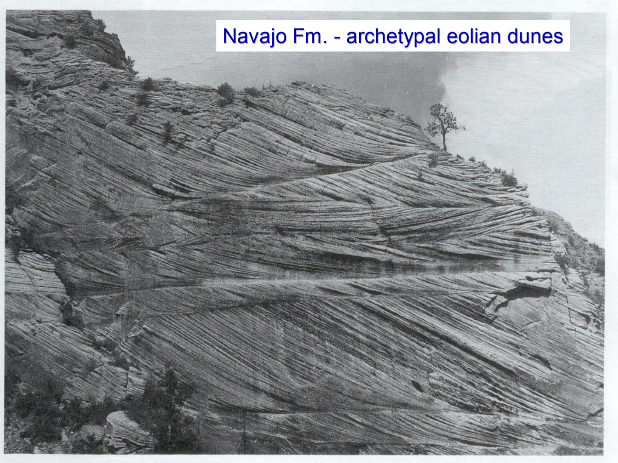


Figure 3. Stratigraphic section of the Jurassic System along the Arizona-Utah state line (after Peterson and Pipiringos, 1979). For location see Figure 2; J-0 to J-5 are unconformities; Glen Canyon Group includes Division A; San Rafael Group includes Divisions B, C, and D. See Figure 4 for explanation of patterns.





Navajo Fm. - archetypal eolian dunes

## Alluvial-Fluvial-Lacustrine

- Examine the transport of clastic sediments from the source (highlands) to the basin.
- Non-clastic deposition (typically stromatolites and evaporites) occur in lacustrine depositional environments.

## Alluvial-Fluvial (Cordillera)

- These comprise the red-beds
- Generally arid environment allows oxidation of iron in the clay matrix and preserves plagioclases.
- Clastic sediments derived from felsic plutons will generate arkosic sandstones and conglomerates.

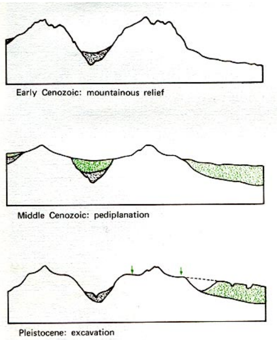


*FIGURE 16–10* **Stages in the development of the central Rocky Mountains. The black pattern indicates early Cenozoic sediments; the colored pattern, Middle Cenozoic sediments. The arrows in the bottom figure indicate the Subsummit surfaces. The High Plains, remnants of the Middle Cenozoic detritus eroded from the mountains, is shown at the right. The vertical scale is greatly exaggerated.**

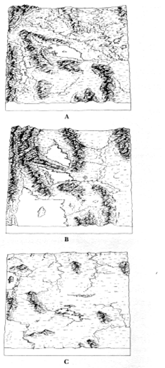


*FIGURE 16–5* **Topography of Wyoming during the Cenozoic Era: A. Late Paleocene, when orogenic forces were still deforming the rocks and relief was high. B. Early Middle Eocene, when relief was greatest and extensive lakes were formed by the westward tilting of the area. C. Late Pliocene, when filling of the basins and erosion of the highlands brought the area to its lowest relief. (Modified from J. D. Love, D. O. McGrew, and H. D. Thomas.)**

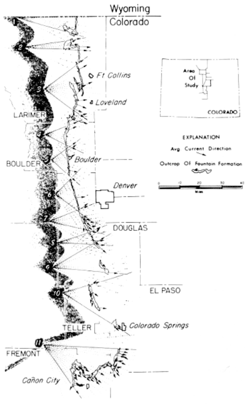


**Fig. 27**—Regional paleocurrent pattern of the Fountain Formation, Pennsylvanian and Permian, Colorado, showing arcuate pattern of paleocurrent vectors from 11 alluvial fans deposited east of the ancestral Rockies (from Howard, 1966).

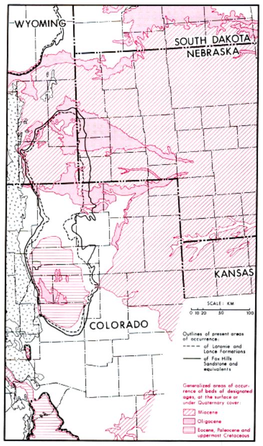


Figure 55. Late Cretaceous and Tertiary deposits. Compiled from state geologic maps of the U.S. Geological Survey and subsurface records.

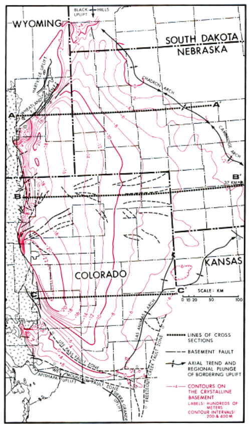


Figure 45. Generalized basement structure of the Denver Basin. Based upon information from Anderman and Ackman, 1963; MacLachlan and Kleinkopf, 1969; Davis and Weimer, 1976; Tweto, 1979a, 1980b, 1983; D. L. Blackstone, Jr., personal communication, 1984; R. A. Johnson, personal communication, 1984; and from geophysical and geological subsurface records. Cross-section lines are those of Figure 46.

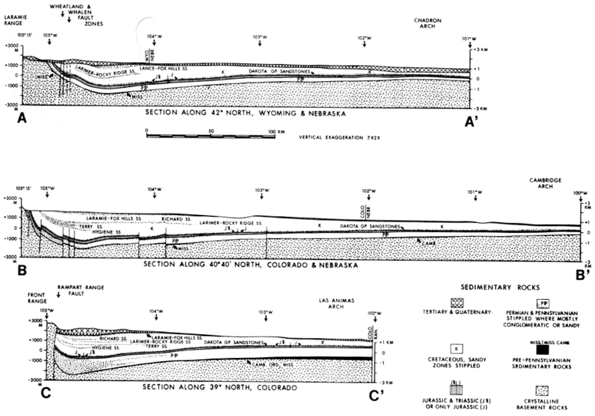


Figure 46. Sections across the Denver Basin along lines of latitude shown in Figure 45. Compiled from work of Anderman and Ackman, 1963; Martin, 1965; Rocky Mountain Association of Geologists Research Committee, 1976; Tweto, 1983; and subsurface data.

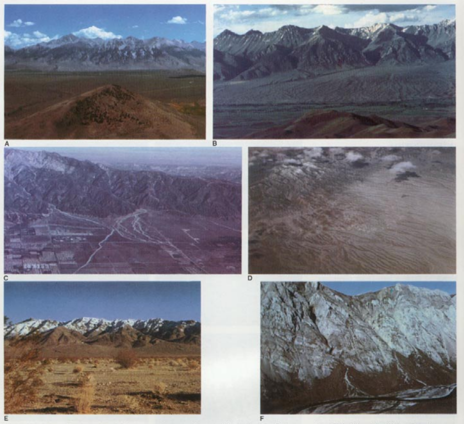


**Fig. 2**—Morphology of coalesced alluvial fans. **A.** Quaternary fans, west flank of Lost River Range, Idaho (photo by T. H. Nilsen). **B.** Quaternary fans, west flank of Lost River Range, Idaho (photo by D. R. Kerr). **C.** Quaternary fans, south flank of eastern San Gabriel Mountains, Los Angeles and San Bernardino Counties, California (photo by T. H. Nilsen). **D.** Quaternary fans, south-central Nevada (photo by T. H. Nilsen). **E.** Quaternary fans, Tiefort Mountains, Mojave Desert, California (photo by R. P. Sharp). **F.** Quaternary fans along Kongakut River, northeastern Brooks Range, Alaska (photo by T. H. Nilsen).

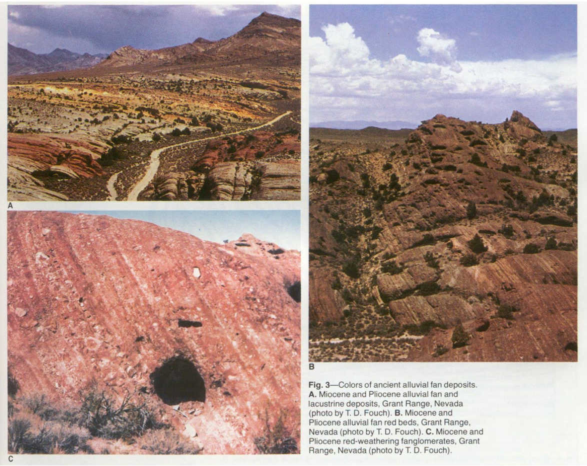


**Fig. 3**—Colors of ancient alluvial fan deposits. **A.** Miocene and Pliocene alluvial fan and lacustrine deposits, Grant Range, Nevada (photo by T. D. Fouch). **B.** Miocene and Pliocene alluvial fan red beds, Grant Range, Nevada (photo by T. D. Fouch). **C.** Miocene and Pliocene red-weathering fanglomerates, Grant Range, Nevada (photo by T. D. Fouch).

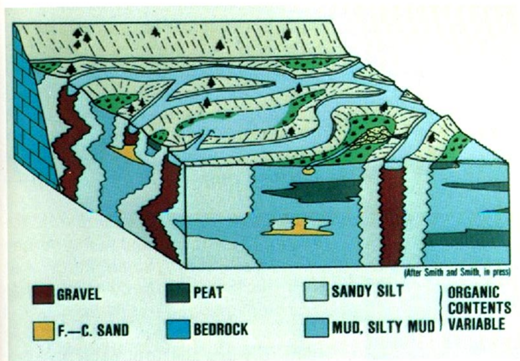
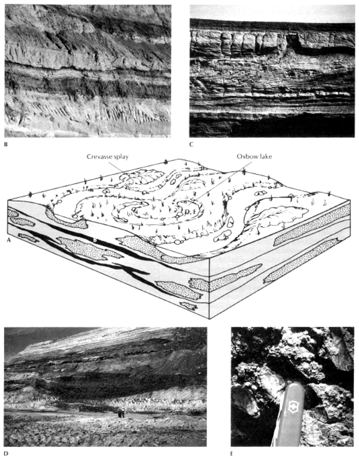


**Fig. 13**—A block diagram of an anastomosing river showing the vertical stacking of channel sandstones and conglomerates. These coarser facies are bounded by floodplain silts, muds, and peats.



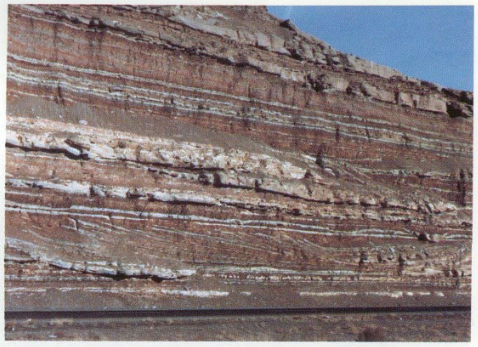


**Fig. 46**—Red fine-grained floodplain deposits of the Triassic Moenkopi Formation of Arizona. The whitish beds are caliche deposits and light-red sandstones at the top are crevasse splays. Many reduced green bands can be seen. A large swale or scour fill is present at the base. About 6 m of section is present.

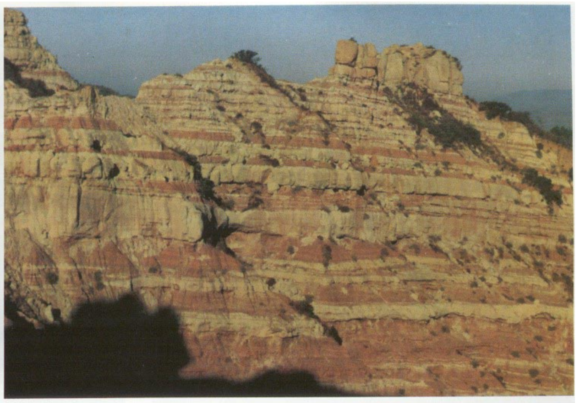


**Fig. 12**—Large outcrop of meandering stream deposits in the Sespe Formation (Oligocene) of California which shows light colored sandstones and red shales. The large sandstone bed in the center of the photograph thins and splits laterally. The more continuous bed above this is about 3 m thick (Photo courtesy J. B. Dunham).

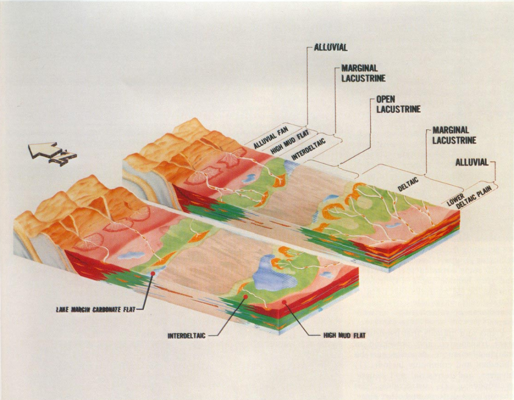


**Fig. 7**—A block diagram illustrating the distribution of interpreted open-lacustrine, marginal-lacustrine, and alluvial depositional environments of the western part of Lake Uinta, Utah, as it existed during the early Eocene. Diagonally striped blue pattern = grain-supported carbonate rock; solid blue pattern = mud-supported carbonate rock; yellow pattern = sandstone; claystone units are shown in their natural colors. Some thin graded siliciclastic units of probable turbidite origin are present in delta fronts and in the open lacustrine faces. Much of the open lacustrine facies is composed of kerogen-rich carbonate units. The width of Lake Uinta in the diagram is about 40 km. Vertical exaggeration is between 15 and 20. Diagram is modified from Ryder and others (1976).

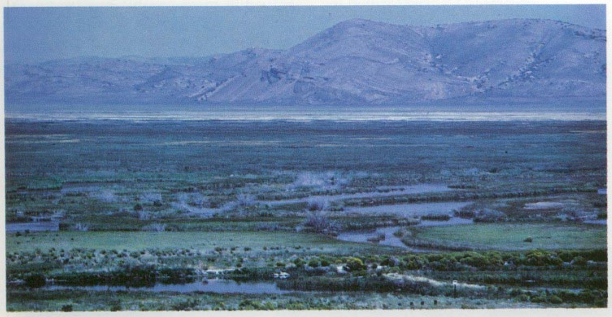


**Fig. 6**—Ruby Lake, Nevada. A lacustrine system in the arid Basin and Range province that consists of marsh lakes. Some lakes are connected by channels with slow-moving currents. Open-lake settings are commonly surrounded by marshlands covered by emergent aquatic plants, grasses, and some small shrubs. Alkalinity of the waters varies with distance from springs or inflowing streams. Evaporite mineral crusts form in some areas in shallow water or on beaches peripheral to the permanent lakes.

## Example of Alluvial to Lacustrine Depositional Systems

Green River Basin of Utah-Colorado-Wyoming

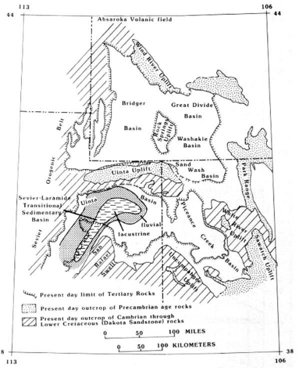
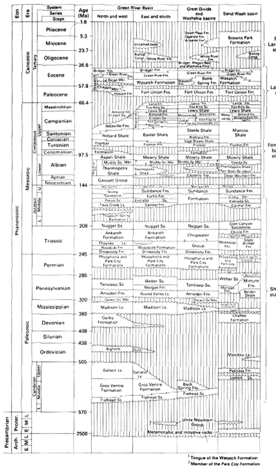
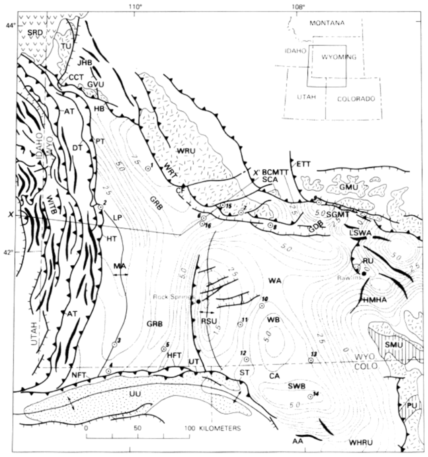


Figure 27. Map showing locations of Precambrian basement outcrops, the Uinta and Piceance Creek Basins, and the basins that make up the greater Green River basin in Utah, Colorado and Wyoming. The approximate extent of the Sevier-Laramide transition sedimentary basin during Late Cretaceous Maastrichtian time is also shown (from Fouch and others, 1983). Key is shown on figure 29.





Basins of the Rocky Mountain region

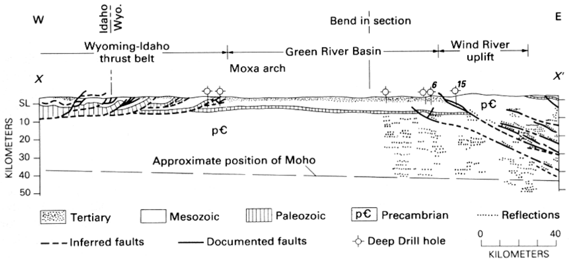


Figure 34. Cross section through the Wyoming-Idaho thrust belt, the Green River Basin, and the Wind River Uplift. Line of section is located on Figure 33. The section is from Bally and Snelson (1980). Drill holes 6 and 15 are identified in Table 2.

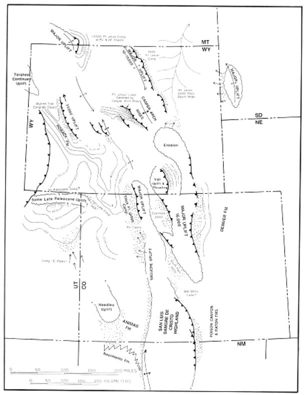


FIGURE 8. Isopach map of Paleocene sediments, showing thick accumulations occurring on the flanks of major uplifts. Large Paleocene vertical displacements occurred on the Sangre de Cristo, Front Range, Saguache, Medicine Bow, Park, Big Horn and Casper arch, Black Hills, Beartooth, and Wind River uplifts with associated thick conglomerates shed into the adjacent basins. Contour interval is 305 m (1000 ft).

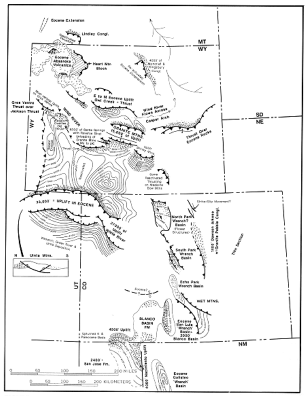
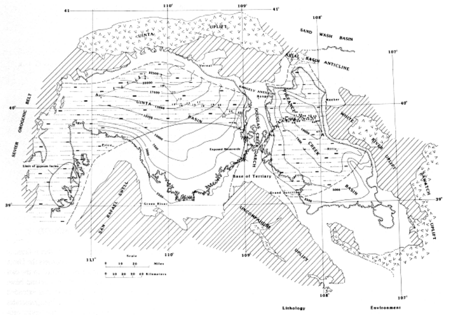


FIGURE 9. Isopach map of Eocene sediments, showing well-defined thicks in partitioned basins. Eocene compressive forces caused uplift of the Uinta–White River system (8200–10,000 m; 27,000–33,000 ft), Granite Mountains (4500 m; 15,000 ft), and Owl Creek Range (3000–4500 m; 9840–15,000 ft). Thrusts were reactivated on the north or south flanks of older uplifts and, simultaneously, wrench basins formed along the east side of the Colorado Plateau (North Park, South Park, Echo Park, San Luis, and Galisteo basins).



| Lithology | Environment |
|---|---|
| Volcaniclastic sandstone | Sandy shelf and slope deposits |
| Carbonate-rich oil shale with some sandstone and siltstone | Marginal lacustrine to offshore lacustrine transition zone |
| Carbonate-rich oil shale | Offshore lacustrine |
| Stromatolitic, ostracodal and oolitic limestone, sandstone, and carbonate mudstone | Carbonate rich marginal lacustrine shelf deposits |
| Sandstone, carbonate mudstone, and some stromatolitic, ostracodal and oolitic limestone | Sandstone rich marginal lacustrine shelf deposits |
| Illitic oil shale | Offshore lacustrine |
| Mollusk rich sandstone, ostracodal limestone, gray shale, carbonaceous shale and coal | Paludal and fresh water lacustrine shelf deposits |
| Varicolored mudstone with lenticular sandstones | Fluvial and alluvial |

Figure 28. Map showing the distribution of lithologies and interpretations of environments of deposition during the maximum extent of late Paleocene age Lake Flagstaff in the Uinta Basin and its equivalent in the Piceance Creek Basin. The isopachs are the approximate original thickness in feet of early Cenozoic sedimentary rocks prior to later periods of erosion. The area labeled "Exposed Mesaverde" on the Douglas Creek Arch is where the Cretaceous-Tertiary unconformity had not, at this time, been onlapped by early Tertiary sedimentary rocks. The accompanying key is for Figures 28 to 32.

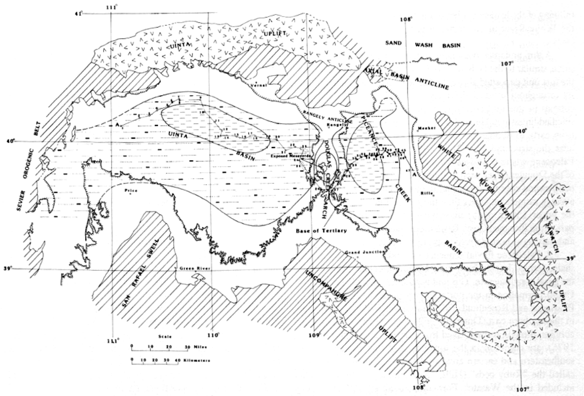


Figure 30. Map showing the distribution of lithologies and interpretations of environments of deposition during maximum extent of early Eocene freshwater lakes. The area labeled "Exposed Mesaverde" on the Douglas Creek Arch is where the Cretaceous-Tertiary unconformity had not, at this time, been onlapped by early Tertiary sedimentary rocks.

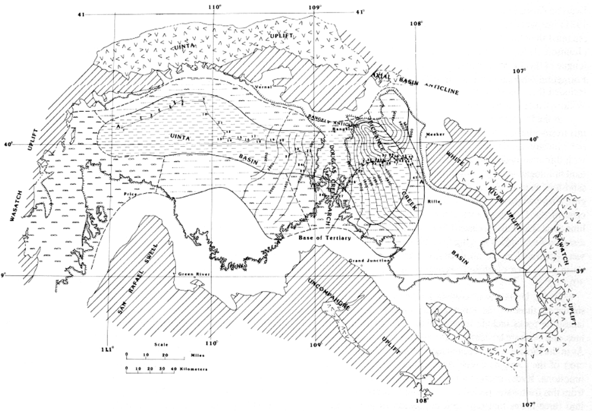


Figure 31. Map showing the distribution of lithologies and interpretations of environments of deposition just after the Long Point transgression. The isopach is the thickness in feet of rocks from the Cretaceous-Tertiary unconformity to the base of the Long Point Bed or its equivalent.

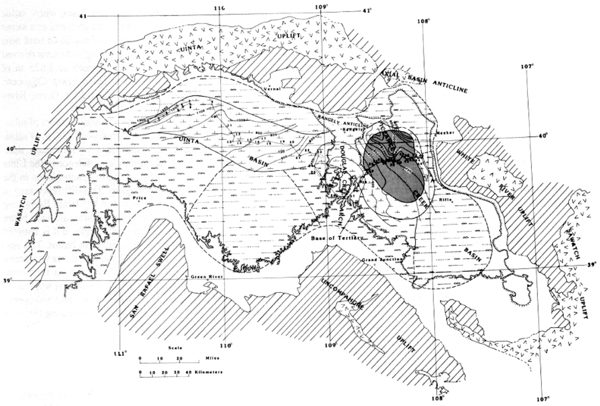


Figure 32. Map showing the distribution of lithologies and interpretations of deposition of the R-4 rich oil-shale zone. The isopach shows the thickness in feet of the interval from the base of the R-4 zone to the base of the Mahogany oil-shale zone.

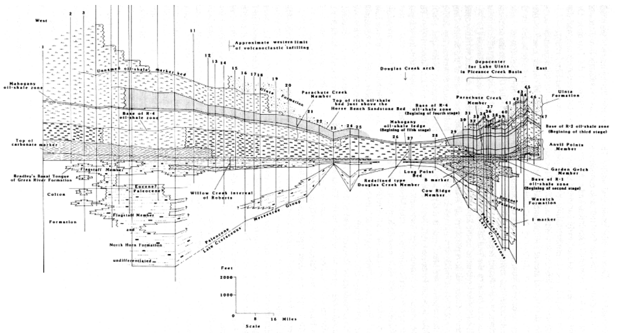
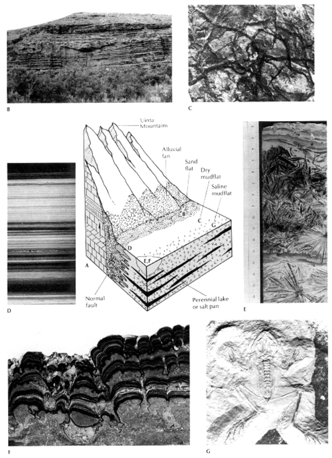


Figure 29. Cross section showing early Cenozoic rocks in the Uinta and Picance Creek Basins. The location of the cross section is shown on Figure 28. The drillholes and measured sections used are listed in Table 1.



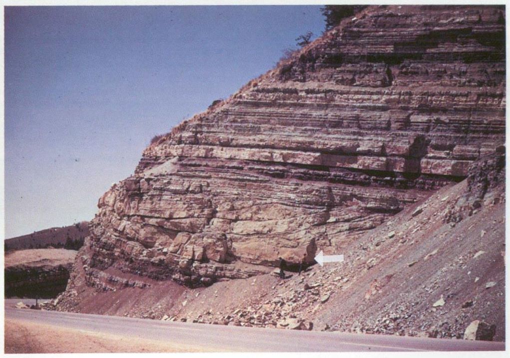


**Fig. 63**—Green River Formation, Willow Creek Canyon, Utah. Channel-form sandstone with well-developed, large-scale, low-angle cross-beds separated by clayey siltstone units and with scour structures and logs at the base of the unit. The overlying flat-bedded units consists of tan to gray, ostracodal, mud-supported carbonate rocks and red, green, and gray claystone and siltstone. The channel was formed in a meandering steam on a lower interdeltaic plain adjacent to Lake Uinta that was periodically transgressed (Ryder et al, 1976). Note men at base of channel for scale.

**Fig. 58**—Douglas Creek Member of the Green River Formation, Bull Canyon, Utah. Flat-bedded depositional complex of discontinuously laminated, mud-supported carbonate beds **(A)** locally capped by stromatolitic algal boundstones with polygonal pull-apart cracks, interbedded with thin-bedded to structureless, green, argillaceous siltstone **(B)**. These units are cut by channel-formed, fine-grained sandstone beds **(C)**. The sandstone units grade upward from large-scale, low-angle tabular to trough cross-strata near base to medium-scale trough cross-strata to small-scale cross lamination at the upper margin of each channel-form bed. This sequence represents cyclic, shallow lacustrine, deltaic, and subaerial delta-plain sedimentation during periods of shoreline regression.

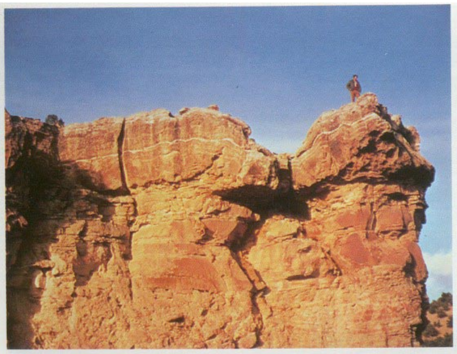


**Fig. 61**—Douglas Creek Member of the Green River Formation, Three-Mile Canyon, Utah. Deformed sandstone, siltstone, and claystone of a fluvial and shallow lacustrine origin. Terrigenous units are overlain by stromatolitic algal boundstone. This depositional complex was formed both on a lower deltaic plain and on a carbonate-flat during a saline phase of Lake Uinta (Fouch et al, 1976).

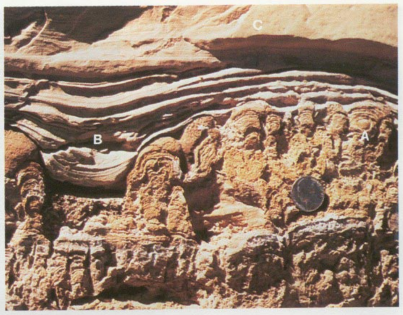


**Fig. 62**—Douglas Creek Member of the Green River Formation, East Tavaputs Plateau, Utah. Stromatolitic algal boundstone **(A)** overlain by an ostracodal, curviplanar, laminated to small-scale cross-laminated, calcareous sandstone **(B).** The sandstone is overlain by a laterally continuous, small-scale cross-laminated, ostracodal, grain-supported limestone **(C)** up to 1 m thick that is turn overlain by stromatolitic carbonate rock. This depositional complex represents cyclic carbonate shoal deposition overlain by terrigenous strata deposited in deltaic and lower delta-plain environments.

**Fig. 44**—Green River Formation (Eocene), Slab Canyon, Utah. Polygonal pull-apart cracks developed in a calcareous siltstone that were filled with sandstone. These beds are part of a marginal-lacustrine complex characterized by laterally continuously bedded siltstone and claystone with rare channel-form sandstone units. The complex was formed in an area of a fluctuating lacustrine shoreline. During periods of exposure, stream channels distributed grains to areas that were previously sites of lacustrine sedimentation. Photograph by R. T. Ryder.

**Fig. 41**—Green River Formation (Eocene), Slab Canyon, Utah. Polygonal pull-apart (dessication) cracks with bird tracks on very thin-bedded calcareous siltstone. The depositional setting of this feature is interpreted to be part of a lacustrine mud flat that was periodically exposed. Photography by R. T. Ryder.

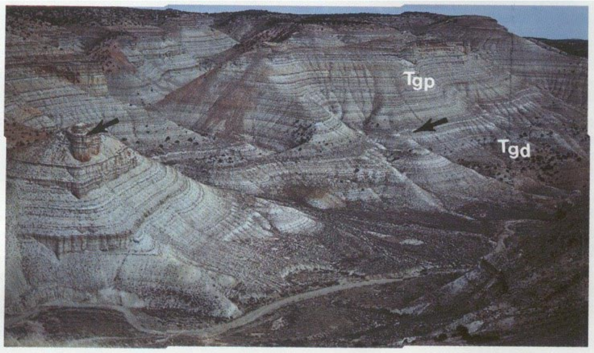


**Fig. 8**—Eocene part of the Green River Formation, Hells Hole, Uinta Basin, Utah. A view of the bedding character of open-lacustrine rocks that formed in a low energy setting of Lake Uinta. The Parachute Creek Member (Tgp) in this part of the Uinta Basin contains several oil-shale zones, the principal one being the Mahogany zone (arrows). This exposure contains over 300 m of nearly continuous strata that contain abundant lipid-rich organic matter. These open-lacustrine rocks grade laterally and downward into marginal-lacustrine rocks of the Douglas Creek Member (Tgd).

**Fig. 9**—Eocene Parachute Creek Member, Green River Formation, Uinta Basin, Utah. Outcrop bedding character of horizontally laminated, kerogen-rich "oil shale" that was preserved in an anoxic, low-energy, open-lacustrine environment of Lake Uinta. The rocks shown are part of the Mahogany ledge exposed near Hells Hole, Utah. 1 cm = 0.33 m.

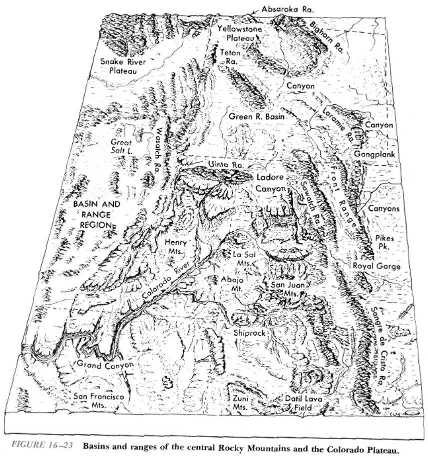


*FIGURE 16–23* **Basins and ranges of the central Rocky Mountains and the Colorado Plateau.**

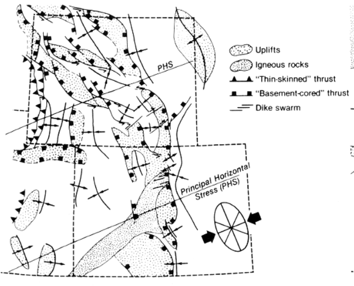


Figure 39. Paleotectonic map of Colorado and Wyoming showing the orientation of the principal horizontal stress (PHS), uplifts, and structures active during the early Laramide Orogeny, Maastrichtian to Paleocene time (simplified from Livaccari and Keith, 1985).

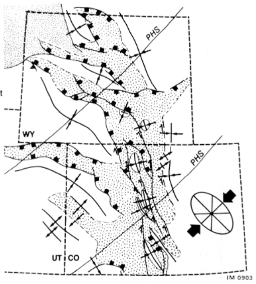


Figure 40. Paleotectonic map of Colorado and Wyoming showing the orientation of the principal horizontal stress (PHS), uplifts, and structures active during the late Laramide Orogeny, Eocene time (simplified from Livacarri and Keith, 1985).

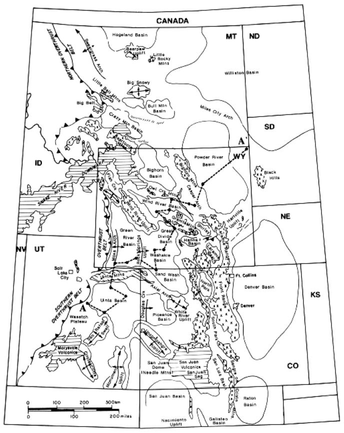


**FIGURE 5.** Map showing Rocky Mountain foreland basins and uplifts. Line of regional cross section shown as A–A′. X's denote Precambrian crystalline rocks, diagonal hachures are Precambrian sedimentary rocks, and horizontal hachures are major Tertiary volcanics.

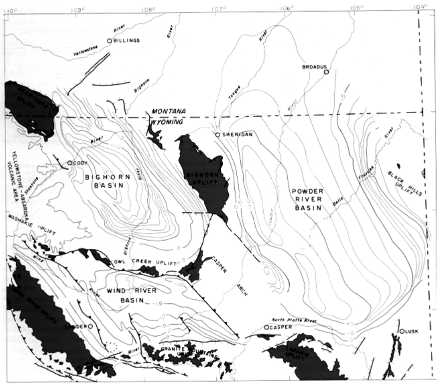


Figure 59. Tectonic map showing Powder River, Bighorn, and Wind River Basins and adjacent uplifts. Precambrian areas on uplifts are patterned. Contours are on the Precambrian surface and at intervals of 5,000 feet. Interbasin areas and uplifts are not contoured. Thrust and reverse faults have sawteeth on upper plate; normal faults have hachures on downdropped plate. Details of structures along the west margins of the Powder River and Bighorn Basins and the north margin of the Wind River Basin are not shown. References to these are given in the individual basin descriptions. Modified from Bayley and Muehlberger, 1968.

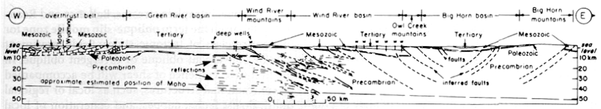
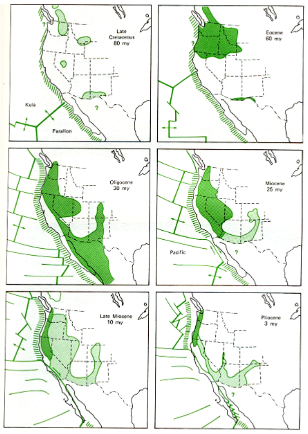


**Fig. 9.43.** Cross section through Powder River and Wind River basins, based on deep-seismic-reflection data. Note that the structural style of these basins is dominated by deep-seated thrust faults, contrasting with the thin-skinned tectonics of the overthrust belt at *left*. (Bally and Snelson 1980)



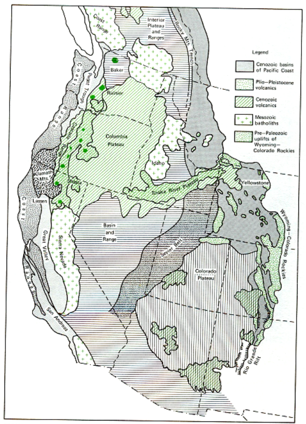


*FIGURE 16–13* **Map of the central Cordillera showing the main structural provinces.**

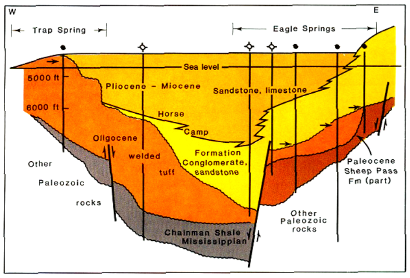


Figure 73—Cross section in Railroad Valley, Nevada, illustrating Tertiary sedimentary and volcanic rocks from the Eagle Springs oil field to the Trap Spring oil field. Oil is produced from fractured lacustrine carbonate rocks of the Sheep Pass Formation and from fractured welded tuff at Eagle Springs. Claypool and others (1979) indicated that the oil at Eagle Springs originated from the thermochemical maturation of organic matter in lacustrine rocks of the Sheep Pass Formation. The Ely Formation is of late Paleozoic age.

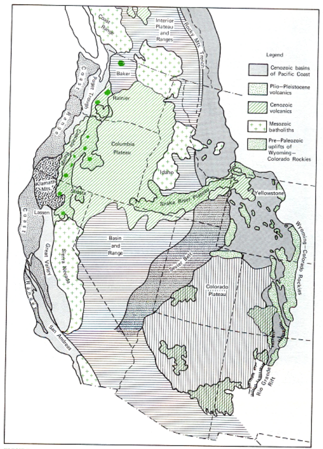


*FIGURE 16–13* **Map of the central Cordillera showing the main structural provinces.**