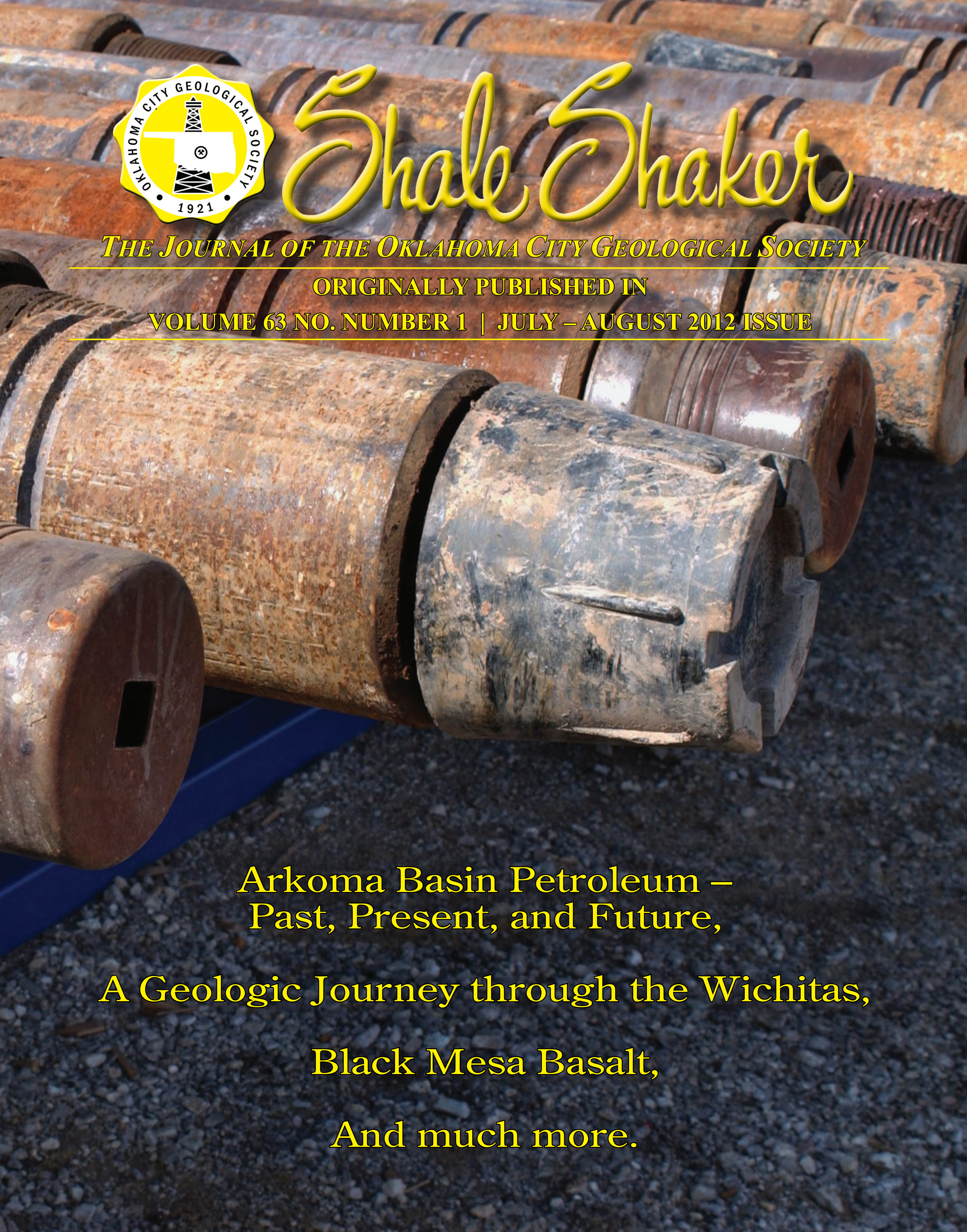

Shale Shaker

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Arkoma Basin Petroleum – Past, Present, and Future,

A Geologic Journey through the Wichitas,

Black Mesa Basalt,

And much more.

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Black Mesa Basalt

Introduction

There are not a lot of volcanic rocks in Oklahoma. Probably the least known are the Colbert and Carlton Rhyolites (Cambrian) in the Arbuckle and Wichita Mountains, respectively; the Hatton Tuff and Mud Creek tuffs (Mississippian) in the Ouachita Mountains; and scattered volcanic ashes from Yellowstone and other Neogene calderas. Most likely the best known and undoubtedly the most visited is the basalt lava flow capping Black Mesa in the northwestern corner of Cimarron County. Much of the top of the mesa is within the Black Mesa Nature Preserve which is operated by the Oklahoma Tourism and Recreation Department in conjunction with Black Mesa State Park; as such, it is accessible to the public and a 4.2-mile hiking trail (one-way) leads to the highest point in the state at an elevation of 4,973 feet above sea level.

The popularity, yet remoteness of Black Mesa, combined with some outstanding geology and the fascinating human (Native American and European) history of the area, make the Black Mesa basalt this issue's "Favorite Outcrop."

Geologic Setting

The oldest strata in northwestern Cimarron County (also known as Dry Cimarron Valley) are the dominantly Upper Triassic Sloan Canyon Formation and overlying Sheep Pen Sandstone (Lucas et al., 1987a) (Figure 1). Older Triassic strata (from older to younger, the Baldy Hill and Travesser Formations) are present just to the west in New Mexico (Baldwin and Muehlberger, 1959). In Oklahoma and adjacent Colorado and New Mexico, about 200 copper mines and prospects were opened in the dominantly fluvial Sheep Pen Sandstone

between 1884 and 1925, although little is known about total production (Fay, 1983). The lacustrine Sloan Canyon Formation contains abundant vertebrate fossils, in fact, Lucas et al. (1987a, p. 107) suggests it "is the most fossiliferous of the Triassic units in the Dry Cimarron Valley," and one of the quarries is very near the trailhead to the top of Black Mesa.

Unconformably overlying the Triassic strata are the Middle Jurassic Exeter Sandstone, a highly cross-stratified eolian deposit which, in turn, is unconformably overlain by the Upper Jurassic Morrison Formation (Figure 1). The Morrison Formation is probably the most famous dinosaur-bone-bearing formation in the U.S. and the 17 quarries excavated by J.W. Stovall between 1935 and 1942 (Hunt and Lucas, 1987) is evidence that Oklahoma contains its share. The Morrison is mostly a claystone with minor silty sandstones and limestones and was probably deposited as a series of floodplains, shallow channels, and lakes.

The Lower Cretaceous Cheyenne Sandstone, Kiowa Shale, and Dakota Sandstone (oldest to youngest) unconformably overlie the Morrison (Figure 1). (This sequence was renamed the Lytle Sandstone, Glencairn Formation, and Dakota Group by Kues and Lucas (1987) to more closely match the nomenclature used in New Mexico and Colorado, rather than Kansas.) The conglomeratic sandstones of the Cheyenne are mostly fluvial; petrified logs as long as 85 feet and 2.5 feet in diameter were noted by Schoff (1943, p. 76), but the petrified wood has been over-collected and is difficult to find. The Kiowa is a poorly exposed, mostly relatively dark

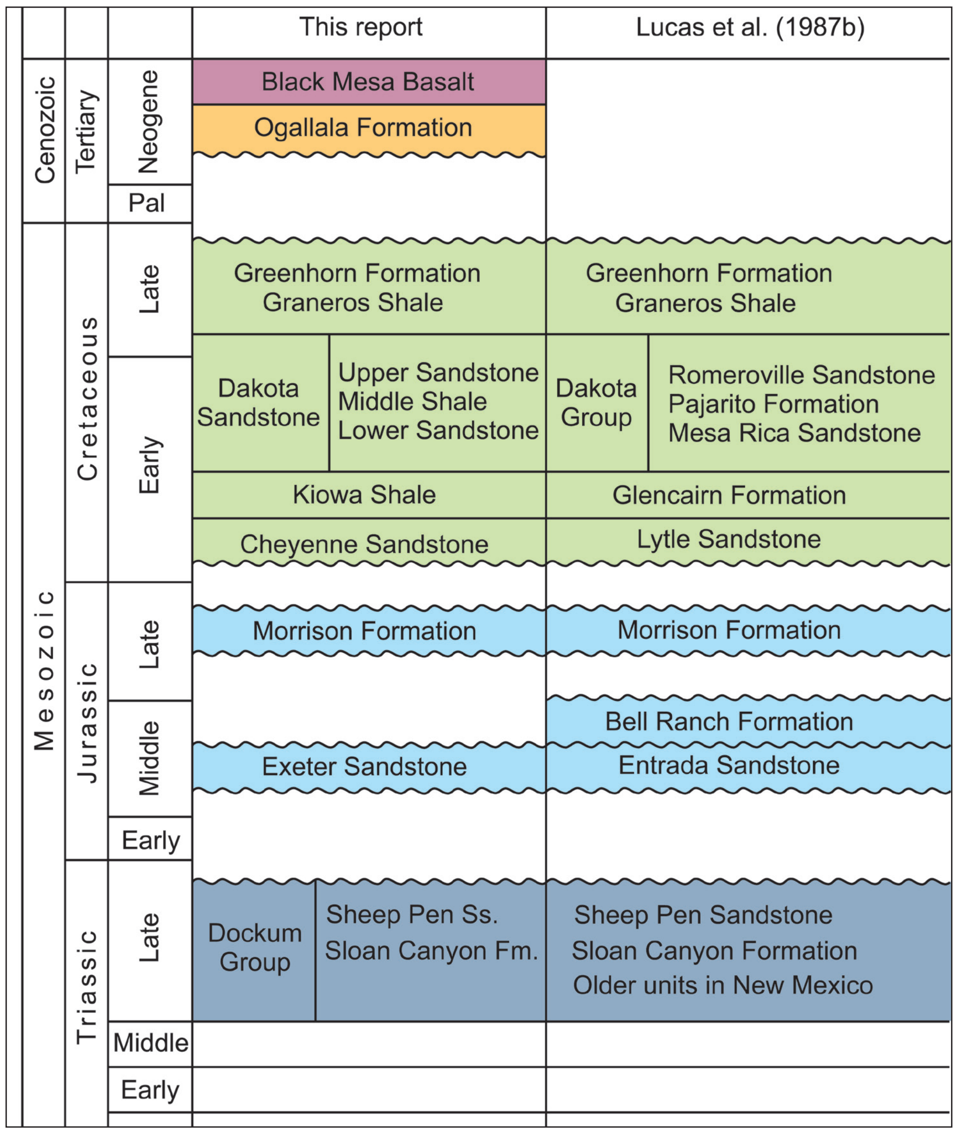

Figure 1. Stratigraphic column and correlation chart of Dry Cimarron Valley, New Mexico and Oklahoma.

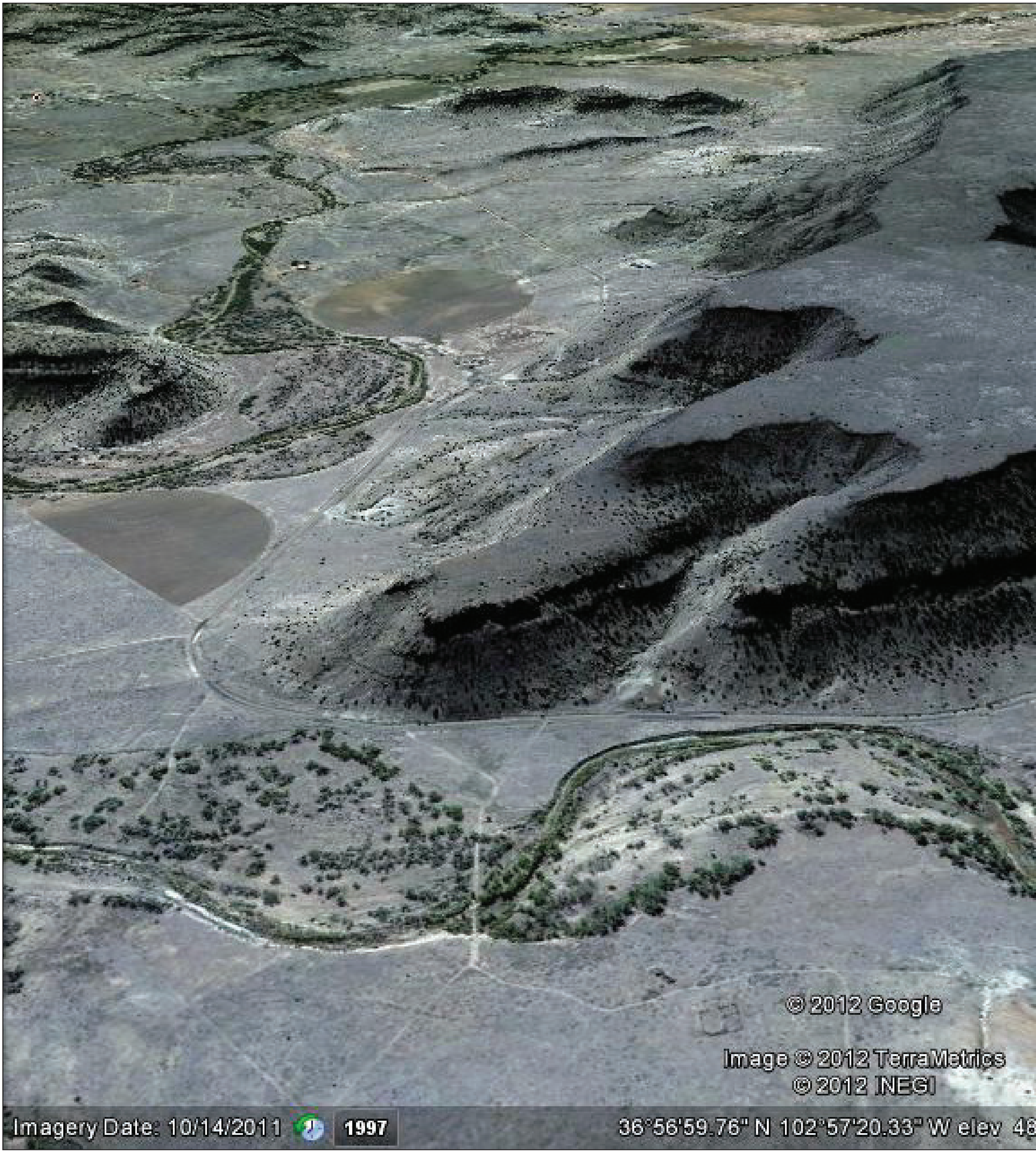
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Figure 2. Google™Earth image of Black Mesa looking to the southwest. The mesa is capped by the Black Mesa basalt; the lower bench in the lower left is underlain by relatively resistant Dakota Sandstone. The conspicuous road in the lower right that ends at the creek leads from the paved road to the dinosaur footprints in the creek bottom. The Black Mesa trailhead is located just to the left (south) of where the bridge crosses the creek upstream from the footprints.

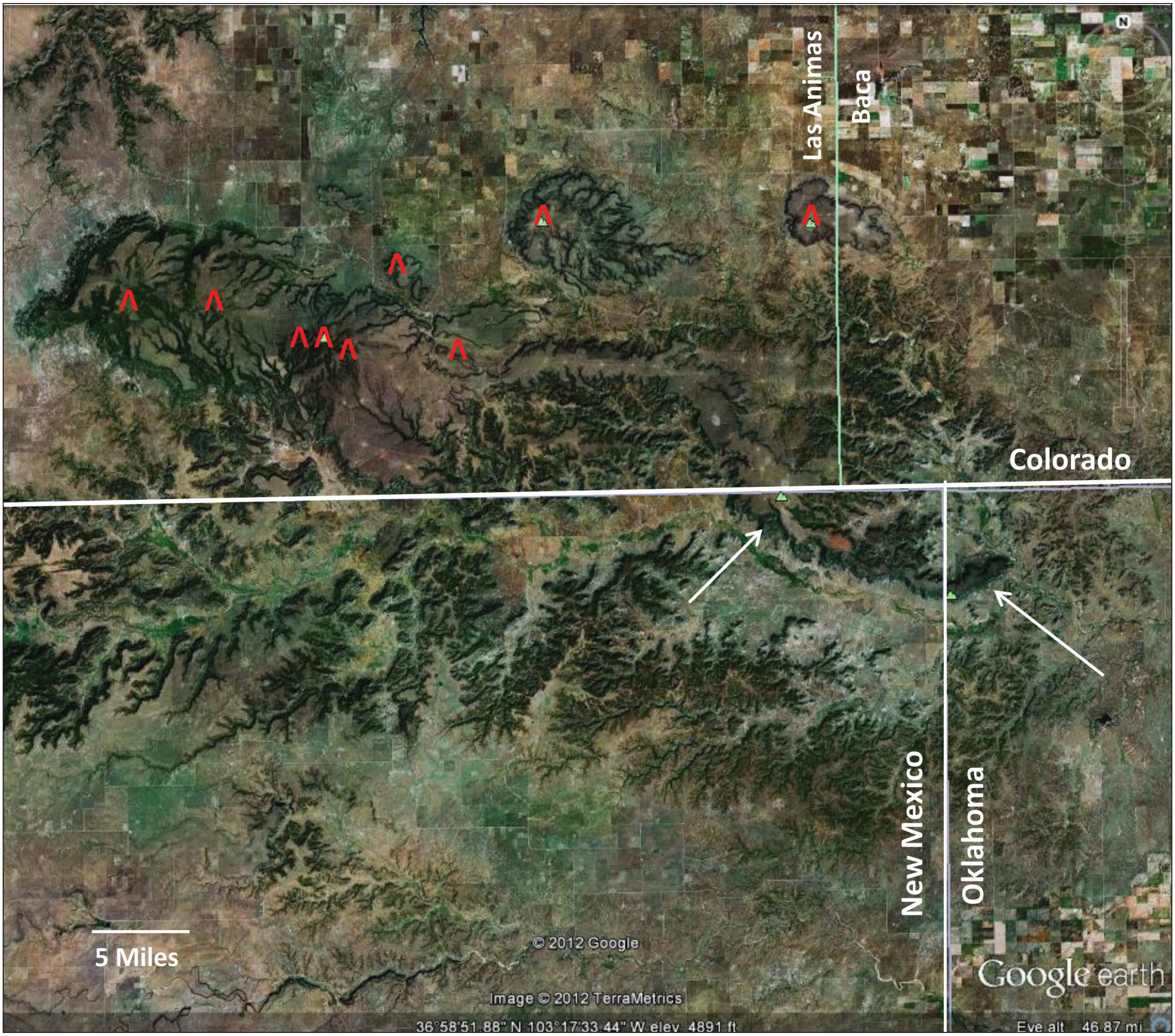

Figure 3. Google™Earth image of three-state area showing Mesa de Maya in Colorado and Black Mesa in New Mexico and Oklahoma (arrow). ^s mark vent areas for lava flows (Scott, 1968). Western white arrow points to where the Black Mesa flow crosses the Colorado – New Mexico state line. The eastern white arrow points to Black Mesa flow in Oklahoma. Note isolated lava flows north of Mesa de Maya in Las Animas County, Colorado.

Figure 4. Vesicles in Black Mesa basalt.

Figure 5. View looking northeast at basalt exposed on southeast edge of Black Mesa.

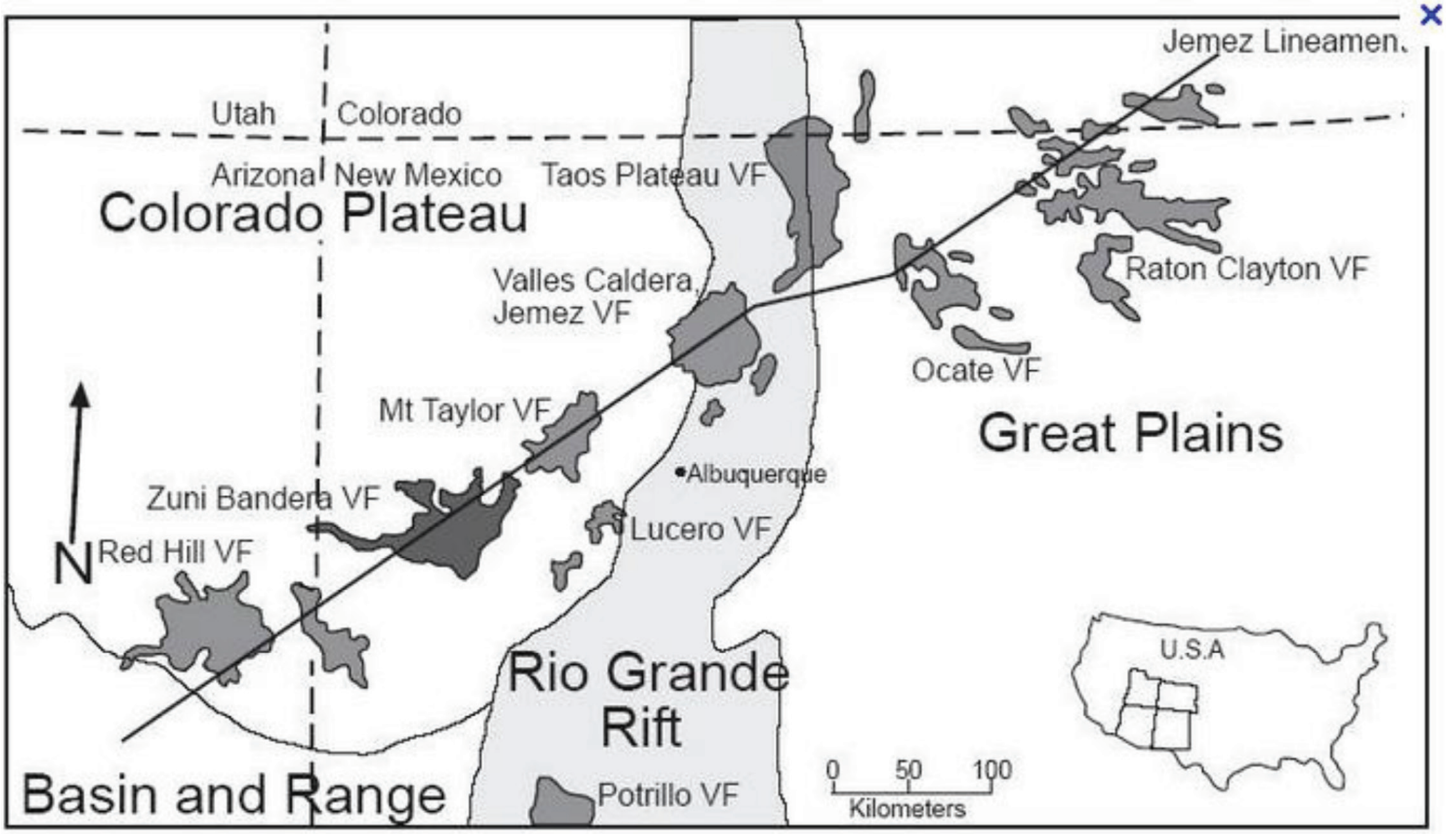

Figure 6. Neogene volcanic fields along the Jemez Lineament (from http://sitemason.vanderbilt.edu/page/iyQ5lm, accessed May 8, 2012)

marine shale containing marine invertebrates, especially the oyster *Texigryphaea*. The Dakota Group is typically divided into three parts, a fluvial sandstone-dominated lower unit; a middle, more fine-grained unit that locally contains coal beds and probably was deposited in a delta-plain environment; and an upper, sandy unit that represents a return to a fluvial environment. Despite the very different environments the Lower Cretaceous units were deposited in and the erosional disconformities that separate them, they represent a relatively continuous record of sedimentation.

The youngest Mesozoic formations in the Dry Cimarron Valley are the Upper Cretaceous Graneros Shale and Greenhorn Formation (Figure 1). The abundance of marine invertebrates fossils in and widespread nature of these units is evidence for a significant rise in sea level and, indeed, the Graneros marks the advance of the Western Interior Seaway through this part of the mid-continent.

Most of the Upper Cretaceous through lower Miocene is missing in Cimarron County; most likely, during this time the area was at least slightly uplifted and undergoing erosion as a result of the Laramide orogeny (uplift of the Rocky Mountains) to the west. The Miocene-Pliocene Ogallala Formation unconformably overlies the Cretaceous (Figure 1) on Black Mesa but thickens greatly to the east where it forms the Oklahoma Panhandle's (and most of the Great Plains states') most important aquifer.

Black Mesa Basalt

The most prominent physiographic feature in the Dry Cimarron Valley is Black Mesa (Figure 2), which includes the highest point in Oklahoma at an elevation of 4,973 feet. Black Mesa is continuous with Mesa de Maya in southern Las Animas County, Colorado, and the two mesas combined are almost 50 miles long (Figure 3). Black Mesa is capped by a basalt lava flow that originated from one or more vents on Mesa de Maya; the closest, about 30 miles away, is described by Scott (1968) as "dikes and plugs of olivine basalt that form ridges and knobs." This possible vent for the flow into Oklahoma is about six miles east of Bar Seven L Buttes, which Rothrock (1925) suggested was the source of the Oklahoma flow.

In Oklahoma, the basalt varies from about 100 to 50 feet thick, probably as a result of having flowed over an irregular topography developed on the Ogallala. It varies from massive to highly vesicular (Figure 4), and along the cliff face at the top of the mesa, the basalt is jointed and locally displays columnar joints (Figure 5). The obvious elongate nature of Mesa de Maya – Black Mesa is evidence that the basalt flowed east-southeast from its source down a paleovalley.

The basalt on Black Mesa is an alkali olivine basalt containing small olivine phenocrysts (largely altered to iddingsite) in a groundmass composed of plagioclase, augite, olivine, and magnetite (Schoff, 1943; Baldwin and Muehlberger, 1959). A chemical analysis of the basalt is shown in Table I (from Rothrock, 1925). The basalt is Pliocene. Hager (1974) dated the basalt at 3.5 +/- 1.0 and 3.4 +/- 1.0 my old (K-Ar). More recently Stroud (1997) dated it at 5.05 +/- 0.02 and 5.10 +/- 0.3 my ($^{40}Ar/^{39}Ar$). The age of the basalt is important for two reasons: 1) It enables an analysis of landscape evolution to be developed that can quantify how much erosion has occurred in the Dry Cimarron Valley area following its eruption, and 2) Where Black Mesa basalt clasts can be identified in the Ogallala to the east, the date establishes a maximum age of the Ogallala.

Raton – Clayton Volcanic Field

The Black Mesa basalt is part of the late Miocene to Holocene Raton-Clayton volcanic field, which occupies much of the northeastern corner of New Mexico (Stormer, 1972) and that includes the spectacular Capulin cinder cone and lava flows dated at 56,000 +/- 8,000 years ago ($^{40}Ar/^{39}Ar$)(Stroud, 1997). The Mesa de Maya – Black Mesa lava flows are the northern part of the field and, except for some small flow remnants about four miles northeast of the eastern end of Black Mesa, the Black Mesa flow is the easternmost Neogene lava flow in the U.S.

Table I. Chemical Analysis of Black Mesa basalt

	Percent
SiO_2	50.96
Al_2O_3	17.54
Fe_2O_3	3.01
FeO	7.46
MgO	5.17
CaO	9.18
Na_2O	2.78
K_2O	0.54
H_2O	0.86
TiO_2	1.31
P_2O_5	0.54
Cr_2O_3	0.04
MnO	0.15
Total	99.54

The Raton-Clayton volcanic field is the northeasternmost volcanic field in a string of Neogene volcanic fields that extend in an east-northeast direction along the Jemez Lineament; these include (from southwest to northeast), the Red Hill (Springerville), Zuni-Bandera, Mt. Taylor, Jemez, Taos Plateau, Ocate, and Raton-Clayton volcanic fields (Figure 6). Magnani et al. (2005) (see also references cited therein) describe several features of the Jemez Lineament as follows:

1. Volcanic rocks range in age from 16.5 my to 1200 years BP.
2. Volcanic rocks are dominantly basaltic with a few silicic volcanoes.
3. There is no age progression of volcanism along the lineament.
4. The lineament coincides with the southern edge of the Proterozoic Yavapai-Mazatzal crustal boundary in northern New Mexico.

Lipman (1980) extends the Jemez Lineament even farther to the southwest to include the Sentinel (Gila Bend) and Pinacate volcanic fields. Thus, the volcanic rocks that erupted along the lineament, including the Black Mesa basalt of Oklahoma, utilized an ancient and deep flaw in the Earth's lithosphere.

Finally ……..

A hike on the trail to the top of Black Mesa to see the basalt flow is well worth the drive to Oklahoma's Dry Cimarron Valley. However, there are many more sites to see and places to visit, including:

1. The Santa Fe Trail Crossing, Cimarron Cutoff, used from about 1820 to 1880.
2. Lake Carl G. Etling in the state park, formed in 1959 and stocked with a variety of fish.
3. Stovall dinosaur quarry no. 1.
4. The Old Woman's profile and Wedding Party in the lower sandstone member of the Dakota Sandstone.
5. The Kenton Museum.
6. Robbers Roost, headquarters of Capt. William Coe's band of outlaws in the 1860s.
7. Dinosaur tracks, probably of a large ornithopod (Lockley, 1986; Mulvaney and Mulvaney, 1988).
8. The (two) Three-State Markers. Current marker is along the road; a second marker dated 1881 is located a couple hundred yards to the northeast.

Acknowledgements

Few geologists can visit northwestern Cimarron County and not be taken with the area's geology. From the old copper mines in the Sheep Pen Sandstone (Upper Triassic), to the dinosaur bones in the Morrison Formation (Upper Jurassic), to the petrified logs in the Cheyenne Sandstone (Lower Cretaceous), to the basalt flow (Pliocene) on Black Mesa, the area is a geologists' playground. And like most geologists, I have long been enamored with the area. But my interest was recently rekindled by Reggie Whitten with the Whitten-Newman Foundation of Oklahoma City. The Foundation has purchased 700 acres on the flanks and top of Black Mesa with the goal of establishing a (for lack of a better "word") field "–ology" camp.

One of the goals of the Whitten-Newman Foundation is to interest young people in the field sciences – geology, paleontology, archaeology, biology, ecology, etc., and what better place in Oklahoma to do it than at Black Mesa? Therefore, the foundation is working with scientists and other professionals from throughout Oklahoma to establish a field camp and field science

program designed to interest and educate our young people in the "–ologies."

I would like to thank Barry Weaver, ConocoPhillips School of Geology and Geophysics, for showing me some current papers on the volcanics of northern New Mexico and for having critiqued an early version of this paper.

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Biographical Sketch

Neil Suneson has worked for the Oklahoma Geological Survey since 1986, when he and some colleagues started mapping the frontal belt of the Ouachita Mountains and the southern part of the Arkoma Basin as part of the USGS-sponsored COGEOMAP and later STATEMAP programs. After working in the Ouachitas, he did some reconnaissance mapping in northwestern Oklahoma and more detailed mapping in the Oklahoma City metro area.

Neil Suneson
Oklahoma Geological Survey

When the Survey became part of the Mewbourne College of Earth and Energy at OU, more of Neil's time was devoted to teaching (including the School of Geology's summer field camp outside of Cañon City, Colorado) and advising students on their theses. His interests range from the Late Tertiary geology of the Oklahoma Panhandle to the Early Paleozoic geology of the Broken Bow uplift in southeastern Oklahoma and everything in between. He even likes (some) igneous rocks.

Prior to working for the Survey, Neil was a petroleum development geologist with Chevron USA where he worked on the Lost Hills Oilfield. He also worked with Chevron Resources Company in geothermal exploration throughout the western U.S. All his college degrees are in geology. He received at B.A. from Amherst College in 1972, an M.S. from Arizona State University in 1976, and a Ph.D. from the University of California – Santa Barbara in 1980. His dissertation, largely funded by the U.S. Geological Survey, was based on mapping in the highly extended terrane of west-central Arizona.

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