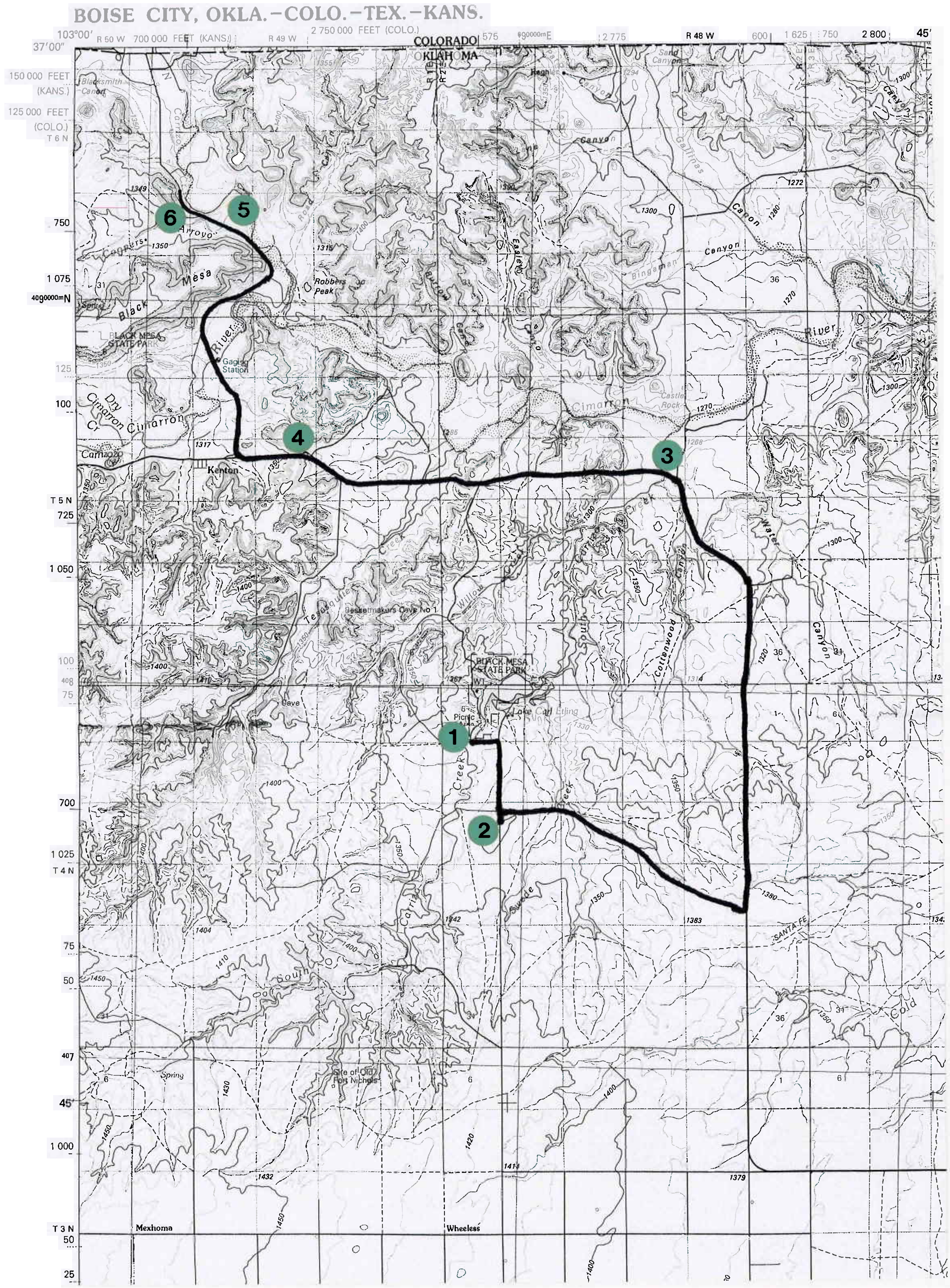
A FIELD TRIP GUIDE TO THE GEOLOGY OF THE BLACK MESA STATE PARK AREA, CIMARRON COUNTY, OKLAHOMA

OKLAHOMA GEOLOGICAL SURVEY
OPEN-FILE REPORT 0F4-99


BOISE CITY, OKLA.-COLO.-TEX.-KANS.
COLORADO
OKLAHOMA
Black Mesa
BLACK MESA STATE PARK
Cimarron
River
Gaging Station
Kenton
Carrizozo
Dry Cimarron Cr
Robbers Peak
Castle Rock
Basketmakers Cave No 1
Lake Carl Etling
Picnic Area
Site of Old Fort Nichols
Mexhoma
Wheeless
SANTA FE
1
2
3
4
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6

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INTRODUCTION

The geology of the area near Black Mesa State Park and northwestern Cimarron County is unique in Oklahoma. Nowhere else in the State are Triassic and Jurassic rocks exposed, except for some small exposures of Triassic rocks near Guymon. Nowhere else in the State have so many dinosaur bones been discovered; so many, in fact, that they are only now being properly catalogued and identified. And nowhere else in the State is there evidence for recent nearby volcanism; Black Mesa, the highest point in Oklahoma at 4973 ft above sea level, is a basalt lava flow that is less than 5 million years old and was erupted from a volcano located in southeastern Colorado.

In addition, the physiography of this part of the Panhandle is completely different from that in the rest of Oklahoma. For the traveler arriving from the east, the seemingly monotonous "flat" of the High Plains suddenly gives way to buttes and mesas reminiscent of "The Old West". This change is physiography is a direct result of the unique geology of this corner of Oklahoma.

REGIONAL GEOLOGY

The geologic framework for this part of Oklahoma was established by Schoff and Stovall (1943). (J. Willis Stovall was a professor of geology at the University of Oklahoma and director of the University Museum, later renamed the Stovall Museum of Science and History (Hunt and Lucas, 1987), and now called the Sam Noble Oklahoma Museum of Natural History). He is perhaps best known for the extensive collections of dinosaur bones he made in the Black Mesa area between 1935 and 1942 with the support of the Work Projects Administration.) Despite some revisions to the stratigraphy of the area (e.g., several papers in Lucas and Hunt, 1987c), the geologic map of Cimarron County and basic geology of the area as described by Schoff and Stovall (1943) have been little improved upon in 55 years.

The stratigraphy of the Black Mesa area is shown in figure 1. The oldest rocks are Triassic (more specifically Carnian and early Norian, i.e., 231 to 215 million years old) and are best exposed just north of Black Mesa. **Stop 6** on this field trip will examine the two Triassic formations that occur in this area - the older Sloan Canyon Formation overlain by the younger Sheep Pen Sandstone. An unconformity (period of non-deposition or erosion) separates the Triassic Sheep Pen from the overlying Jurassic Exeter Sandstone. (Note - Throughout this brief guidebook, the formation names used by Schoff and Stovall (1943) will be used. We recognize, however, that the terminology proposed by Lucas and Hunt, 1987c) may be equally valid.) The Exeter Sandstone is about 157 to 152 million years old; therefore, the unconformity between the Sheep Pen and Exeter represents about 60 million years of geologic history in this part of Oklahoma about which we have no information. Several lines of evidence suggest the Triassic formations were deposited in or near stream channels; in contrast, the Exeter

Sandstone is clearly an ancient sand dune deposit, and we will see evidence for this at **Stop 6**.

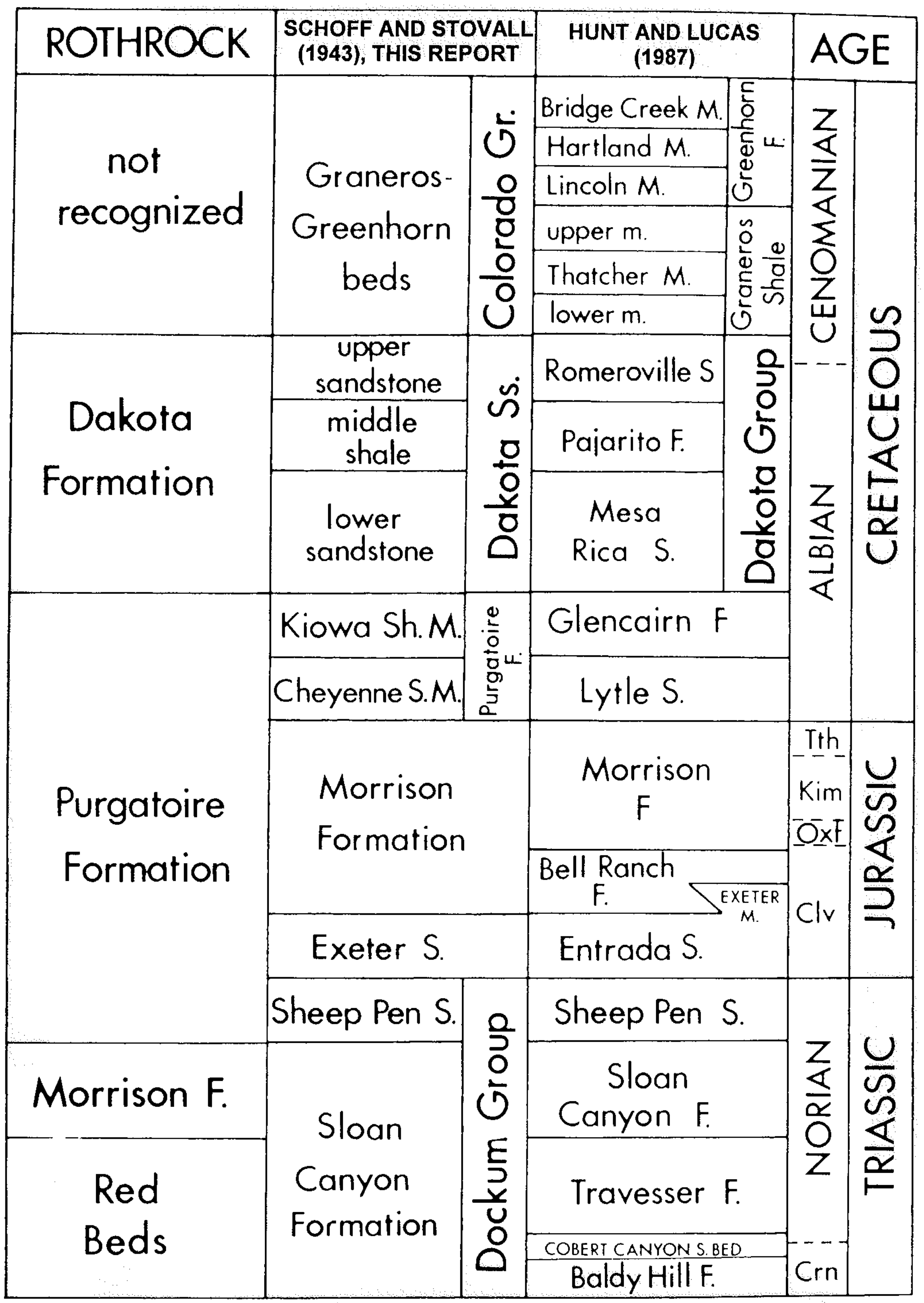


Fig. 1. Stratigraphic nomenclature of Mesozoic strata in the Black Mesa area, northwestern Oklahoma, of Schoff and Stovall (1943) and Hunt and Lucas (1987). Modified from Hunt and Lucas (1987).

The middle Jurassic Exeter Sandstone is overlain by the late Jurassic Morrison Formation. The Morrison is about 150 to 134 million years old and the contact between the Exeter and Morrison is also an unconformity, albeit one that does not represent much geologic time. The Morrison Formation is "famous" throughout the western United States for the dinosaur bones and footprints that are found in it. Among the more outstanding places where the public can see evidence for dinosaurs in the Morrison are Dinosaur Ridge outside Denver and Dinosaur National Monument near Vernal, Utah. We will visit the Morrison Formation and Stovall's quarry no. 1 at **Stop 3** and see dinosaur tracks in the Morrison at optional **Stop 5** of this field trip. The Morrison Formation in Oklahoma, like the Triassic, was deposited as channel and floodplain deposits, although locally it contains lake deposits.

The late Jurassic Morrison Formation is overlain by a series of conformable early to late Cretaceous formation that range in age from about 106 million years to 92 million years. Obviously, another major unconformity separates the Jurassic from Cretaceous rocks in the Black Mesa area. The Cretaceous formations are, from bottom to top, the Cheyenne Sandstone, Kiowa Shale, Dakota Sandstone, and Graneros-Greenhorn beds (Fig. 1). Conglomerate beds (present at **Stop 4**) in the Cheyenne are evidence for deposition in a swiftly moving stream or river. Marine fossils in the Kiowa (present at **Stop 4**) are evidence that at least part of it was deposited in the ocean. Petrified logs, leaf fossils, and dinosaur footprints in the Dakota are evidence for a return to a mostly non-marine environment of deposition. We will see abundant evidence for the non-marine character of the middle shale member of the Dakota at **Stop 1**. The abundance of limestone with marine fossils in the Graneros-Greenhorn (**Stop 2**) is the first indication that a major seaway developed in this part of Oklahoma.

At first glance, the strata in this part of Cimarron County appear horizontal; in fact, they dip very gently to the southeast, although this general tilt is interrupted by some very broad, open folds. Because the strata dip southeast, older rocks are generally exposed to the northwest (e.g., **Stop 6**) and younger rocks are generally exposed to the southeast (e.g., **Stop 2**). The Mesozoic rocks dip southeast off the east flank of the Sierra Grande Arch, a north-northeast-trending broad uplift centered in northeastern New Mexico. The Sierra Grande Arch was active during the formation of the ancestral Rocky Mountains in the Pennsylvanian (about 320-290 m.y. ago) and was reactivated during the formation of the present-day Rocky Mountains during the Laramide orogeny of late Mesozoic - early Cenozoic age (about 80-50 m.y. ago). The origin of the smaller folds that are superposed on this eastern flank of the Sierra Grande Arch is unknown.

ACKNOWLEDGMENTS

This guidebook is an outgrowth of an ongoing program of regional digital geologic mapping by the Oklahoma Geological Survey under the U.S. Geological Survey's STATEMAP project. The program consists of literature review, field checking of existing geologic maps, and digital compilation at a scale of 1:100,000. The Boise

City 1° sheet was completed under USGS STATEMAP Agreement No. 1434-HQ-97-AG-01798.

This guidebook is also a preliminary version of a formal OGS publication in preparation by the authors. We welcome any comments or suggestions by the users of this guidebook on how to improve the final version.

ROAD LOG FOR BLACK MESA FIELD TRIP

(Note: This road log is based partly on four, excellent, recently published road logs of the Black Mesa State Park area (Lucas and others, 1987a; Lucas and Hunt, 1987a, 1987b; Mulvany and Mulvany, 1988). The appendices are numbered to correspond to the field trip stops.)

0.0 Start road log at Black Mesa State Park office (App. 1, p. 32). Drive south.

0.1 Petrified logs to right were collected by park personnel from the lower sandstone member of the Dakota Sandstone and set upright in concrete bases. Petrified wood is relatively common in the lower sandstone member in the Black Mesa area but none is in "growth position", i.e., all the wood fell and was transported to its present location before it was petrified. In contrast, "in situ" wood is present in the middle shale member of the Dakota.

Two brief notes about collecting petrified wood: 1) In this part of Oklahoma, all land that is not in the state park is privately owned. Collecting in Black Mesa State Park is prohibited and collecting on private land requires permission of the landowner. 2) Collecting petrified wood on federally managed land (e.g., Bureau of Land Management land in adjacent Colorado or New Mexico) is permitted. Laws found in Title 43 (Dept. of the Interior) state that any wood collected must be for private use and not be sold. In addition, there is a maximum of 25 lbs. plus one piece per day with an annual maximum of 250 lbs. (Daniels, 1998, p. 163-164).

0.8 Low-water bridge over South Carrizo Creek. Cross bridge, turn east, and park.

STOP 1. MIDDLE SHALE MEMBER OF THE DAKOTA SANDSTONE

The middle shale member of the Dakota Sandstone is well exposed in the cutbank on the west side of South Carrizo Creek just above the slab crossing (Fig. 2). About 44 ft of the middle part of the member is exposed and has been measured and studied in detail by Kues and Lucas (1987, p. 197); the underlying lower sandstone member and overlying upper sandstone member are not exposed here (Table 1).

The middle shale member of the Dakota Sandstone at this locality consists of interbedded sandstone and shale. The tops of many of the sandstone beds contain ripple marks (evidence for deposition by moving water) and trace fossils (evidence that after the sand was deposited, animals burrowed through the sand looking for food). In places small, poorly silicified tree trunks are preserved in an upright position. Some of the blocks that have fallen off the cliff contain well-preserved leaf fossils. Kues and Lucas (1987) noted that some of the shale in the outcrop contains lignite (unit 5 in Table 1).

Fig. 2. Middle shale member of Dakota Sandstone at Stop 1 on west side of South Carrizo Creek.

Section F—South Carrizo Creek

Measured in the NE¼ NE¼ NW¼, sec. 7, T4N, R2E in the western bank of South Carrizo Creek just south of Black Mesa State Park, Cimarron County, Oklahoma.

unit	lithology	thickness (m)
	Pajarito Formation:	
15	Clayey sandstone; grayish orange (10 YR 7/4) and dark yellowish orange (10 YR 6/6); weathers to moderate brown (5 YR 3/4); quartzose; very fine-fine grained; subangular, poorly sorted; slightly calcareous; ripple laminar to bioturbated.	0.5
14	Interbedded clayey sandstone and shale; same lithologies and colors as unit 12.	1.5
13	Clayey sandstone; very pale orange (10 YR 8/2) and moderate yellowish brown (10 YR 5/4) unweathered; weathers to dark yellowish brown (10 YR 4/2) and dusky yellowish brown (10 YR 2/2); quartzose; medium grained; well sorted; well rounded; slightly calcareous; laminar; UNM locality 1480 (dinosaur footprints) at top of unit.	0.6
12	Interbedded clayey sandstone and shale; sandstone is yellowish gray (5 Y 8/1), quartzose, very fine grained, well rounded, moderately sorted, non-calcareous and laminar to bioturbated; shale is yellowish gray (5 Y 8/1) and medium dark gray (N 4); non-calcareous.	1.4
11	Clayey sandstone; very pale orange (10 YR 8/2) and yellowish gray (5 Y 8/1); hematized burrows are moderate brown (5 YR 4/4); quartzose; fine grained, well sorted; well rounded, non-calcareous; bioturbated.	0.7
10	Clayey sandstone; very pale orange (10 YR 8/2) and pale yellowish brown (10 YR 6/2); quartzose; fine grained; well sorted; well rounded; slightly calcareous; bioturbated to ripple laminar.	0.8
9	Interbedded shale and sandstone; same lithologies and colors as unit 5.	2.6
8	Sandstone; grayish orange (10 YR 7/4); weathers to moderate reddish brown (10 YR 5/4) and moderate brown (5 YR 4/4); quartzose; very fine-fine grained; rounded-subrounded; well sorted; non-calcareous; hematitic; massive.	0.8
7	Interbedded shale and sandstone; same lithologies and colors as unit 5.	0.3
6	Sandstone; grayish orange (10 YR 7/4); weathers to dark yellowish orange (10 YR 6/6) and moderate brown (5 YR 4/4); quartzose; fine-medium grained; well sorted; subrounded-rounded; non-calcareous; hematitic; massive.	0.4
5	Interbedded shale and clayey sandstone; shale is medium gray (N 5) and light olive gray (5 Y 6/1), contains some lignite that is dark gray (N 3) and is non-calcareous; sandstone is moderate brown (5 YR 4/4), weathers grayish orange (10 YR 7/4), quartzose; fine-coarse grained, very poorly sorted, subrounded, carbonaceous in places and intensively bioturbated.	1.2
4	Sandstone; very pale orange (10 YR 8/2) with moderate brown (5 YR 3/4) and dark yellowish orange (10 YR 6/6) hematitic streaks; quartzose; very fine-medium grained; poorly sorted; subrounded-rounded; some hematized plant stems; non-calcareous; intensively bioturbated.	0.3
3	Interbedded siltstone and silty shale; siltstone is medium gray (N 5) and dark gray (N 4) and non-calcareous; shale is pale yellowish orange (10 YR 8/6) and moderate brown (5 YR 4/4) and non-calcareous.	0.8
2	Sandstone; very pale orange (10 YR 8/2); weathers to moderate yellowish brown (10 YR 5/4); quartzose; fine-medium grained; rounded-subrounded; moderately sorted; non-calcareous; massive with some trough crossbeds.	0.8
1	Sandstone; medium gray (N 5) and grayish orange (10 YR 7/4); quartzose, very fine-medium grained; poorly sorted; subrounded; carbonaceous; calcareous; ripple laminar.	0.6+

Table 1. Measured section of middle shale member of Dakota Sandstone (Pajarito Formation of Kues and Lucas (1987)). From Kues and Lucas (1987, p. 197)

Several features in this outcrop of the middle shale member of the Dakota Sandstone are evidence that it was deposited on a delta (Fig. 3) and that the shales probably are floodplain deposits that were periodically covered by floodwaters that deposited the sandstone beds (crevasse-splay deposits). Carbonized plant debris is present in some of the shale and sandstone beds; this is typical of a delta environment. The presence of wood in growth position is also evidence that these sediments were deposited in a fresh-water environment. Unit 5 in Table 1 (from Kues and Lucas, 1987) contains lignite. Lignite is a brownish-black coal that is intermediate in coalification between peat and subbituminous coal (App. 1, p. 33). Lignite is derived from plant material found in swamp or marsh environmentS which are common in deltas. Unit 13 in Table 1 (from Kues and Lucas, 1987) contains footprints of an ornithopod dinosaur (Fig. 4).

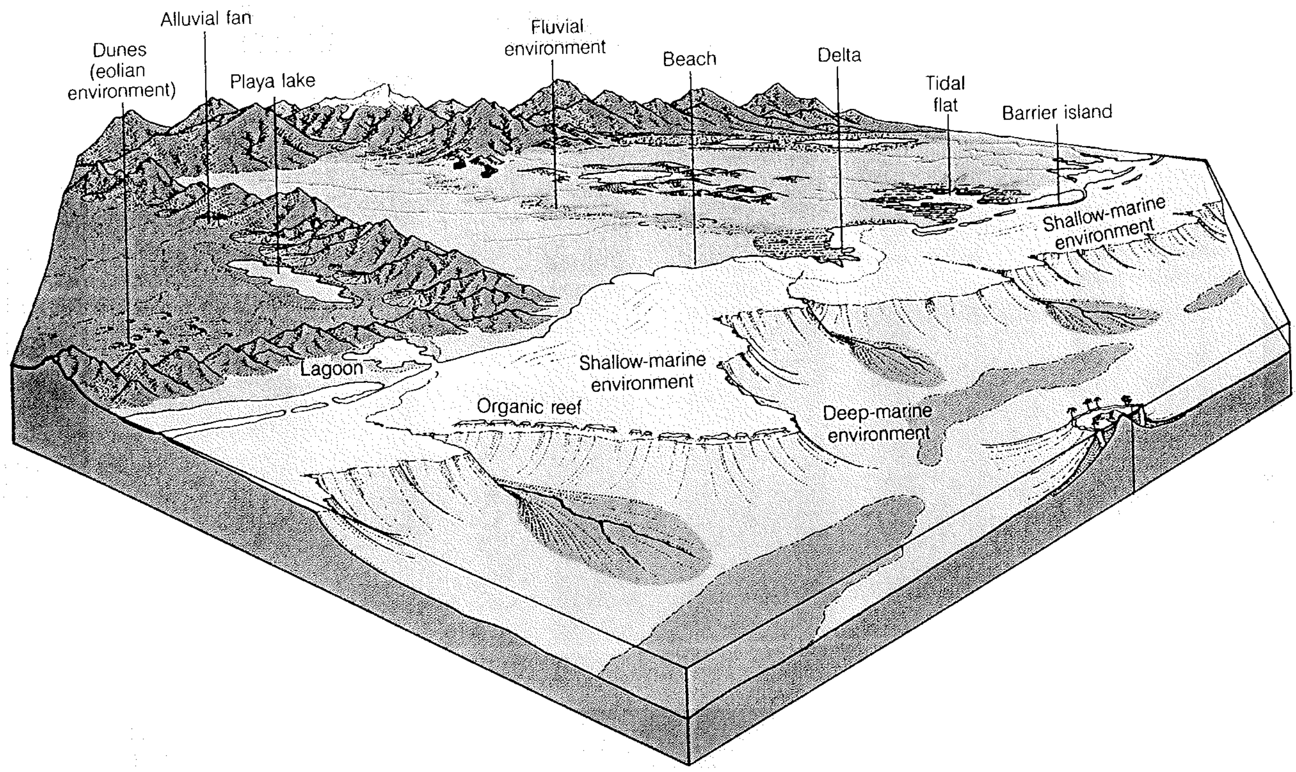


Fig. 3. Major sedimentary environments in idealized block diagram. Most of the Triassic, Jurassic, and older Cretaceous formations in the Black Mesa area were deposited in a fluvial (river) or delta environment. The youngest Cretaceous formations were deposited in a shallow marine environment. (Diagram modified from Hamblin, 1989, p. 105)

Historical note - Rothrock (1925) noted that lignite is exposed about 5 mi south-southwest of Stop 1 and that "two drifts ... were driven some years ago during a boom of what was to be the town of Mineral". (The Mineral townsite (App. 1, p. 36) is located about 1.5 mi southwest of **Stop 1**.) Rothrock (1925) also noted a second exposure of the same lignite about 6 mi southwest of **Stop 1**. "It has been worked by stripping and is used locally" (p. 87).

Continue east.

Fig. 4. Footprint of ornithopod dinosaur found in middle shale member of Dakota Sandstone at Stop 1. (From Kues and Lucas, 1987, fig. S.2-2)

1.3 Road ends at T intersection. Turn right (south).

2.4 Turn left (east) and park. Walk back to north-south road, turn left (south) and walk towards top of hill.

STOP 2. GRANEROS SHALE AND GREENHORN FORMATION

The outcrops at the road intersection are in the upper part of the Graneros Shale. Above it (to the south, along the road) are outcrops of the Hartland Member of the Greenhorn Formation. This section (as well as that exposed north of the road intersection) was measured and studied in great detail by Kaufman and others (1977) (Figs. 5 and 6).

Along the north-south road just south of Black Mesa State Park, Kaufman and others (1977) divided the Graneros Shale into three members (from bottom to top, the lower unnamed member, Thatcher Limestone Member, and upper unnamed member) and the Greenhorn Formation into three members (from bottom to top, the Lincoln, Hartland, and Bridge Creek Members). The lower and upper unnamed members of the Graneros are mostly easily eroded sandy or silty mudstones. The Thatcher Limestone is a relatively resistant sandy limestone about 1 ft thick. The most common rock types in the Greenhorn Formation are shaly chalk and sandy limestone (calcarenite in Fig. 6). Chalky limestone is less common.

There is a modest variety of well-preserved marine fossils in the Graneros Shale and Greenhorn Formation along the road. The only vertebrate fossils found by Kaufman and others (1977) in these formations are rare fish bones, scales, and teeth. Trace fossils, particularly worm and arthropod burrows, are present but difficult to identify. Microfossils such as foraminifera occur throughout the section.

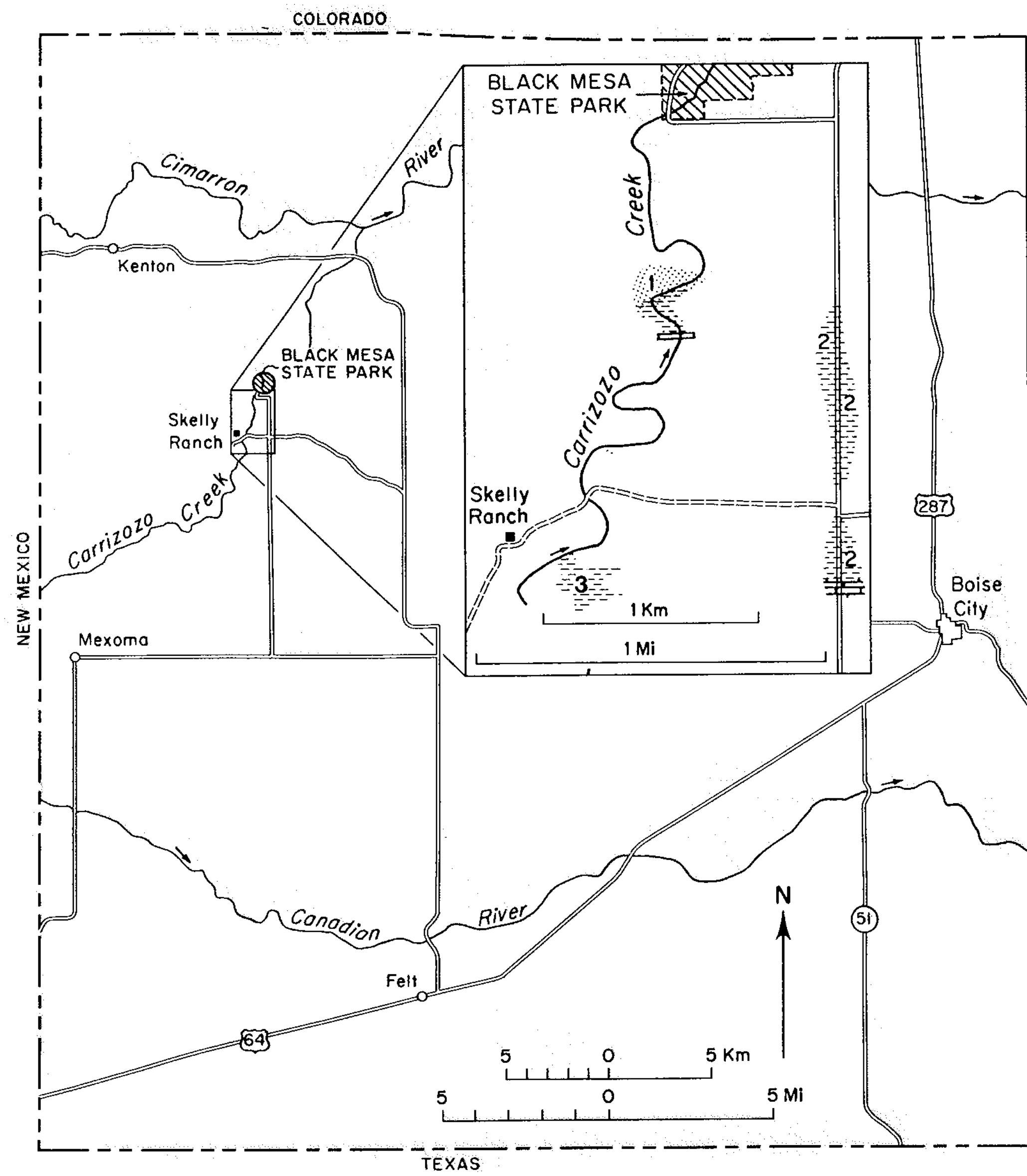


Fig. 5. Map of westernmost part of Cimarron County, showing location of sections measured by Kaufman and others (1977). Locality 2 (along road) is measured section shown on Fig. 6. (From Kaufman and others, 1977, fig. 1)

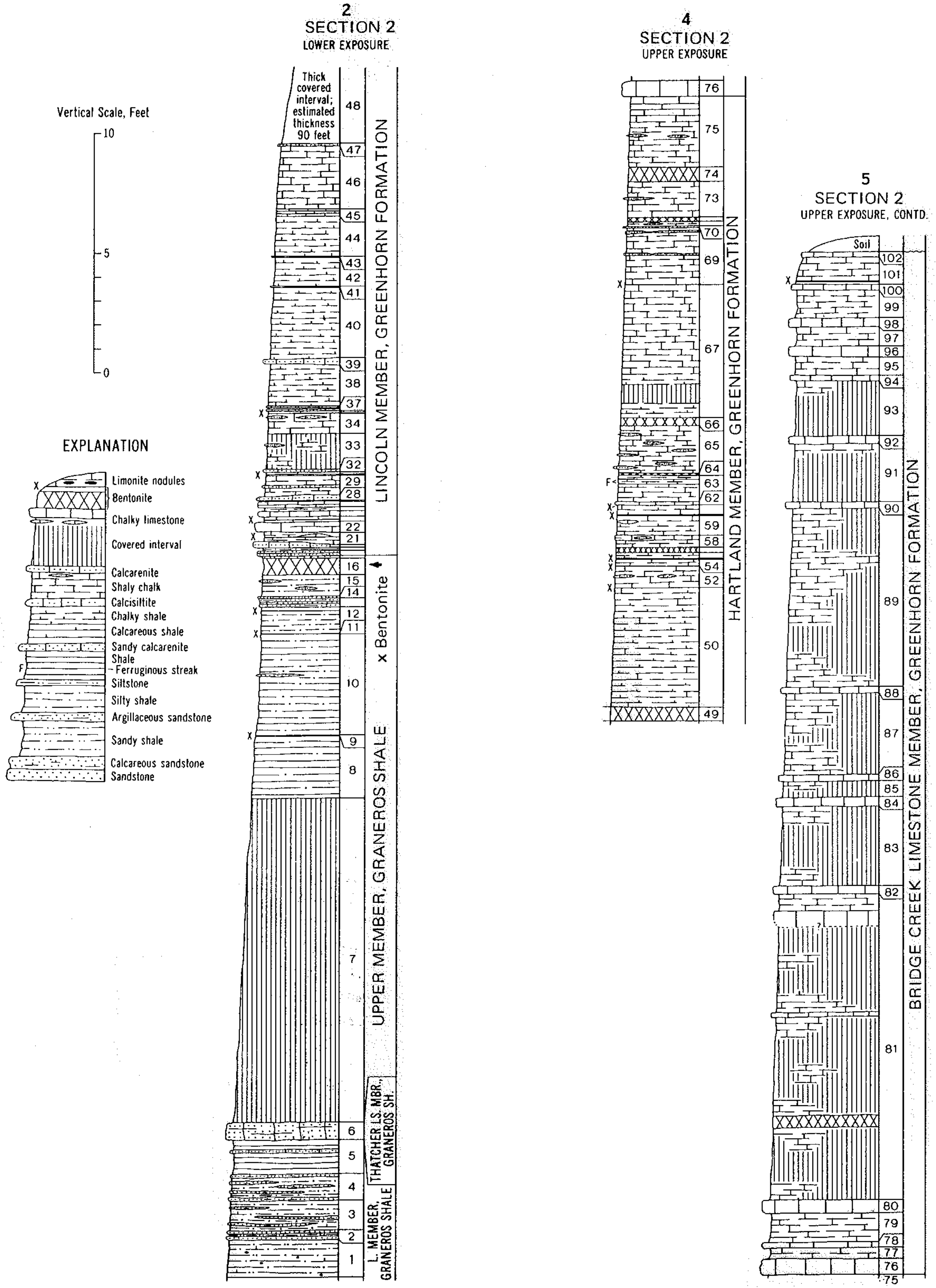
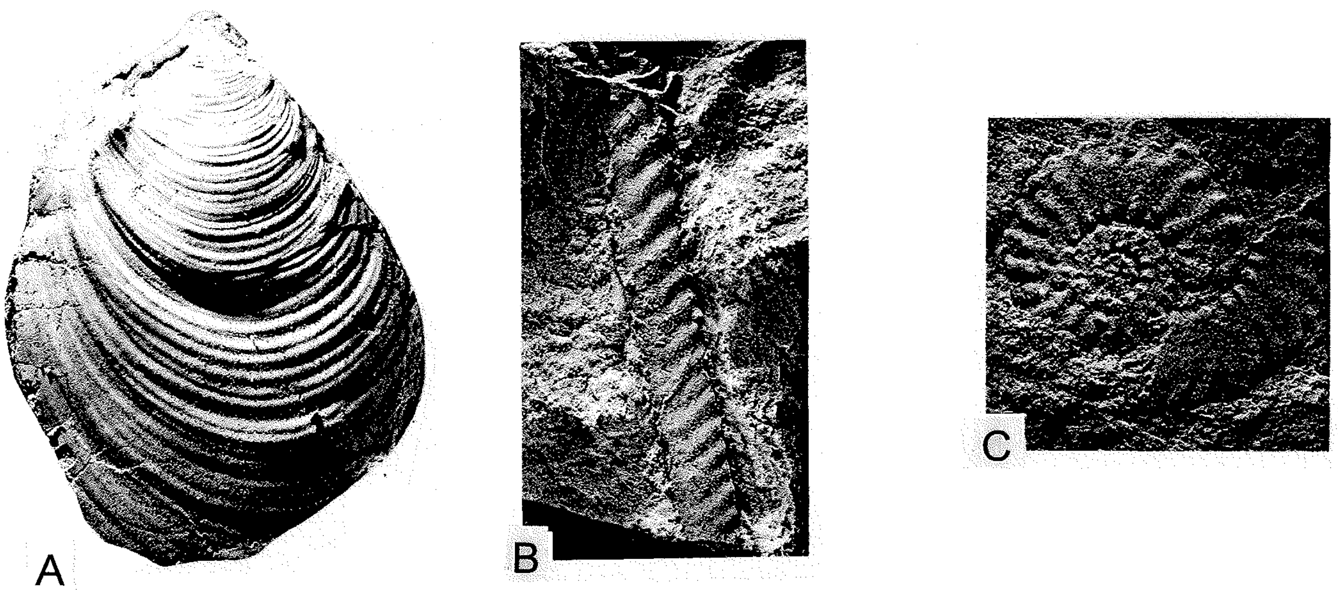


Fig. 6. Stratigraphic column showing Upper Cretaceous rocks along north-south road just south of Black Mesa State Park. Location shown in Fig. 5. (From Kaufman and others, 1977, fig. 3)

Perhaps the most common and easily found fossils are invertebrates. The lower unnamed member of the Graneros is barren of macrofossils. The Thatcher Member contains a few inoceramid (Fig. 7A) and ostreid (oyster) bivalves. The upper unnamed member also contains a few bivalves. The Greenhorn Formation, in contrast to the Graneros, is richly fossiliferous throughout its entire exposure. Most of the fossils are mollusks and many show a moderate to high degree of detail (Kaufman and others, 1977, p. 29). Bivalves are common and include, among other families, inoceramids (Fig. 7A), oysters (Ostreidae), and scallops (Pectinidae). Ammonites (Fig. 7B, C) are relatively common. Other bivalves, gastropods, corals, and brachiopods are rare.



Figs. 7A, 7B, and 7C. A - Inoceramid. B. Straight ammonite. C. Coiled ammonite. (From Kaufman and others, 1977)

A note on collecting invertebrate fossils: At the present time, there are no loaws governing collecting invertebrate fossils on public lands except for those lands that have special managerial status, which include national parks, national monuments, tribal lands, and military reservations. Collecting anything anytime on these lands is strictly prohibited or requires the permission of the local land manager. On BLM or Forest Service land, however, there are policies that govern collecting. In general, collecting modest quantities of invertebrate or plant fossils (excluding petrified wood, described above) for personal use or enjoyment is permitted. This includes roadcuts and public right-of-ways, such as **Stop 2**.

The reason Kaufman and others (1977) studied the Cimarron County section in such detail was twofold: 1) to compare the Cretaceous rocks here with similar-aged rocks in Kansas, Colorado, and Texas; and 2) to better document what is known as the Western Interior Cretaceous seaway, a large body of marine water that separated eastern and western landmasses of North America through much of the Cretaceous. They concluded that: 1) The Cimarron County Cretaceous rocks are very similar to the same-aged rocks in Kansas and Colorado, but somewhat different from those in Texas. However, there are enough similarities between the Oklahoma and Texas strata to allow them to be correlated. 2) The fauna in Oklahoma is a mixture of Western Interior and Gulf Coast species. 3) The Dakota - Graneros - Greenhorn sequence records the establishment of the Interior seaway. The Dakota represents the transition from a marginal marine to marine environment along a fluviodeltaic coastline (Kaufman and others, 1977, p. 3). The lower unnamed shale member and Thatcher Limestone Member of the Graneros were deposited in marine water less than 100 ft deep. The upper unnamed member of the Graneros was deposited in water probably more than 150 ft deep. The Lincoln and Hartland Members of the Greenhorn were deposited in water more than 200 ft deep, and the Bridge Creek Member "far from shore".

Continue east.

3.5 Cross Swede Creek.

4.9 Approximate contact between the Upper Cretaceous (Cenomanian) Graneros Shale (about 95 m.y. old) and the middle Miocene to Pliocene Ogallala Formation (no older than about 15 m.y.). The contact between the two formations is an unconformity representing about 80 million years of the Earth's history about which we have little information in this area. Most likely, this part of the Earth's crust was topographically high throughout most of the end of the Mesozoic and first part of the Cenozoic; any sediments that may have been deposited were eroded.

7.1 Intersection with main highway to Boise City (to right) and Kenton (to left). The Santa Fe Trail (App. 2, p. 40) crosses the highway about 1/2 mile to the right. An historical marker and turnout are located along the highway.

Turn left.

For the next several miles, the road crosses gently rolling topography typical of eroded Ogallala Formation. The Ogallala extends from here to just east of the east side of Beaver County- it is the formation you travel on if you drive the Northwest Passage (Hwy. 3) across the Panhandle. Outcrops tend to be unspectacular and consist of poorly consolidated clayey sand and gravel, commonly cemented by caliche (calcium carbonate formed by the capillary action of water in soils and near-surface rocks). The pebbles in the gravel consist of a large variety of rock types. Much of the Ogallala Formation consists of braided-stream deposits that were derived by erosion of the Rocky Mountains. This explains the wide variety of pebbles.

13.5 Excellent outcrops of three formations are present on the north (right) side of the road. From bottom to top, these are the Cheyenne Sandstone, Kiowa Shale, and lower sandstone member of the Dakota Sandstone. These formations are described in detail at **Stop 4** of this field trip.

14.6 Fork in road; stay left on main road.

14.7 Pull off into small parking area on north (right) side of road.

STOP 3. STOVALL'S DINOSAUR BONE QUARRY 1

Perhpas one of the most illustrious vertebrate paleontologists in Oklahoma is John Willis Stovall, who was a professor of geology and director of the museum at the University of Oklahoma from 1930 until his death in1953. Hunt and Lucas (1987) summarized Stovall's work in Cimarron County and the following is their abstract:

"J.W. Stovall (1891-1953) spent a large portion of his professional career studying the geology and paleontology of the Cimarron Valley in Oklahoma and New Mexico. He was attracted to the area by the discovery of dinosaur bones in the Morrison Formation and subsequently wrote his Ph.D. dissertation on the Mesozoic stratigraphy and paleontology of the area. With financial support from the WPA, Stovall excavated 17 dinosaur quarries between 1935 and 1942 in Cimarron County, Oklahoma. Approximately 6,000 bones were collected from these quarries which were all in the Morrison Formation. Taxa recovered included *Apatosaurus, Camarasaurus, Diplodocus, Atlantosaurus, Stegosaurus, Camptosaurus, Allosaurus, Ceratosaurus, Saurophagus maximus* and *Goniopholis stovalli* (App. 3, p. 42). These quarries are present at two discrete stratigraphic intervals near the top of the Morrison, were excavated in light gray mudstone and contained generally disarticulated and disassociated bones, most of which represent sauropod postcrania. Stovall made important paleontological discoveries in the Triassic and Cretaceous strata of the Cimarron Valley and revised the stratigraphic nomenclature advocated by earlier workers." (p. 139)

Figure 8 is a map showing the location of Stovall's 17 dinosaur quarries. His dinosaur bone quarry 1 is on the north side of road (Fig. 9). The following description of this quarry is from Mulvany and Mulvany (1988, p. 16):

"Dinosaur quarry marked by sign and concrete replica of an *Apatosaurus* femur. The quarry is in the Morrison Formation. In 1931, a road construction crew collected some dinosaur bone fragments at this location. (Fay (1983, p. 6) credits Mr. Truman Tucker, who lived in the northwestern corner of Cimarron County, with discovering the Morrison dinosaur bones in 1931). The workers showed them to R.C. Tate of Kenton, who then contacted John Willis Stovall at the University of Oklahoma. From 1935 to 1942, Stovall directed the excavation of this and 16 other dinosaur quarries in the Cimarron River Valley. Funding and workers were provided by the Works Progress Administration (changed to Works Projects Administration in 1939). Thirty-five hundred bones were collected from this quarry. In addition to the *Apatosaurus* femur, bones of *Camarasaurus, Stegosaurus, Saurophagus maximus, Ceratosaurus*, and *Camptosaurus* were excavated."

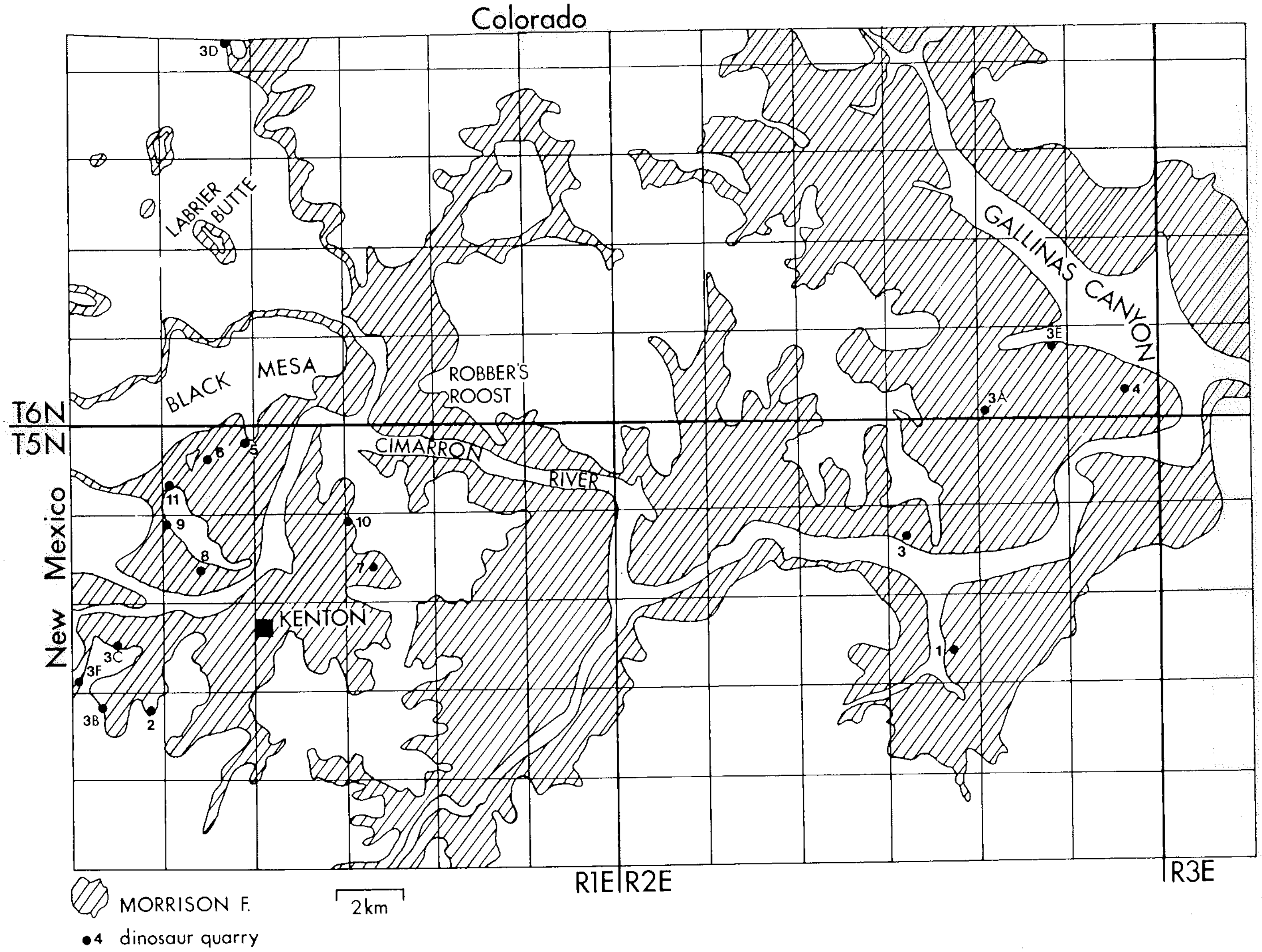


Fig. 8. Map showing location of Stovall's Morrison dinosaur quarries in Cimarron County, Oklahoma. Numbers shown are those used by Hunt and Lucas (1987). (From Hunt and Lucas, 1987, fig. 2)

In addition to the quarry itself, the Morrison Formation is also of interest at this stop. Schoff and Stovall (1943, p. 255-256) measured about 50 ft of Morrison Formation beneath the Cheyenne Sandstone Member of the Purgatoire Formation at the quarry. Their measured section (Table 2) is typical of the multi-colored mudstone and shale in the Morrison throughout the field-trip area. The Morrison is especially well-exposed on the south side of the road. The purplish-gray shale contains many calcareous concretions, which the uninformed might mistake for dinosaur bones.

Fig. 9. Stovall's dinosaur bone quarry no. 1 along Oklahoma Highway 325. The low sandstone ledge at the top of the quarry is in the Morrison. Note the cement cast of an *Apatosaurus* femur.

20. SEC. 15, T. 5 N., R. 2 E., DINOSAUR QUARRY NO. 1, NORTH SIDE HIGHWAY 64, 8 MILES EAST OF KENTON, JUST EAST OF BRIDGE OVER SOUTH CARRIZO CREEK

Cretaceous
Purgatoire formation
Cheyenne sandstone member
Unconformity
Jurassic
Morrison formation

6. Sandstone, buff, almost quartzitic in places, separated from the underlying clays by a very irregular surface	2.0
5. Shale, cream, banded with light purple	1.0
4. Shale, purple, banded with lenses of lighter colored, harder material	2.3
3. Shale, purple, dense, hard, forming a distinct band, with irregular upper and lower surfaces	1.4
2. Shale, gray, contains dinosaur bones, and many concretions; concretions occur throughout, but there are two distinct bands or layers 3 inches thick, occurring about 1.3 feet below top of unit	8.5
1. Shale, alternating layers of purple, gray, and buff, a few inches to 6 feet thick; the lowest is greenish-gray, and crops out in bed of South Carrizo Creek	35.0

Bed of Creek

Table 2. Measured section at **Stop 3** by Schoff and Stovall (1943, p. 255-256)

14.8 Cross South Carrizo Creek.

15.8 "Old Maid" natural window in lower sandstone member of the Dakota Sandstone on right (north) (Fig. 10).

Fig. 10. "Old Maid" or "Old Woman's Head" natural window in lower sandstone member of Dakota Sandstone.

17.5 Erosional features in the lower sandstone member of the Dakota Sandstone on left (south) are called "Three Sisters" or "Wedding Party" (Fig. 11) by local residents. The highly cross-stratified character of the lower part of the Dakota is well-preserved on the "Sisters" and adjacent pinnacles (Fig. 12).

17.8 Intersection with road to left (south) to Black Mesa State Park. Continue straight ahead.

18.9 The road begins a gradual descent from the lower sandstone member of the Dakota Sandstone (the ledge-forming sandstone unit at the top), through the underlying Kiowa Shale, to the Cheyenne Sandstone, and finally to the Morrison Formation .

Shells of *Texigryphaea tucumcarii* (a fossil oyster) are present in the Kiowa Shale along the road (Lucas and others, 1987a, p. 11). Multi-colored shales of the Morrison Formation crop out in the ditch on the left (south) side of the road at the base of the slope.

18.8 Cross Tesesquite Creek. The generally flat area for the next several miles is Morrison Formation.

Fig. 11. "Three Sisters" or "Wedding Party" in lower sandstone member of the Dakota Sandstone.

Fig. 12. Cross-stratified sandstone typical of the lower sandstone member of the Dakota Sandstone. Note generally uniform direction of crossbeds.

19.4 The Morrison contains small stromatolites on the low hill immediately north of the road. Stromatolites are calcareous, sphere-like algal growths. Neuhauser and others (1987) have identified stromatolites in the Morrison Formation in Union County, New Mexico (about 30 miles west of here). They suggest that the stromatolites occur in a lacustrine facies of the Morrison that was deposited in an extensive, closed lake basin.

20.5 Turn right on unpaved road with sign to "Easter Pageant" (App. 4, p. 46). "The Kenton Easter pageants began in 1952. Each Easter weekend, local residents act out the crucifixion and resurrection of Jesus, based on scripts written by local church people" (Lucas and others, 1987a, p. 11).

20.6 Road to right (north). Stay left.

20.8 Park just before unpaved road joins main highway. This gap between the low mesas to the north and south is shown on modern topographic maps as "101 Pass"; in older literature, it is also known as "101 Gap". The "101" refers to the 101 Ranch, located near here (App. 4, p. 46).

STOP 4. CHEYENNE SANDSTONE, KIOWA SHALE, DAKOTA SANDSTONE

The basal part of the Cretaceous section in the Dry Cimarron Valley area is well-exposed in "101 Pass". The age of the strata is late early Cretaceous (or Albian)(106 - 96 million years old). The Cheyenne Sandstone is exposed at road level and is overlain by the Kiowa Shale, which forms most of the slope. The hill is capped by the lower sandstone member of the Dakota Sandstone.

The Cheyenne Sandstone has been described in detail by Schoff and Stovall (1943), who called the unit the Cheyenne Sandstone Member of the Purgatoire Formation, and Kues and Lucas (1987), who named the same unit the Lytle Sandstone. Kues and Lucas (1987, p. 169) appear to have agreed with Scott (1970), who noted "the lithologic differences between the Kansas Kiowa and the Colorado Glencairn, as well as the lack of physical continuity of the Kansas Cheyenne and Colorado Lytle." While we recognize the views of Kues and Lucas (1987) regarding the stratigraphic nomenclature of the Cretaceous units in Oklahoma, Kansas terminology is firmly entrenched in Panhandle literature; therefore, for simplicity, we continue to use it.

The Cheyenne Sandstone is relatively easily recognized throughout the area because it forms a prominent white cliff above a slope underlain by easily eroded siltstones and shales of the Morrison Formation and below a slope formed by the Kiowa. The Cheyenne Sandstone is composed of sandstone, siltstone, and conglomeratic sandstone as thick as 70 ft, with an average of about 35 ft. Trough- and planar-crossbeds (Fig. 13) are common in the sandstones and cobbles as large as 6 in. in the conglomerates are mostly chert with lesser amounts of quartzite, quartz, schist, and limestone. The conglomerate beds (Fig. 14) occur as lenses and none are traceable throughout the area. Schoff and Stovall (1943, p. 76) noted that petrified logs as long as 85 ft and 2.5 ft in diameter are common, especially at the base of the unit. The Cheyenne Sandstone was probably deposited by a fluvial (river) system flowing generally to the east-northeast.

Fig. 13. Highly trough cross-stratified sandstone and pebbly sandstone typical of the Cheyenne Sandstone.

Fig. 14. Pebble conglomerate in Cheyenne Sandstone.

The Kiowa Shale is mostly a dark gray to black shale interbedded with relatively thin sandstones and siltstones (Schofff and Stovall, 1943). The base is generally marked by a fossiliferous sandstone as thick as 10 ft named the Long Canyon Sandstone Bed by Kues and Lucas (1987). The middle part contains one or more fossiliferous horizons dominated by shells of the bivalve *Texigryphaea* (Fig. 15). Locally, the top of the Kiowa contains abundant plant fossils. Lucas and others (1987a, p. 9) interpret the basal Kiowa (Glencairn) sandstone as marking the trangression of an Early Cretaceous seaway, the middle part as a marine shale, and the upper part as estuarine deposits marking the retreat of the Glencairn sea. The overlying non-marine lower sandstone member of the Dakota Sandstone marks a return to an environment similar to that of the Cheyenne Sandstone.

Fig. 15. *Texigryphaea* shells found in Kiowa Shale. (From Kues and Lucas, 1987, p. 180)

Schoff and Stovall (1943) divided the Dakota into three members: a lower sandstone, middle shale, and upper sandstone (Fig. 1). Kues and Lucas (1987) applied the name "Mesa Rica" to the lower Dakota sandstone based on the physical continuity and lithologic similarity of the sandstone in the Dry Cimarron Valley with the type Mesa Rica Sandstone in Quay County, New Mexico. In the field-trip area, the lower sandstone member of the Dakota Sandstone is a conspicuously crossbedded, light-colored fine-grained sandstone that forms the cliffs or ledges at the top of most of the mesas and bluffs. Conglomerate layers are rare. The most common fossil in the lower Dakota Sandstone is petrified wood. Noe (in Rothrock, 1925) described fossil leaves from the Dakota, which Schoff and Stovall (1943, p. 91) stated came from the "lower Dakota". Kues and Lucas (1987, p. 187) suggested the leaves probably came from the middle shale member (their Pajarito Formation, visited at **Stop 1** on this trip) and not the lower sandstone. The sedimentary structures, rock types, and petrified logs, and absence of marine fossils, are evidence that the lower sandstone member of the Dakota Sandstone was deposited in a fluvial-deltaic environment

In addition to the cliffs formed by the lower Dakota Sandstone, "equally striking are the fantastic columns, generally capped by a hard, somewhat ferruginous layer of sandstone that has been carved by the combined action of wind and rain. Some of these features are landmarks, and have received names that are well known throughout the region. At Old Maid Gap ... a rough image of a human head has been named the "Old Maid" because of its resemblance to a rather sharp-featured, female person. South of U.S. Highway 64 ... are three columns called "Three Sisters". These particular features have been carved from the lower member of the Dakota, but similar ones are common in the upper member, as well." (Schoff and Stovall,1943, p. 88-89).

21.8 Intersect road to right (north). Turn right.

Immediately to the west is the small town of Kenton, Oklahoma. The following description of Kenton is from Lucas and others (1987a, p. 11):

"The Kenton area was settled by ranchers in the 1870's; before that the only inhabitants were outlaws operating from "Robber's Roost", located near Black Mesa to the north, (App. 5, p. 50)), who preyed upon freight caravans traveling the Santa Fe Trail. The town of Kenton was established in 1890, and grew with the arrival of homesteaders and a brief attempt to mine copper nearby (Fay, 1983). After Cimarron County was formed in 1907, Kenton served briefly as the county seat before it was moved to Boise City. By 1910, Kenton numbered about 250 inhabitants and had a bank, newspaper and numerous commerical establishments, but has declined since then to the quiet village we see today."

23.5 Cross Cimarron River. At about 11:00 is Stovall's dinosaur quarry 5. The following description of this quarry is from Lucas and Hunt (1987b, p. 58):

"... The scar in the hillside is Stovall's dinosaur quarry 5 (Hunt and Lucas, 1987). This quarry produced many postcranial elements of sauropod dinosaurs, most of which are assignable to *Diplodocus*. Some bones were well preserved, but most were fragmentary."

Mulvany and Mulvany (1988) noted that petroglyphs are present on some boulders on the northwest slope of the small hill behind the quarry.

24.1 Road to left to dinosaur quarry. Continue on main road.

25.1 Ahead and to the right (about 1:00) is Robbers Roost (App. 5, p. 50).

26.8 Cross Coopers Arroyo. Near the bridge is a parking area for the trailhead to the top of Black Mesa and the Black Mesa Nature Preserve (App. 5, p. 48).

27.0 Dirt road to right (east). This road leads to optional **Stop 5** which we will visit if we have time. Turn right.

27.4 Park in circular area.

STOP 5. DINOSAUR TRACKWAY IN MORRISON FORMATION

The following description of this stop is from Mulvany and Mulvany (1988, p. 20):

"Bipedal dinosaur trackway is visible in reddish brown, desiccation cracked, argillaceous lower Morrison sandstone exposed in the bed of Coopers Arroyo. If the trackway is clear of stream deposits, you will see a sequence of 28 clawless tridactyl footprints made by a large ornithopod as it walked N5°W (present-day bearing) (Fig. 16). The trackway is curved to the left and is slightly pigeon-toed. The deformed and upraised margins of the footprints indicate that the dinosaur was walking on wet sediment. Interestingly, two of the prints (numbers 8 and 9, counting from the south end) are juxtaposed and are half as deep as all the others; the dinosaur was standing stationary on both feet when it made these two prints. So the trackway has two walking portions interrupted by a stop. Average stride for the walking portions is 1.90 meters (stride is the straight line distance between successive left or right prints). Average pace angulation for the walking portion is 156° (pace angulation is the obtuse angle formed by three successive prints). Such high pace angulation indicates that the dinosaur was an efficient walker; that is, it carried its legs close to the midline of its body. For purpose of comparison, co-leader Pat (a bipedal mammal) has 169° walking pace angulation. Average length for ten prints we measured is 0.43 meters. How big was the dinosaur? For bipedal dinosaurs, hip height is about four times foot length, and total body length is about three times hip height. So this particular dinosaur's hip height was about 1.72 meters (5.6 feet), and its total body length was about 5.16 meters (16.9 feet). How fast was it walking? Using an equation developed by Alexander (1976) that expresses speed as a function of stride and hip height, we have determined that this dinosaur was walking at the rate of 1.2 meters per second (2.7 miles per hour). There are two other shorter trackways in the arroyo. The thick, structureless, fine-grained, loess-like deposits that form vertical banks along Coopers Arroyo probably were deposited during the Pleistocene. We have found mammal bones and teeth in these deposits about three-fourths of a mile upstream."

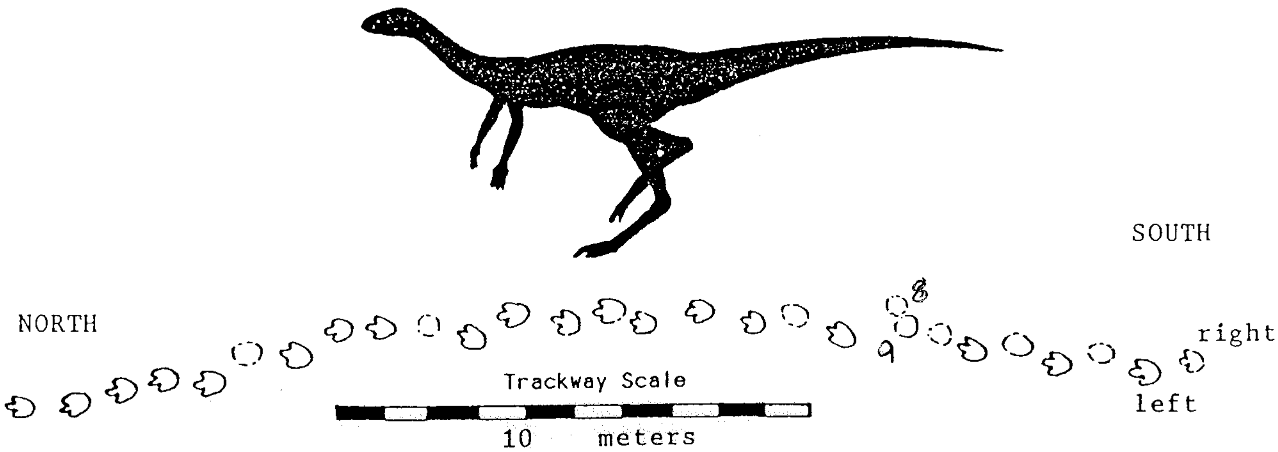


Fig. 16. Ornithopod dinosaur trackway in Coopers Arroyo (modified from Lockley (1986)) and silhouette of an ornithopod dinosaur (from Lambert (1983)). From Mulvany and Mulvany (1988, fig. 14).

Conrad and others (1987) also described this site but believed it to be in the Jurassic Bell Ranch Formation. Lucas and Hunt (1987b) believe this assignment is incorrect because the Bell Ranch is only 8 ft thick at Labrier Butte. The following description is from Conrad and others (1987, p. 134-135):

"Six km southeast of the Sheep Pen tracksites, brown silty track-bearing exposures of Jurassic age crop out in a small tributary of Carrizo Creek in northwestern Oklahoma. The tracksite, which exhibits three trackways of large dinosaurs, was illustrated by Lockley (1986, pl. 2 and fig. 16). ... Following the existing designation (Lockley, 1986, p. 38), two of the trackways can be compared with the ichnogenus *Gypsichnites* (Fig. 12, reproduced here as Fig. 17). Traditionally this ichnogenus has been attributed to a large ornithopod, whereas the other trackway, in the lower of the two track-bearing beds, appears to represent a theropod. ...

"Because the Bell Ranch trackways exhibit a short step, broad, blunt toes and an inward (positive or pigeon-toed) rotation of the pes, the maker was almost certainly a large ornithopod. ... The tracks measure about 45 cm in length and 40 cm in width with an average stride of about 180-185 cm (range of steps from 88-100 cm).

"The somewhat smaller footprints (length 45 cm; width 36 cm) in the lower of the two track-bearing beds comprise a single trackway with a longer stride (215-220 cm) than the "*Gypsichnites*" from the overlying bed. The lack of inward rotation of the pes and slender configuation of the digits suggest theropod affinities (Lockley, 1986)."

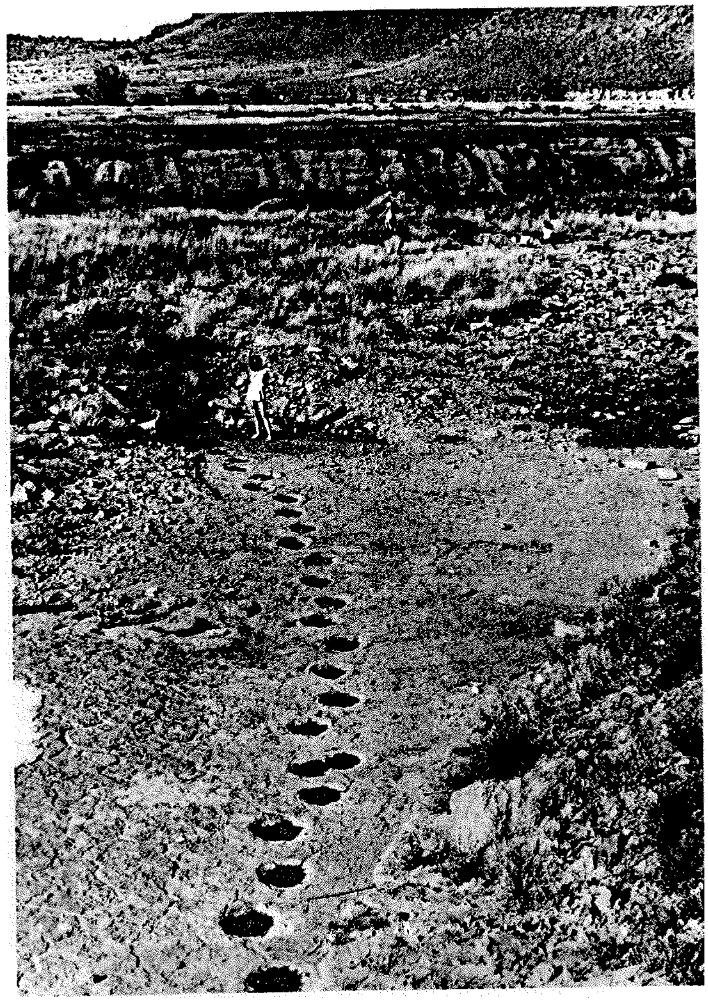


Fig. 17. Dinosaur tracks in the Morrison Formation, Carrizo Creek, Oklahoma. (From Conrad and others, 1987, fig. 12).

Return to main road.

27.8 Turn right (north).

27.9 Cross cattle guard, followed by unpaved road to left. Turn left.

28.0 Park in quarry. The quarry is at the base of Labbrey Butte. Most of the Mesozoic section in the Black Mesa area is exposed on the flanks of the butte (Fig. 18). From the base of the butte to the top, the formations are: Triassic Sloan Canyon Formation and

Sheep Pen Sandstone; Jurassic Exeter Sandstone and Morrison Formation; Cretaceous Cheyenne Sandstone, Kiowa Shale, and Dakota Sandstone.

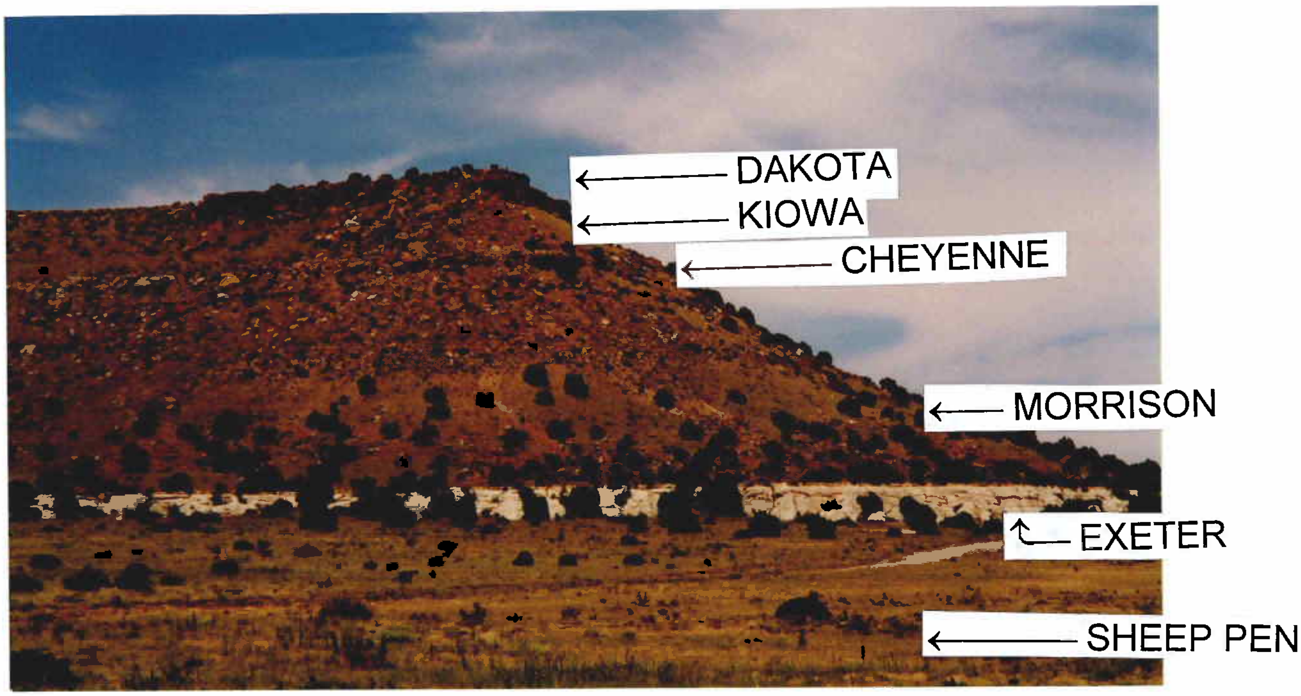


Fig. 18. Photograph of south end of Labrier Butte, showing Triassic to Cretaceous strata exposed on slopes.

STOP 6. QUARRY IN SLOAN CANYON FORMATION AND SHEEP PEN SANDSTONE (TRIASSIC)

The Triassic Sloan Canyon Formation and Sheep Pen Sandstone are the oldest formations exposed in the Black Mesa area. Lucas and others (1987b, p. 352) consider these formations to be Norian (223 to 215 million years old). In northeastern New Mexico, older Triassic formations (from bottom to top, the Santa Rosa, Baldy Hill, and Travesser Formations) are present; the upper two have also been identified by Lucas and others (1987c) in Oklahoma in Picket House Draw about 30 miles east of here.

The following description of this stop is from Lucas and Hunt (1987b):

"Quarry in Sloan Canyon Formation at base of Labrier Butte. The conglomerate in the floor of this quarry has produced metoposaurid amphibian and phytosaurian reptile remains. Most of the bone material is fragmentary, but a partial amphibian skull and a variety of complete teeth have been collected from this locality. The sandstone at the top of the backwall of the quarry is the Sheep Pen Sandstone. The stratigraphic sequence of Labrier Butte, behind the quarry, extends up to the (lower sandstone member of the Dakota Sandstone.)"

Mulvany and Mulvany (1988, p. 22-23) provide some additional information on the quarry:

"Note the fault exposed in the face of the quarry; this near vertical fault strikes N79°W and offsets the strata 2 ft. The north side moved down with respect to the south side. Locally in this area, Sheep Pen contains copper minerals (chalcocite, malachite, and azurite). Around the turn of the century, prospectors dug many pits and tunnels in this region in their search for economic copper deposits. The total amount of ore mined in Cimarron County is not known; however, the small sizes of the workings suggest that very little was mined. The largest and richest copper ore deposit was found and mined nine miles north of here in Baca County, Colorado."

Several additional features of the Sloan Canyon and Sheep Pen are noteworthy at this outcrop. Note that the Sheep Pen Sandstone in the quarry adjacent to the main road appears to erode into the underlying red shale of the Sloan Canyon (Fig. 19). The most likely explanation for this is that the Sheep Pen is a broad channel deposit that did, in fact, erode slightly into the underlying mud. This is in accord with the observation by Fay (1983, p. 1), that the Sheep Pen was deposited as point bars by rivers, which he suggested were flowing to the west. Also, the Sloan Canyon immediately beneath the Sheep Pen is not well-stratified; it breaks or crumbles into small equipdimensional blocks, the sides of which are slightly glossy. This "blocky shale" is typical of paleosols, which are ancient soil horizons. The likely depositional environment of the uppermost part of the Sloan Canyon was a mudflat that was periodically submerged and then exposed along enough for soil development. It was then eroded into and buried by a channel sand (Sheep Pen Sandstone).

An interesting aspect of the Sheep Pen Sandstone is that 14 copper prospects occur in it in this area (Fay, 1983). "The prospects were opened before 1899, supposedly by the "Klondikers" from Woodward in northwestern Oklahoma. Approximately 200 mines and prospects in the Sheep Pen Sandstone were opened from 1884 to 1925 in adjacent Baca County, Colorado, and Union County, New Mexico. The total production is unknown, but probably less than 10,000 tons of ore was mined in Oklahoma." (Fay, 1983, p. 1).

The Jurassic Exeter Sandstone is very well exposed immediately above the Sheep Pen Sandstone and can be seen just west along the dirt road and up the hill. Like the Cheyenne and Dakota Sandstone observed at **Stop 4**, the Exeter is cross-bedded, however, on a much larger scale (Fig. 20). Also, unlike the Cheyenne and Dakota, the cross-bedded sandstone of the Exeter does not contain any conglomerate layers. The large crossbeds and absence of coarse-grained sediments is evidence that the Exeter is aeolian, i.e., is an ancient sand-dune deposit.

Fig. 19. Sheep Pen Sandstone overlying and eroded into siltstones and shales of the Sloan Canyon Formation.

Fig. 20. Aeolian cross-bedding in the Exeter Sandstone.

This stop is also an excellent place to discuss the origin of Black Mesa. The following description is from Mulvany and Mulvany (1988, p. 18):

"Black Mesa is a long, narrow, slightly sinuous, flat-topped ridge that begins about 30 miles to the northwest in Las Animas County, Colorado, and ends here. The mesa is capped by basalt along its entire length. From top to bottom, the stratigraphic profile of Black Mesa at this location is as follows: Raton Basalt, Ogallala, Dakota, Kiowa, Cheyenne?, and Morrison. The geologic history of Black Mesa provides a classic example of "inversion of relief". During the Pliocene [about 5 to 2 million years ago] the top of the Ogallala, on which the basalt now rests, was the floor of a valley. Basaltic lava, originating from vents located in Las Animas County, flowed down the valley and solidified into a hard rock that resists erosion. From that time until now, erosion has preferentially occurred in the soft sedimentary rocks flanking the basalt. Thus a valley was transformed - "inverted" - into a mesa."

A monument marks the highest point in Oklahoma, 4973 ft above sea level, on Black Mesa. The monument is located in the Black Mesa Nature Preserve (App. 5, p. 48).

THIS IS THE END OF THE FIELD TRIP. If you would like to visit the common corner of Oklahoma, New Mexico, and Colorado, follow the directions below.

Return to main road.

0.0 Turn left (north) on main road.

2.8 Road turns left (west). The left side of the road is Cimarron County, Oklahoma. The ridge side of the road is Baca County, Colorado.

3.2 Road bends right (northwest).

3.3 Fork in road. Take left (west) fork.

4.1 Directly ahead is Union County, New Mexico. Just to the north is Colorado. Stop at the stone pillar marking the triple junction (App. 5, p. xx).

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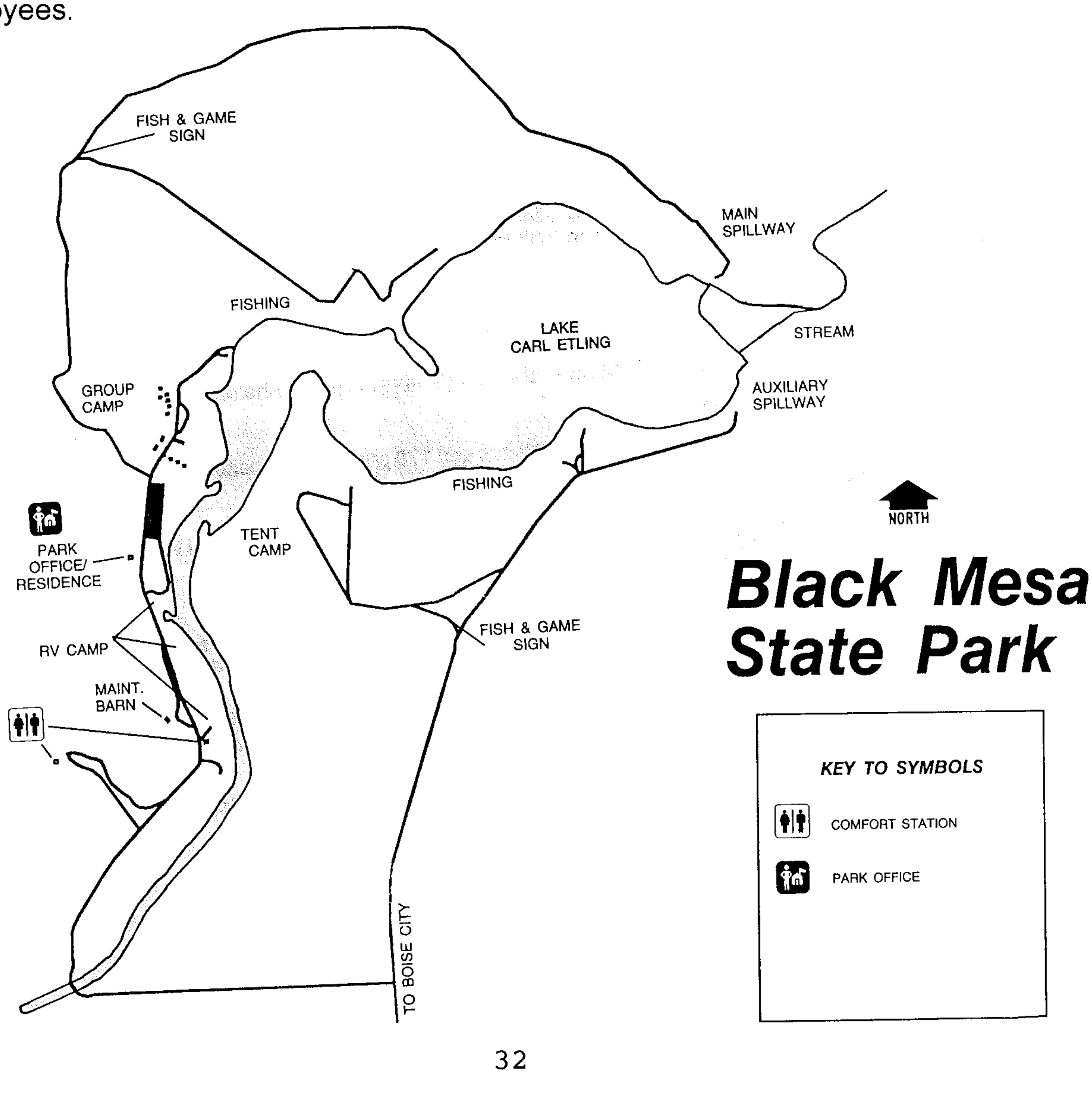
APPENDIX 1

BLACK MESA STATE PARK

Black Mesa State Park is located in northwestern Cimarron County on State Highway 325. A 200-acre lake, Lake Carl G. Etling, was formed by a dam built across South Carrizo Creek in 1959. The lake is fed by a natural spring and originally stocked with trout, catfish, bass, northern pike, and channel catfish. The lake and park are controlled jointly by the Oklahoma Wildlife Conservation Department and the Oklahoma Department of Tourism and Recreation. The lake section is closed November 1 to February for wildlife protection.

West of the lake are a few pieces of petrified wood found in the area and moved to the site by the late Carl Etling, the state representative for whom the lake is named. Many of the trees along the banks of the channel and lake were planted by Mr. Etling and friends, who were anxious to provide a place of recreation for area residents. The buildings were erected by the State Parks department and they and the grounds are maintained by State employees.



COAL

Thin beds of lignite coal are found in the middle member of the Dakota Sandstone in the extreme western part of Cimarron County near the headwaters of Tesequite and South Carrizo Creeks. At the Tesequite Creek site, coal was exposed in two drifts, located in sections 19 and 20, T. 4 N., R. 1 E., which were driven during a boom of what was to be the town of Mineral. The largest of the two drifts is near the center of section 19, T. 4 N., R. 1 E., and the following section was exposed at this place:

Section of Coal Beds, Cimarron County

	Ft. In.
Top—	
Sandstone	3′ 0″
Shale, soft, black	6″
Coal, blocky bone	6″
"Soapstone" fire clay mixed with carbonaceous material	2′ 6″
Coal, lignitic	1′ 6″
Fire clay	To bottom

Two samples from this drift were analyzed in the laboratories of the Oklahoma Geological Survey. A sample taken across the entire 5-foot face of carbonaceous material between the fire clay and overlying sandstone gave the following results:

Lignite, Cimarron County, Oklahoma

	Percent
Moisture	8.65
Volatile combustible matter	22.40
Fixed carbon	15.04
Ash	53.91
	100.00
Sulphur	0.50
Heating value in B. T. U., 2,710 per pound	

A second sample which contained only the pure lignite from the 1.5-foot seam above the fire clay analyzed as follows:

Lignite, Cimarron County, Oklahoma

	Percent
Moisture	12.64
Volatile combustible matter	31.25
Fixed carbon	35.34
Ash	20.77
	100.00
Sulphur	0.55
Heating value in B. T. U., 7,550 per pound	

A second exposure of coal at the same horizon was found in the NW 1/4 of section 5, T. 3 N., R. 1 E., in the bed of South Carrizo Creek. This seam was worked by stripping and used locally. This 18-inch thick coal seam is traceable for more than a quarter of a mile along the stream bed until it is lost under the cover of rock debris washed over the outcrops. The following section was taken in a stream cut, a few hundred feet up stream from the Will Baker Ranch house:

Section of Lignite Bed, Cimarron County, Oklahoma

Top—	Ft. In.
Massive sandstone	1' 2"
Shale, gray, sandy	10"
Sandstone, thin bedded, gray, medium-grained	1' 4"
Lignite	1' 6"
Shale, sandy, some black in color, grading into sandstone below	7"
Sandstone	To bottom

A sample of this lignite was analyzed in the laboratory of the Oklahoma Geological Survey, giving the following:

Anaylsis of Lignite, Cimarron County, Oklahoma

	Percent
Moisture	11.35
Volatile combustible matter	30.09
Fixed carbon	40.58
Ash	17.98
	100.00
Sulphur	0.40
Heating value in B. T. U., 8,500 per pound	

Although this coal is not a first class lignite, it has higher heating values than the lowest grades of lignite. The low moisture content is partly the result of water loss after the sample was taken. The sulfur content is low, while the ash is high. These thin, inferior quality coal seams could not be profitably worked on a large scale. However, the coal provided an alternate fuel source to nearby settlers.

(modified from Rothrock, E. P., 1925, p.86-88)

A coal sample was collected by LeRoy Hemish, Coal Geologist with the Oklahoma Geological Survey, in 1980. The sample site is near the base of the cliff about 100 yards west of the low water bridge at Stop Number 1. The sample was analyzed in the laboratory of the Oklahoma Geological Survey, giving the following as received results:

	Percent
Moisture 33.4	
Volatile matter 22.0	
Fixed carbon 17.2	
Ash 27.4	
	100.0

Sulfur 0.1

Heating value in B.T.U., 3,471 per pound

A moisture free sample had a heating value of 5,214 B.T.U./pound

D 388

TABLE 1 Classification of Coals by Rank[A]

Class/Group	Fixed Carbon Limits (Dry, Mineral-Matter-Free Basis), %		Volatile Matter Limits (Dry, Mineral-Matter-Free Basis), %		Gross Calorific Value Limits (Moist,[B] Mineral-Matter-Free Basis) Btu/lb		Mj/kg[C]		Agglomerating Character
	Equal or Greater Than	Less Than	Greater Than	Equal or Less Than	Equal or Greater Than	Less Than	Equal or Greater Than	Less Than	
Anthracitic:									
Meta-anthracite	98	. . .	. . .	2	. . .	. . .	. . .	. . .	nonagglomerating
Anthracite	92	98	2	8	. . .	. . .	. . .	. . .	
Semianthracite[D]	86	92	8	14	. . .	. . .	. . .	. . .	
Bituminous:									
Low volatile bituminous coal	78	86	14	22	. . .	. . .	. . .	. . .	commonly agglomerating[F]
Medium volatile bituminous coal	69	78	22	31	. . .	. . .	. . .	. . .	
High volatile *A* bituminous coal	. . .	69	31	. . .	14 000[E]	. . .	32.6	. . .	
High volatile *B* bituminous coal	. . .	. . .	. . .	. . .	13 000[E]	14 000	30.2	32.6	
High volatile *C* bituminous coal	. . .	. . .	. . .	. . .	11 500	13 000	26.7	30.2	
					10 500	11 500	24.4	26.7	agglomerating
Subbituminous:									
Subbituminous *A* coal	. . .	. . .	. . .	. . .	10 500	11 500	24.4	26.7	nonagglomerating
Subbituminous *B* coal	. . .	. . .	. . .	. . .	9 500	10 500	22.1	24.4	
Subbituminous *C* coal	. . .	. . .	. . .	. . .	8 300	9 500	19.3	22.1	
Lignitic:									
Lignite *A*	. . .	. . .	. . .	. . .	6 300†	8 300	14.7	19.3	
Lignite *B*	. . .	. . .	. . .	. . .	. . .	6 300	. . .	14.7	

[A] This classification does not apply to certain coals, as discussed in Section 1.
[B] Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.
[C] Megajoules per kilogram. To convert British thermal units per pound to megajoules per kilogram, multiply by 0.002326.
[D] If agglomerating, classify in low-volatile group of the bituminous class.
[E] Coals having 69 % or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of gross calorific value.
[F] It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and that there are notable exceptions in the high volatile *C* bituminous group.
† Editorially corrected.

(1994 Annual Book of ASTM Standards, section 5, volume 05.05, Gaseous Fuels: Coal and Coke, p.170)

MINERAL CITY

by Frances Skelley Murdock

Mineral City (later Mineral) was located 12 miles southeast of Kenton, and 25 miles west and north of Boise City. Joseph B. Thoburn (The History of Oklahoma, 1916) wrote "There was a heavy tide of immigration into southwestern Kansas and southeastern Colorado in 1885-1886. Soon the settlers began to swarm across the border into No Man's Land. In 1886 two coal mines were opened in the western part of the present Cimarron County and a townsite, known as Mineral City, was laid out." A big two-story stone building was erected, and the first people to run it (to my knowledge) were members of the Bill Metcalf family. Mr. Barker, who had been sheriff while living in Kingman, took over the rock store building to supply area settlers with their needs. The building was large--60 by 25 feet--and it housed a hotel, store, post office, and dances were also held there.

Mineral City Post Office was established in 1888, with Sebastian Baker from Kansas as its first postmaster. The settlement had been founded in 1885 by the group including Baker, who made up the Western Land and Mining Company from Kingman, Kansas. They operated their coal mine five miles west of Mineral City for some two years. Settlers in the area purchased coal from there until the vein was depleted and the mine abandoned. The name of the settlement was changed to Mineral after a few years, and William E. Campbell became postmaster. No dates were given for the time he served.

John Skelley purchased the store building from the Bakers in 1897 and became postmaster on April 22, 1898. He was also a United States land commissioner. The post office was moved in 1907 from its original location in the old stone structure to a new frame building a short distance away. In 1908 the rock building was destroyed by a tornado. After statehood, John Skelley, as land commissioner, took filings and relinquishments on all claims in the western and southwestern parts of Cimarron County. In February, 1911, Mineral Post Office was discontinued and the mail was sent to Wheeles. Mineral is located on the present Skelley Ranch, which is operated by a granddaughter of the first John Skelley, Kay Prather, and her husband, Don.

There were four mail routes a day coming to the Mineral Post Office. There was one from Kenton west of us run by a Mr. Young, who had a ranch just west of Kenton. He drove a team of little mules. The route from Clayton came to Moses, where it was brought by another driver to Mineral. There was a route from Regnie??, Colorado, on the north run by Lindsey Allen. The route on the east from Garrett was carried many years by Mr. Shugart.

All carriers would arrive around noon. Mail from different routes was sorted by the Skellys and put into locked mail sacks according to the direction it was to go. The carriers ate lunch which they brought with them, or purchased canned goods and crackers from the store. They ate off the counter while their teams rested and were fed. Many people came to the post office after their mail, as there were no rural deliveries. If people wished to travel from one of these points to another or into Clayton they rode the mail hack for a fee.

The post office and store serviced a large area for residents as well as transients. It was on a main route for homesteaders going into New Mexico when it was opened to filing. Many covered wagons parked near the store at a nearby creek, the South Carrizo, a clear sparkling stream, ideal for camping. They would replenish their supplies from the store. Many ranchers and homesteaders who were already settled in the area would make it Mineral to camp and renew supplies as they went to the breaks between there and Kenton to get posts for fencing and wood for fuel.

My mother helped in the store and post office in addition to raising a family and keeping house. When help was available she had a woman to assist with cooking, laundry, and housework, as there were many extras to feed and house, as well as boarding school teacher and a hired man who helped with ranch work. Ours was a busy household.

We children spent many hours in a dry goods bar under the counter near Mother, before we were old enough to walk. As we got older we used big wooden dry goods boxes for playhouses. Few toys were available, but we made our own playthings. Nails and string were fences, sticks and rocks were people and stock. Days were spent playing paper dolls, if we could get a catalog to cut up. We would have houses with furniture for different rooms, and families cut from pictures, with changes of clothes, and we lived their lives day by day. I remember once when cutting out of a catalog got me into serious trouble. My folks had planned to order my brother, George, a small tool box for Christmas. When they started to prepare the order, I had already used the tool box in my paper doll family's business. To punish me Dad made me sit down and cut newspapers hours and hours. I was very careful with my cutting after that.

We Skelleys had music in our lives after one trip Dad made to Kansas city with a shipment of cattle and brought back an Edison phonograph with cylinder records and a morning glory horn. Two of the records were "When You and I Were Young, Maggie" and "Nearer My God to Thee". We had a telephone line which ran on barbed wire fences to Kenton. We would put the phonograph on the table, roll the table as near the phone as possible, give the general alarm of five long rings, then play the records to all who were on the line. Different families told how they pushed and shoved to see who would get to hold the receiver and enjoy the music.

There were 13 telephones on the line, and everybody knew the sound of others' voices, and even the click of their receivers. There was one lady, Grandma Cochran, who blamed the kids for everything that went wrong--no answer, too much static, couldn't hear, or any other problem. She would shout, "You Baker kids, get off that line!" "You Skelley kids, get off that line!" We meant no harm. We just wanted to keep up with the times and have some news to pass along.

Our school at Mineral was built of hand-cut stone. Part of it was destroyed by the tornado in 1908. It was then rebuilt and enlarged. Three teachers who taught there during my memory later became county superintendents of schools in Cimarron County: Mrs. Hettie

Britton, who was the first woman county officer; Zilpha McClain, (later Mrs. Lawrence French), and George Gillis, a pioneer rancher and teacher.

When Mr. Gillis taught a Mineral, it was in the days when oxen were used to pull Wagons. Mr. Gillis had a team of oxen he drove back and forth from his ranch east of Mineral on week-ends. He would bring a barrel to water and food supplies to last him a week or more, and batch at the school. Mr. Gillis was a great reader and was always interested in a book, and would read as he drove the oxen. He sometimes became so absorbed in his reading that he would not realize the oxen had wandered off the road and were grazing in the pasture, possibly headed in the wrong direction, when he came back to the present.

Shortly after the turn of the century, when the Mineral store was at the height of prosperity, my dad had a large inventory of groceries, dry goods, hardware, and ranch supplies, including Hodkins gloves and Hyer boots. One night some wandering cowboys decided they would help themselves to the gloves, boots, pocket knives, canned goods, and other items. The break-in was discovered the following morning, and officers were soon on their trail, as it was a federal offense to break into a building where a post office was housed.

The officers quickly located the trail which was easily followed by shells which were discarded as the enjoyed the peanuts, a part of their loot. Later a spot was found where they made camp and ate the canned sardines and fruit they had taken. They were apprehended and punished accordingly.

Medication on our store shelves consisted of sulfur, Sloan's lineament, Carter's Little Liver Pills, carbolic salve, Syrup Figs, and the terrible, obnoxious asafetida. Most children were forced to wear a bag of it tied around their necks all winter, with the assumption that it would keep all germs away. It was a glorious day when spring came and that "stinky bag" was removed, along with the unsightly, bulging lone-handles.

One night in October, 1908, all the family, visitors, and hired hands (18 in all) were peacefully sleeping when Father was awakened by vivid lightning. He was hard of hearing, so in order to inspect the weather at first-hand he stepped outside. The wind nearly blew him off the porch, but he grabbed a porch post as a flash of lightning gave him a glimpse of the vacant old rock store building as it disintegrated a few hundred yards away. At practically the same instant the southwest corner of the roof of our house and the brick chimney were shattered. It was all over in less than a minute, but a great deal of destruction was caused over the country by the storm. The 19 people in our house that night were very lucky.

A neighbor, Clay Brown (great-uncle of Mrs. Adolph (Ernestine) Stevens), was killed and his wife badly injured when their house was completely destroyed about four miles south of us.

Camp Nichols was located a few miles from Mineral. Dad was always interested in this historic area, and took many visitors and state officials to see the old fort. He was quite familiar with everything around the deserted ruins. One day he visited the area and notices that a headstone had recently been removed from the grave of a soldier. This angered him to think someone would show such irreverence, so he began to search among recent newcomers on the flats. At a certain house, there was a very flat familiar-looking rock being used as a doorstep. He turned it over, and there was the inscription. My dad was very angry with the man, and made him load the stone in his wagon, take it back to Camp Nichols, and put it where he found it.

I enjoyed every day of the 24 years I lived at Mineral. I was born, raised and married in the same house there. I have a storehouse of memories, and feeling of pride for my pioneer family who helped make history in Cimarron County.

(slightly modified; *in* The Tracks We Followed, edited by Norma Gene Butterbaugh Young, 1991, p.160-161)

APPENDIX 2

SANTA FE TRAIL

There are several sites in Cimarron County which show impressions left in the prairies by the heavily laden wagons and the countless thousands of hooves of the oxen and horses that pulled them along the old Santa Fe Trail.

This trail, about 775 miles in length, was the first of three pioneer roads to the newly opened West. The Santa Fe Trail was the one by which trade was established between the frontier of the United States at Westport (now Kansas City) on the Missouri River, and the settlement of Santa Fe in Spanish territory. Occasional explorers and traders are said to have passed over the route as early as the middle 1500's, but it was not until Mexico declared her independence from Spain in 1821 that regular trade began to flow over the Santa Fe Trail.

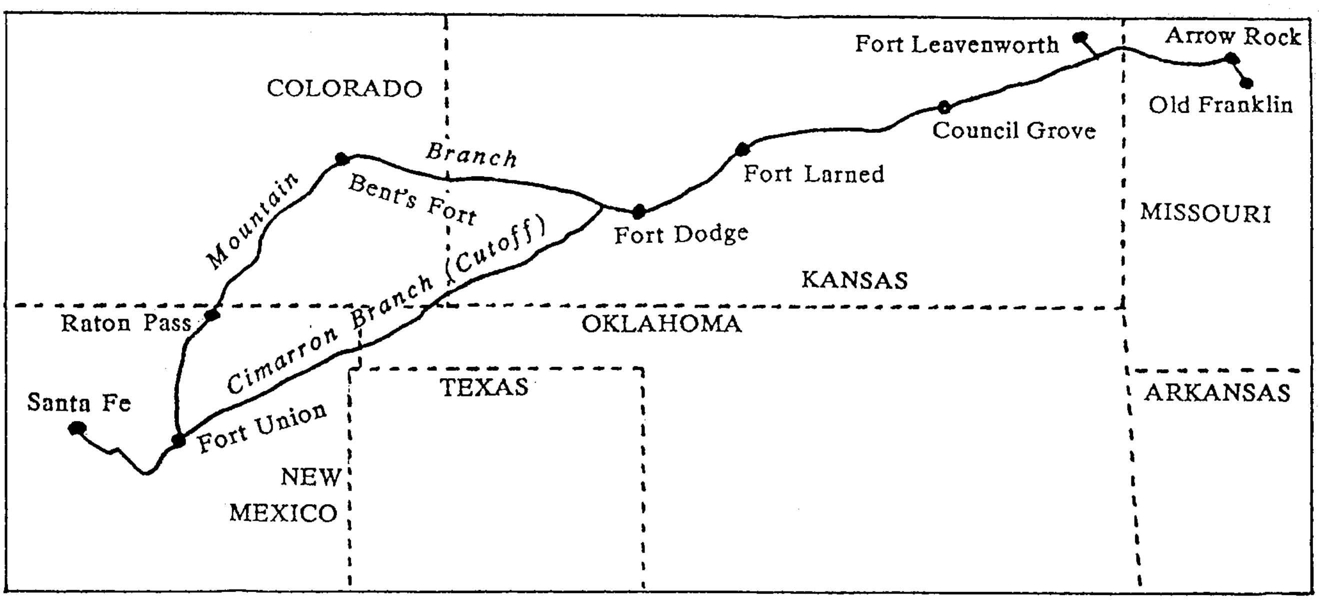
The other two land routes to the far west (the Oregon Trail and the California or Overland Trail) may be said to date from 1843 and 1849, respectively.

The more direct Cimarron Cut-off departed the original Santa Fe Trail about 30 miles north of present-day Meade, Kansas, on the Arkansas river, and extended to southwestern Kansas, across the southeastern corner of Colorado and present-day northwestern Cimarron County. It joined the original trail at what is now Watrous, New Mexico, and continued on to Santa Fe.

The Cut-off followed the Cimarron River watershed through Cimarron County. The greatest hazard to travelers was that of renegade Indians and outlaws through No Man's Land, which is now the Panhandle of Oklahoma. Because of this menace to wagon trains, Kit Carson was ordered by the U.S. War Department to establish a military post about half way between Fort Union, New Mexico, and Fort Dodge, Kansas. In June, 1865, Carson sent reports to Washington from Camp Nichols, New Mexico, although the site was actually five miles east of the New Mexico line, in what was then known as the Neutral Strip or No Man's Land.

(Boise City Chamber of Commerce Pamphlet)

Routes of the Santa Fe Trail



APPENDIX 3

DINOSAURS

Allosaurus fragilis, life restoration by Mark Hallett.

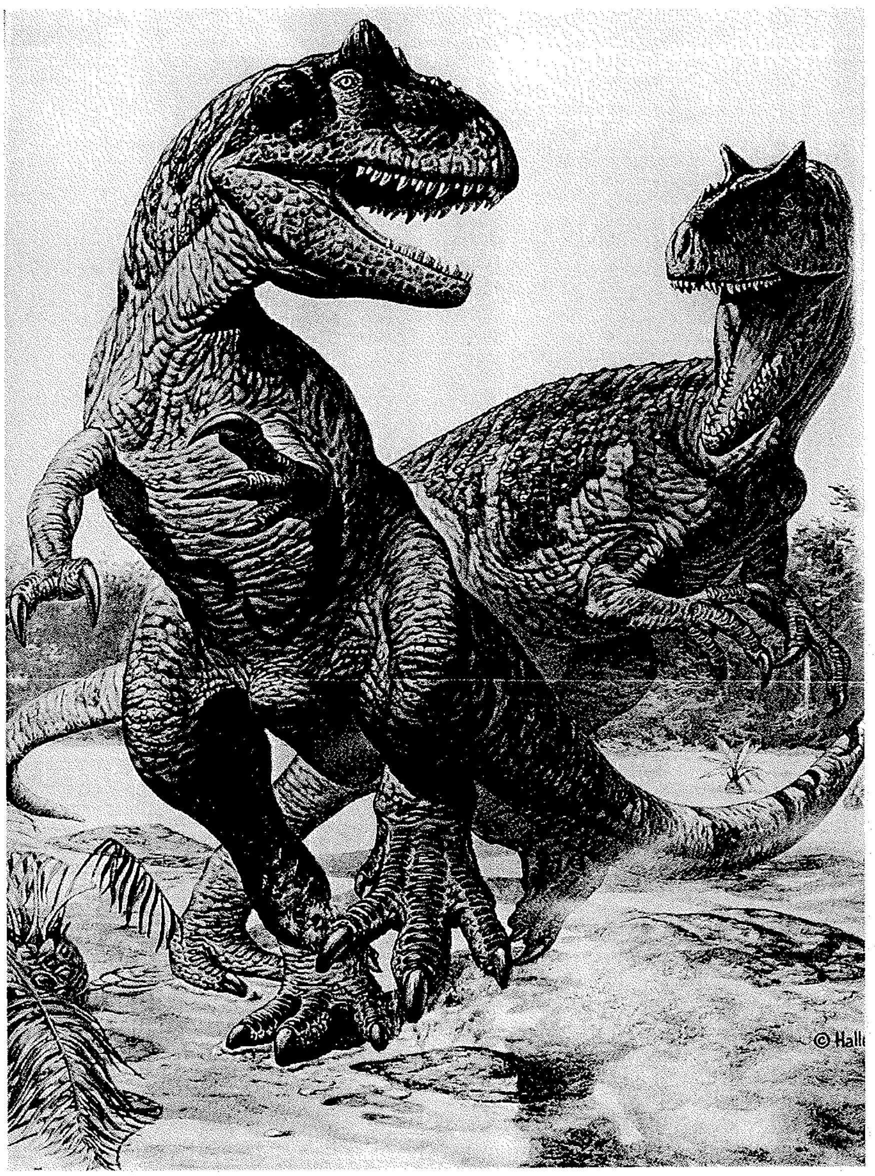
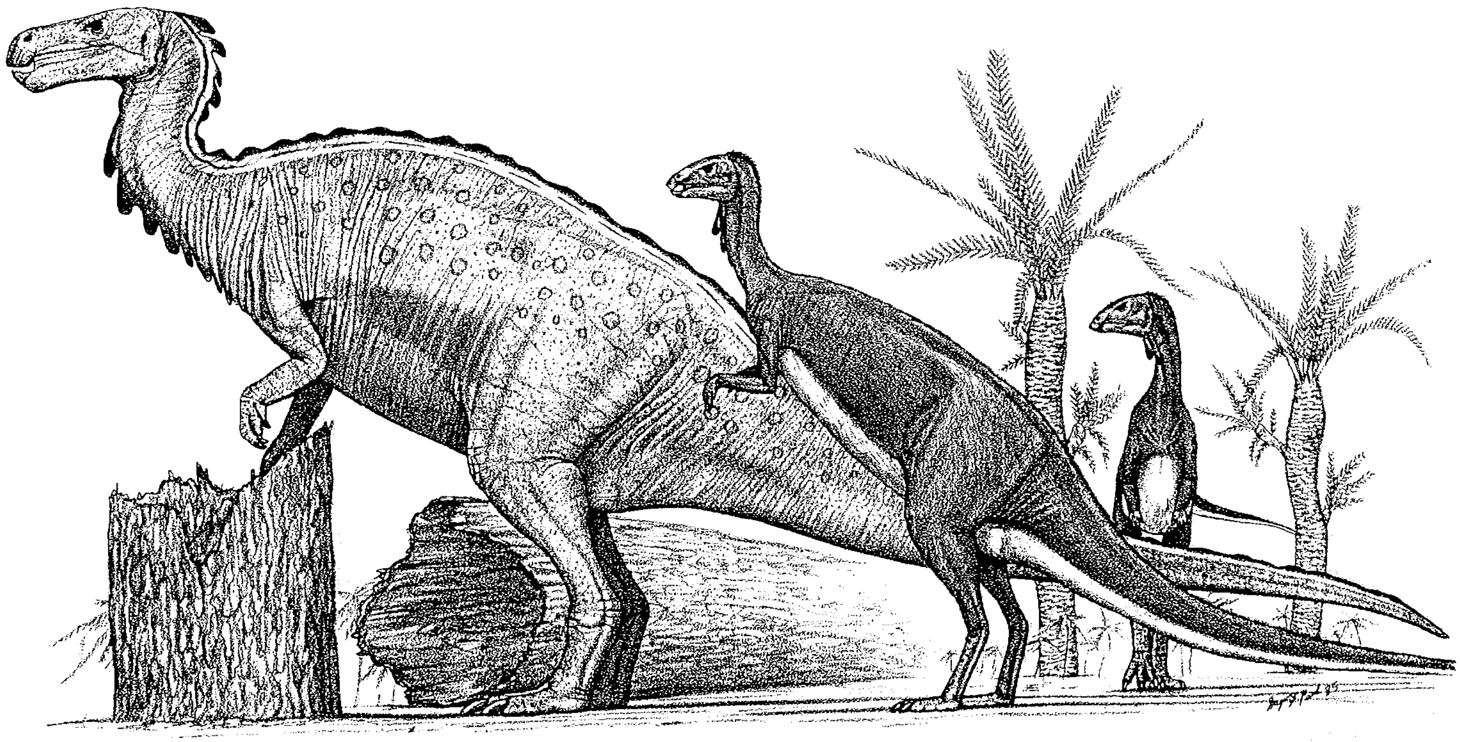
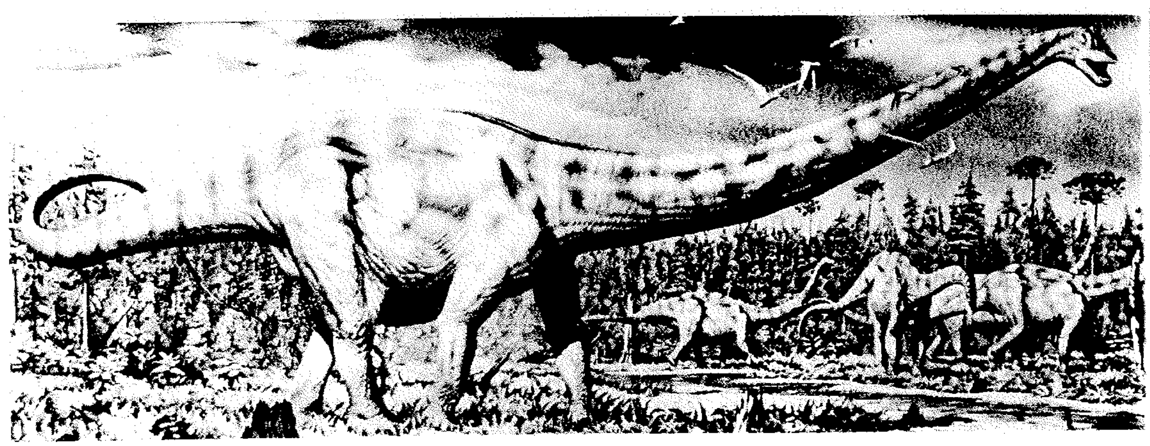


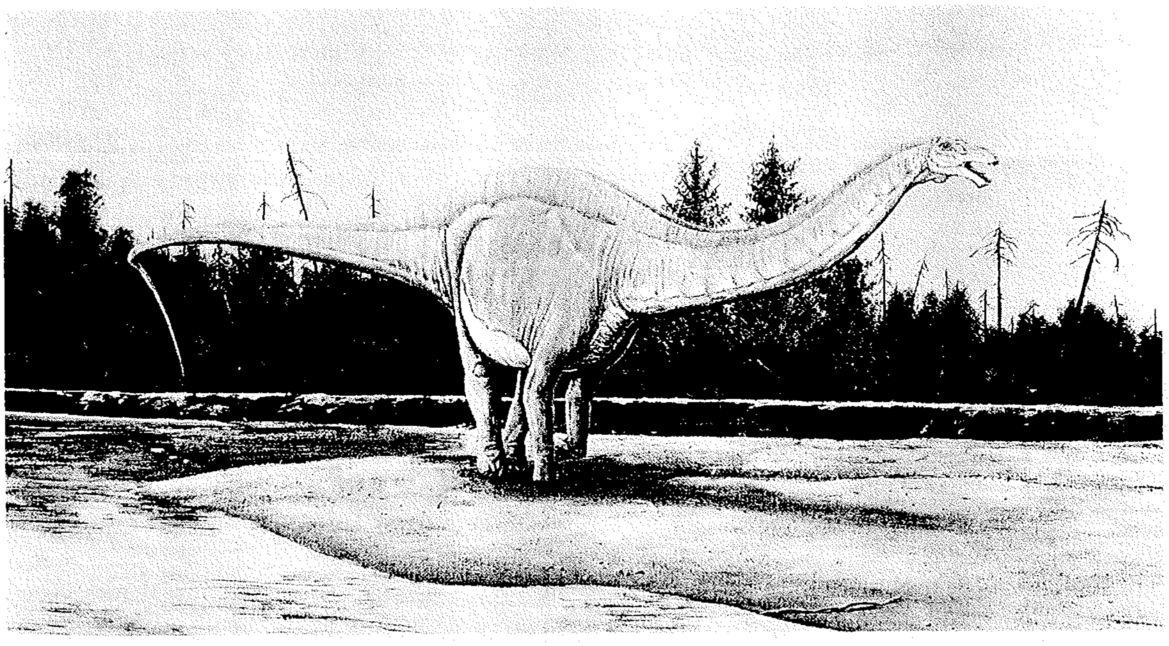
Illustration by Gregory S. Paul.



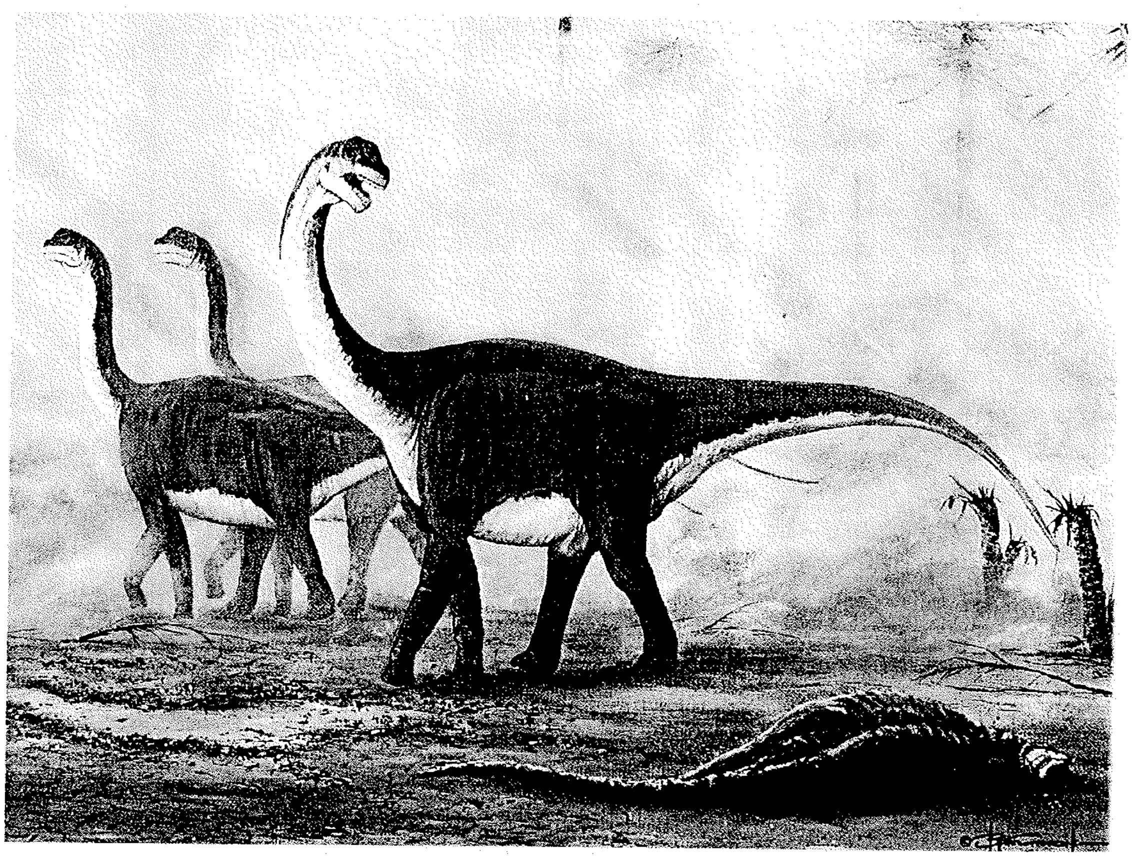
Camptosaurus dispar (left) and two *Dryosaurus altus.*



Diplodocus carnegii, life restoration by Mark Hallett.

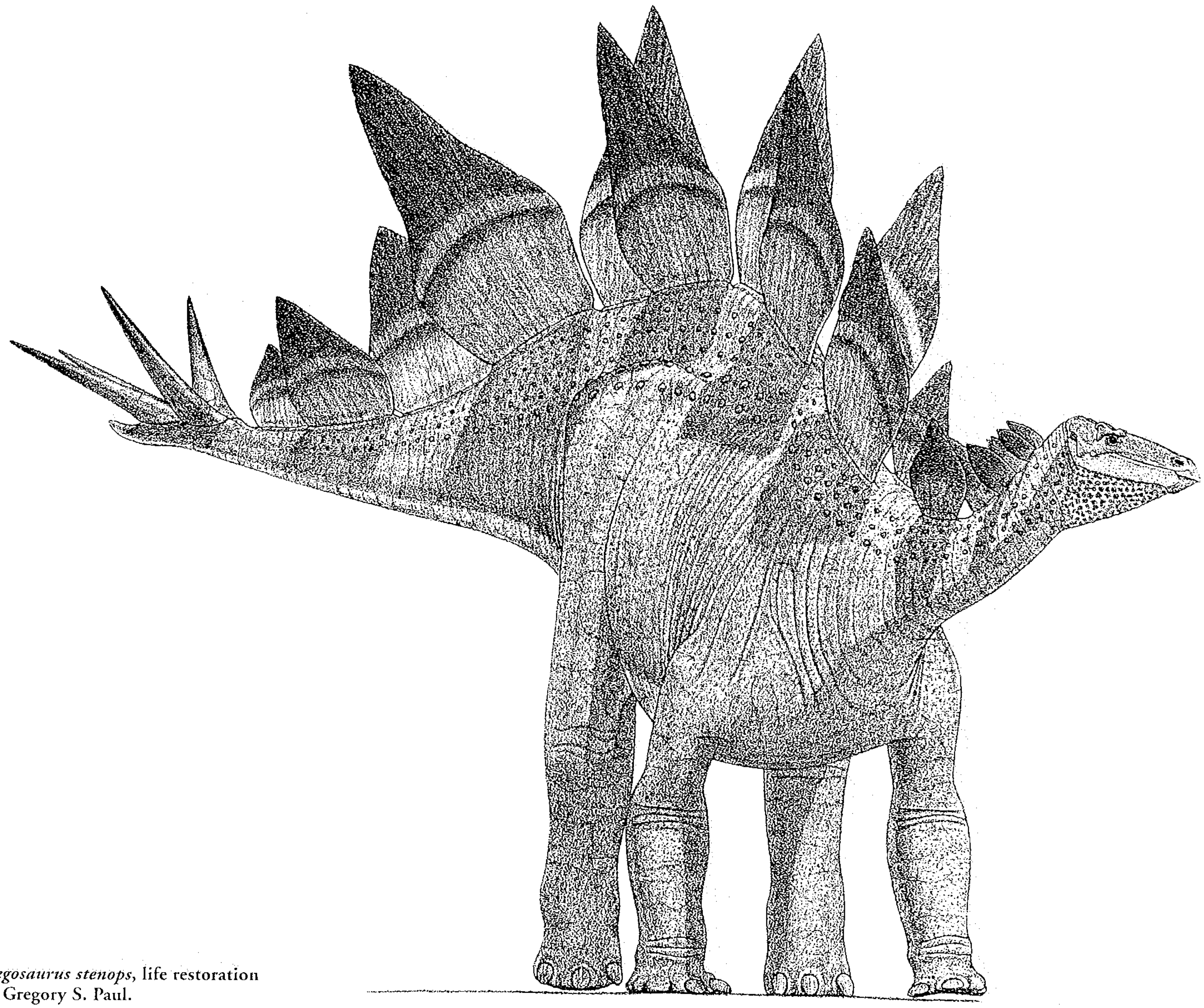


Apatosaurus ajax, life restoration by Brian Franczak.



Camarasaurus supremus, life restoration by Brian Franczak.

Stegosaurus



Stegosaurus stenops, life restoration by Gregory S. Paul.

All dinosaurs illustrations from: Glut, Donald, F., 1997, Dinosaurs the encyclopedia, 1076p.

APPENDIX 4

101 RANCH

The ranch headquarters off to the north of the road, a little more than three miles east of Kenton, is the original 101 Ranch, pre-dating the famous Miller Brothers' Ponca City 101 Ranch by a decade or more. The ranch began operations around 1877, operated by the Prairie Cattle Company, a Scottish syndicate. It was one of the earliest in this part of No Man's Land, and is now owned and operated by Mrs. Ina K. Labrier.

Mrs. Labrier's father-in-Law, H. C. Labrier, came to the area in 1886 at the age of 18 and went to work for the 101 outfit. The ranch was later broken up, and H. C. Labrier and two of his sons eventually became owners of much of the original ranch.

(from: The Tracks we Followed, edited by Norma Gene Butterbaugh Young, 1991, p.104)

EASTER PAGEANTS

The first idea of an Easter Pageant was conceived by two young families on an outing three miles east of Kenton in 1951. They found themselves in a natural amphitheater, with a small cave at the "stage" area. It was a beautiful setting, with craggy hills in front and to the right side of them, and hill in the distance covered with rocks, cedars, and piñon pines.

One of the men in the group was a Methodist pastor, and after discussing their idea thoroughly among themselves, he hurried to the little village of Kenton to talk over the plan of a simple outdoor service with the Baptist minister.

They had no trouble finding enough interested area residents to make up a cast. After a few rehearsals, they gathered at the site on that Good Friday for prayer and fellowship before presentation of the first performance on Easter Sunday. An unexpected audience gathered as passers-by on the highway stopped to watch and were invited to join them. The result was the first Good Friday service, and was incorporated as a major part of the Easter week-end observance for many years.

Before the 1954 performance, those who were involved in the performance asked for and received help from Christians of surrounding communities, from many walks of life. Practically every member of the Kenton Community, as well as some across the state lines in Colorado and New Mexico, have participated monetarily and with their time and effort through the years. Among these are teachers, ministers, merchants, and professional men and women. Included in the talents and experience utilized are script writers, costume designers, make-up people, carpenters, musicians, electricians, sound men, cooks and dishwashers, printers, artists, painters, ranchers, farmers, housewives, and young people from pre-schoolers through college students. Telling the story of the Redemption in an acceptable manner is the purpose of those involved.

Following the presentation of the 1957 pageants, the first board of trustees recommended the organization be incorporated for the purpose of perpetuating the services from year to year. This non-profit corporation, called Kenton Easter Pageants, Inc., operates under the laws of the State of Oklahoma. The organization receives support for its operations from individuals and business institutions in the area. Contributions are always gratefully accepted.

After the first few years of production, three separate services were held, on Good Friday evening at sunset, Holy Saturday in the evening, and Easter morning at sunrise. This plan continued until the late 1970's, when the Saturday story was incorporated into the Friday and Sunday pageants, and the Good Friday pageant was moved to Saturday. The change was necessary for the benefit of those persons involved. They were unable to devote all their week-end to the performances, which necessitated ignoring their families and business duties.

(modified from: Roy Butterbaugh and Norma Gene Young *in* The Tracks we Followed, edited by Norma Gene Butterbaugh Young, 1991, p.93-95)

APPENDIX 5

BLACK MESA NATURE PRESERVE

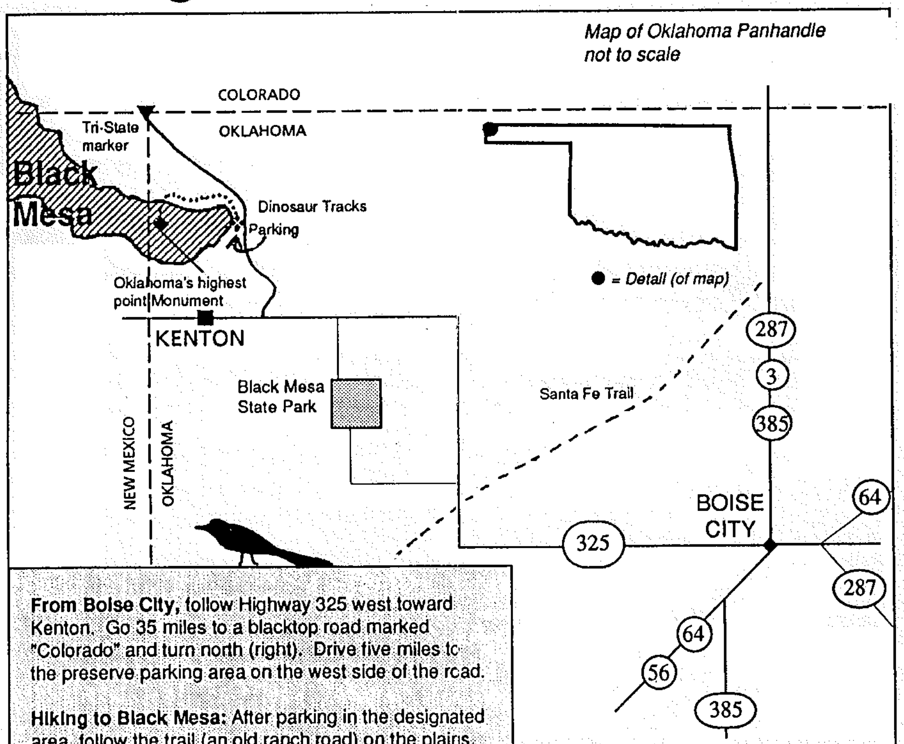
The Nature Conservancy, a private owner and manager of nature preserves, purchased this 1,600 acre preserve in 1991. The preserve protects about 60% of the mesa top in Oklahoma in addition to talus slopes and plains habitat. A native granite monument marks the highest point in Oklahoma--4,973 feet above sea level.

The Black Mesa area supports 31 state rare species (23 plants and 8 animals) and four community types. The Black Mesa area is where the Rocky Mountains meet the short grass prairie. It is unique in that it represents an area where many species are at the easternmost or westernmost portions of their range. Vegetation on the top of the nearly-flat mesa is comprised of a bluestem-grama shortgrass community. The mesa's talus slopes support a oneseed juniper-shrub oak woodland, while neighboring buttes have a oneseed juniper-piñon woodland. Both woodland communities are eastern extensions of Rocky Mountain Foothills vegetation. The plains below the mesa support a blue grama-buffalo grass, galleta grassland, and a bluestem-grama grassland.

Black Mesa is a birder's paradise any time of the year. Golden eagles, scaled quail, black-billed magpies, and piñon jays are just a few birds that may be observed. Black bears, bobcats, mule deer, and antelope are some of the mammals that may be seen in the mesa region. Look out for venomous rattlesnakes which may be active at any time, particularly during the morning and afternoon in cool weather.

The preserve is open dawn to dusk. Allow at least four hours to walk from the parking area to the top of the mesa and back.

Getting there

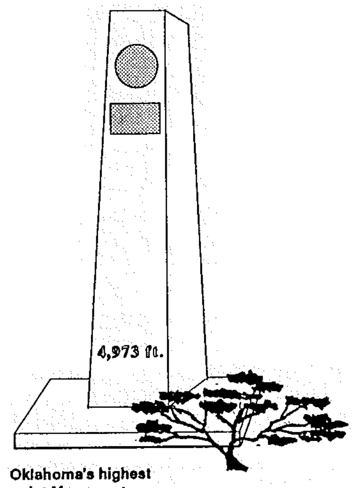


From Boise City, follow Highway 325 west toward Kenton. Go 35 miles to a blacktop road marked "Colorado" and turn north (right). Drive five miles to the preserve parking area on the west side of the road.

Hiking to Black Mesa: After parking in the designated area, follow the trail (an old ranch road) on the plains. You will see the trail winding up the Mesa. Climb and follow it to the top. The Mesa trail leads to the monument marking the highest point in Oklahoma. The round-trip distance from parking area to monument is about eight miles. Bring at least one quart of water per person, and wear a hat and other sun-protective clothing. Allow four to six hours for the round-trip. Enjoy the view!

BLACK MESA

NATURE PRESERVE



Oklahoma's highest point Monument atop Black Mesa

The Nature Conservancy

Design by WriteAngle/Tulsa

A Cooperative Project between The Nature Conservancy and Oklahoma Tourism and Recreation Department

THREE-STATE MARKERS

The blacktop road that takes the tourist to the dinosaur tracks goes on in a general northwesterly direction to the Colorado state line. Follow a ranch road off to the west to a monument marking the three sates--Oklahoma, New Mexico, and Colorado.

There are two posts marking the northwest corner of the Oklahoma. The oldest of which is farthest north and was set by the survey of 1881. This marker is a sandstone pillar four and a half feet above ground, and one and half feet square at the end. It is marked 37° NL, 103° WL.

The second corner is about 300 feet south of the first stone and was set by the survey made in 1900. This marker was a sandstone pillar two feet above ground and one and a half feet square on the end and is sometimes referred to as the Preston Monument. This marker was removed in 1928 by Arthur D. Kidder and replaced with the present monument. This monument is the first marker seen from the road.

(Rothrock, E. P., 1925, Geology of Cimarron County, Oklahoma, p.8-9; author unknown; published in: The Tracks we Followed, edited by Norma Gene Butterbaugh Young, 1991, p.105)

ROBBERS' ROOST

A band of outlaws led by Captain William Coe made No Man's Land its headquarters in the late 1860's. They built a rock fortress-like building later known as "Robbers' Roost" that was almost impenetrable. The gang would make forays to Fort Union, New Mexico Territory, and Fort Lyons, Colorado Territory, to steal Army horses and mules. The Army brands, "US" on the right shoulder, were blotched or branded over, and most of the stock was taken to eastern Kansas and Missouri and sold to settlers.

The outlaws are also thought to have preyed on freight caravans traveling the Santa Fe Trail 14 miles south of the hideout, and scattered ranches in the vicinity.

The outlaws' "home" was 16 by 30 feet, with walls three feet thick. The roof was several feet of dirt, supported by branches and wild grass on cottonwood ridge poles. A fireplace at each end of the building provided heat and cooking facilities. There were no windows in the building, but portholes, four inches square on the outside, widening to 18 to 20 inches inside, which enabled the gunmen to direct their fire over a wide range. These also provided ventilation, as did a door at each end of the small fortress.

The building was strategically placed on a ridge that jutted southwest from Robbers's Roost Mesa. The Mesa extended into the middle of the valley enabling look-outs to view approaches from up and down Cimarron Valley and north up Carrizo Valley.

Five miles northwest of the hide-out, in a well-hidden and well-watered canyon, the gang maintained a fully equipped blacksmith shop with tools stolen from Santa Fe caravans. The anvil was mounted on a block of walnut of a size and character making it seem probably that it came from the Missouri River country. In this shop, which was the outlaws' horse pasture, their mounts were shod and any other necessary iron work done. The canyon in later years was called Blacksmith Canyon, and the name is still used.

Leader of the outlaw gang, Coe, was a tall, well-built man about 35 years old at the beginning of his operations in the area. He was a stonemason and carpenter and worked at these trades for a time at Fort Union, which was established in 1851. He was a southerner, but that is all the factual information known about him. Coe is though to have come to the area about 1864, and it may have been his presence as much as Indians in the vicinity that prompted the Army to establish Camp Nichols in 1865.

Coe's band of followers was estimated to be from 30 to 50 in size, but seldom were all of them at the stronghold at any one time. Raiding parties were kept in various locations most of the time, and after stealing livestock it was necessary to drive them to market in the opposite direction from where they were stolen. But when the men reported in at the roost, life was not dull. Coe had set up a bar, brought in a piano, and there were always girls on the premises.

In February of 1867, several members of the Robber's Roost gang are said to have raided the sheep camp west of their headquarters of brothers Juan and Ramon Bernal and Juan and Vicente Baca from Las Vegas, New Mexico Territory. They attacked the herders, killing two of them, and drove off 3,400 head of sheep toward Pueblo, Colorado Territory, then a small trading post. Following this outrage, the Bernals and Bacas and others in the area who had suffered from operations of the outlaws, sent a delegation to Fort Lyons, on the Arkansas River near Las Animas, where troops under the command of Colonel William H. Penrose were asked to help in breaking up the gang.

The following story has been told so many times that it is accepted as fact by many people. A few old-timers, however, say they never heard this version until a writer during the 1930's wrote of it. It is widely reported that the writer had a "right vivid imagination".

A spy was sent from Fort Lyons to "join" the gang for a few months, and following the report to his superiors, in the fall of 1867, a contingent of 25 regulars from the post marched south almost a hundred miles to the stronghold, with a six-inch field piece in tow.

They positioned the cannon nearly three-quarters of a mile to the northwest of the roost, on the lower slopes of Black Mesa, a short distance back of the west bank of North Carrizo Creek. At sunrise the next morning the bombardment began, and the walls of the stone structure across the stream began to crumble. Some of the bandits put up a fight; a few were killed; others fled to the surrounding hill, Coe among them.

The soldiers marched back to Fort Lyons, accompanied by several prisoners, many of whom were badly wounded. Their trail, marked by soldiers, was given the name Penrose Trail, and was later followed by cattlemen driving herds north for shipment to market.

However, there is nothing in Army records to indicate an assault by Penrose's men on the roost, but there is a record that a group of soldiers led by Penrose left Fort Lyons in late 1867 in an attempt to capture some renegade Indians. They followed them through Raton Pass, all the way to Palo Duro Canyon, and it was 1868 before they returned to Fort Lyons. In an account written by Penrose, he described this area but said nothing about the Coe gang.

The final downfall of Coe came through the efforts of a woman, Mrs. Madison Emory, and her young son, Bud Sumpter. He told his captors afterward: "I never figured to be outgeneraled by a woman, a pony, and a boy."

The prisoner was taken to jail at Pueblo and kept under guard of troops pending indictment and trial in the Third Judicial District of Colorado Territory. But vigilantes soon decided that either the risk of holding him was too great, or that justice for a criminal like Coe was too slow.

The night of July 20, 1868, some men came to the trooper on guard, saying it was necessary to change Coe's quarters. The vigilantes put him in a wagon, tied a rope around his neck, and drove to a cottonwood on the bank of Fountain Creek. According to the Colorado Chieftain of July 23, he was found there the next morning, still handcuffed and in leg irons, knees touching the ground. The body was cut down and buried beneath the tree on which he had met his fate.

Many years later, while excavating an area in Pueblo for a new road (in the vicinity of Fourth Street), workmen found the skeletal remains of what was though to be the "King of Robbers' Roost." So there had been no escape for him the third time he was caught.

(author unknown; published in: The Tracks we Followed, edited by Norma Gene Butterbaugh Young, 1991, p.20-21)

MESOZOIC STRATIGRAPHY OF BLACK MESA AREA

SCHOFF AND STOVALL (1943), THIS REPORT		AGE	
Graneros-Greenhorn beds	Colorado Gr.	CENOMANIAN	CRETACEOUS
upper sandstone	Dakota Ss.	ALBIAN	CRETACEOUS
middle shale	Dakota Ss.	ALBIAN	CRETACEOUS
lower sandstone	Dakota Ss.	ALBIAN	CRETACEOUS
Kiowa Sh. M.	Purgatoire F.	ALBIAN	CRETACEOUS
Cheyenne S.M.	Purgatoire F.	ALBIAN	CRETACEOUS
Morrison Formation		Tth, Kim, Oxf, Clv	JURASSIC
Exeter S.		Clv	JURASSIC
Sheep Pen S.	Dockum Group	NORIAN	TRIASSIC
Sloan Canyon Formation	Dockum Group	NORIAN, Crn	TRIASSIC