J. W. Stovall and the Mesozoic of the Cimarron Valley, Oklahoma and New Mexico

Adrian P. Hunt and Spencer G. Lucas

1987, pp. 139-151. https://doi.org/10.56577/FFC-38.139

in:

Northeastern New Mexico, Lucas, S. G.; Hunt, A. P.; [eds.], New Mexico Geological Society 38 th Annual Fall Field Conference Guidebook, 354 p. https://doi.org/10.56577/FFC-38

This page is intentionally left blank to maintain order of facing pages.

J. W. STOVALL AND THE MESOZOIC OF THE CIMARRON VALLEY, OKLAHOMA AND NEW MEXICO

ADRIAN P. HUNT and SPENCER G. LUCAS
Department of Geology, University of New Mexico, Albuquerque, New Mexico 87131

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*. 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.

INTRODUCTION

In the 1949 edition of *American Men of Science*, John Willis Stovall listed his principal research interest as the "geology of the Cimarron River Valley in Oklahoma" (Cattell, 1949, p. 2415). Having been drawn to the area by accident in 1931, Stovall spent a large portion of his career studying the stratigraphy and vertebrate paleontology of the Cimarron Valley. Although he published only six articles on this area, he made a significant contribution to the stratigraphic framework used by later workers and made substantial contributions to the paleontology of the area. The purpose of this paper is to review the contribution of J. Willis Stovall to the geology of the Cimarron Valley and, particularly, to publish a synthesis of his work on the Late Jurassic dinosaurs of the Oklahoma Panhandle.

EARLY LIFE

J. Willis Stovall (Fig. 1) was born in Montague, Texas (now in Oklahoma), on 28 January 1891, the son of a pioneer physician (Branson, 1954). After schooling in Oklahoma and Texas and briefly working in Canada, Stovall joined the Army Air Corps with the entry of the United States into the First World War. After his discharge he held various jobs working for a packing company and a shipping line, traveling widely (Branson, 1954). After putting his younger brother and sister through school, Stovall finally achieved his goal of becoming a pre-medical student. He receive his B.S. in 1923 from Union University (Jackson, Tennessee) and was an instructor there until 1925. Stovall then moved to Vanderbilt University to study geology, and he received an M.S. in 1927 with a thesis on the stratigraphy and paleontology of the Ordovician Cannon Limestone (Branson, 1954). He then worked briefly as an instructor at George Peabody College before going to Yale in 1927, where he spent a year studying vertebrate paleontology under Richard Swann Lull and preparing exhibits at the Peabody Museum of Natural History. After a year at Yale, Stovall was married and decided in 1928 to move to the University of Chicago where he studied under Alfred Sherwood Romer (Branson, 1954). Having completed his course work at Chicago, Stovall had no plans for a Ph.D. dissertation and decided to take a job in 1930 as an instructor in geology and director of the museum at the University of Oklahoma (Cattell, 1949; Branson, 1954). At Oklahoma he was rapidly promoted to assistant professor in 1931, even though he did not receive his Ph.D. until 1938. Stovall became a full professor in 1940 (Cattell, 1949).

INITIAL INTEREST IN THE CIMARRON VALLEY

Stovall initially intended to undertake a Ph.D. dissertation on Plio-Pleistocene mammals from Oklahoma, and he did publish several papers on this subject (e.g., Stovall and Johnston, 1934a, b, 1935; Stovall and Self, 1936; Stovall and McAnulty, 1939; Stovall, 1940). However, Stovall's attention to this project was soon distracted by the discovery of dinosaur bones in Cimarron County, Oklahoma.

Reports of the initial discovery of dinosaur bones in the Morrison Formation in Cimarron County are contradictory (Stovall, 1932, 1938a, b; Ray, 1941; Young, 1986). What is clear is that in 1931 a road-construction crew working 7 mi (11.6 km) east of Kenton drove a grader through a very rich bonebed. Pard Collins and Truman Tucker, who were either cowboys (Ray, 1941) or construction workers (Stovall, 1938a; Young, 1986) or both, collected some large bone fragments and showed them to R. C. Tate in Kenton. The next year Tate contacted Stovall, who "with a scientist's curiosity and elation could not wait for a weekend, but placed an assistant in charge of his classes, jumped

FIGURE 1. Undated portrait of J. Willis Stovall when he was director of the University Museum (later renamed the Stovall Museum of Science and History) and professor of geology at the University of Oklahoma. Photograph courtesy of the Stovall Museum of Science and History, University of Oklahoma.

into his professional flivver, and chugged out to the Panhandle the very next day" (Ray, 1941, p. 37). "Accompanied by L. I. Price, the writer [Stovall] went immediately to the location and in about thirty minutes had uncovered a perfect rib. This rib, seven feet long, was tentatively identified as belonging to *Brontosaurus*" (Stovall, 1938a, p. 37). Further preliminary excavations revealed additional large, well-preserved bones, and Stovall immediately rushed an announcement of his discovery to print (Stovall, 1932).

Stovall quickly realized that the Cimarron Valley was virtually unstudied geologically, and this area became the center of his research. As he put it:

> The discovery of Morrison dinosaurs in Cimarron County, Oklahoma, which is much further east than these forms had previously been reported, aroused the interest of the writer in the Morrison formation in the Cimarron valley. A study of the Morrison led quite naturally to a study of all formations in the area, and an investigation of literature made evident the fact that such a study was not desirable but needed (Stovall, 1938a, p. 1).

Actually a small number of Morrison dinosaur bones had been collected by Stanton (1905) from the Cimarron Valley in New Mexico (Lucas and Hunt, 1985).

MORRISON DINOSAUR QUARRIES

Work Projects Administration

It quickly became apparent that a considerable labor force was required to excavate the quarry east of Kenton. Although students from the University of Oklahoma could and would do some of the labor, Stovall applied to the newly formed Works Progress Administration (WPA) for federal funds to support further work. The WPA was formed earlier that year (1935) by President Roosevelt as a work program for the unemployed victims of the Depression to preserve their skills and self-respect. Stovall took ample advantage of this labor pool and used WPA work crews from 1935 until 1942 (Table 1), both at Kenton and at a variety of other excavations around Oklahoma, as well as in the museum at the university in Norman.

The Works Progress Administration, which changed its name to Work Projects Administration in 1939, supplied large amounts of money to the University of Oklahoma to support Stovall's paleontological projects in Oklahoma. Stovall was not the only paleontologist to receive such support. For example, R. T. Bird, the renowned collector for the American Museum of Natural History, also received WPA support to excavate dinosaur trackways in Texas (Farlow, 1987). However, the University of Oklahoma probably received more money for paleontology from the WPA than did any other group. Quarterly accounts of the project show that from 10 June 1940 to 2 February 1942 the University of Oklahoma received a maximum of $12,465.47 and a minimum of $7,415.82 per quarter. This money was supplied through the University of Oklahoma as sponsor to the state supervisor Ralph B. Shead and finally to the project director J. Willis Stovall. Stovall and Shead had to submit detailed quarterly reports to the WPA, many of which are preserved in the Western History Collection at the University of Oklahoma Library. For its part, the University of Oklahoma supplied $3,000–$3,500 per

TABLE 1. WPA projects that supplied funds for excavation in Cimarron County, Oklahoma.

WPA Projects in Cimarron County	
Date	Project
27 May 1935 - 9 December 1937	165-65-8005, serial number S-158
10 December 1937 - 25 September 1938	465-65-3-146, serial number S-189, work project number 4143
10 September 1938 - 9 June 1940	665-65-3-89, work project number 5353
10 June 1940 - 12 February 1942	65-1-65-2652, work project number 7100

quarter for personnel and equipment expenses. This large sum was used to pay for three or more organizational units. Unit 1, known as the "headquarters unit," was stationed at the University of Oklahoma and usually employed about 27 certified workers and one non-certified supervisor (Stovall and Shead, 1941a). These men prepared fossils, constructed exhibits, undertook educational projects such as the production of movies and provided supervisory and clerical services for the project. In addition to unit 1, two and rarely three other units actually excavated fossil bones. Although the Morrison dinosaurs had been the incentive to ask for WPA funds, there was never more than one unit in the Kenton area. Other units worked very successfully in the Permian, Lower Cretaceous, Pliocene and in rocks of other ages in Oklahoma. The Kenton group was unit 3 and employed as many as five men but, "this rough, isolated region is very sparsely settled and certified workers are scarce. The number of men employed has varied from four during June, to one during the latter half of August" (Stovall and Shead, 1941b, p. 5).

Excavation

There has been much confusion concerning the number of dinosaur quarries excavated in Cimarron County. Stovall published or compiled conflicting maps which showed varying numbers of quarries with different numbering schemes (Stovall, 1938a, pl. 10; Stovall, 1938b, fig. 1; Stovall, 1943, pl. 2; West, 1978). This problem arose because no sequential numbering system was introduced until 1941. Before that time each WPA project had its own numbering scheme; e.g., "the pit numbers show [*sic*] in this report for Unit #3 are, local temporary numbers, applying to Work Project #7100 only. These pits will finally be renumbered in the chronological order of their excavation" (Stovall and Shead, 1940c, p. 1). Only in 1941 did Stovall and Shead consolidate the numbers of the quarries (Stovall and Shead, 1941b). By 1942 they noted that "twelve different sites have been located to date and nine of these have been more or less completely excavated during the past six years" (Stovall and Shead, 1942, p. 5). However, when the information from the three maps is compiled (Stovall, 1938a, pl. 10; Stovall, 1938b, fig. 1; Stovall, 1943, pl. 2; West, 1978) it becomes apparent that there were 17 quarries or "pits" (Fig. 2, Table 2). We have attempted to consolidate the numbering system (Table 2), giving greatest weight to

TABLE 2. Numbering system of Morrison dinosaur quarries utilized in this report compared with that used in earlier reports.

Quarry Number This Report	Quarry Number Stovall (1938a,b)	Quarry Number Stovall (1943)	Quarry Number 1941 Map West (1978)
1	1	1	1
2		2	
3	2	3	2
3A	3		
3B	4		
3C	5		7
3D	6		
3E			3
3F			4
4		4	
5		5	5
6		6	6
7		7	
8		8	8
9			9
10			10
11			11

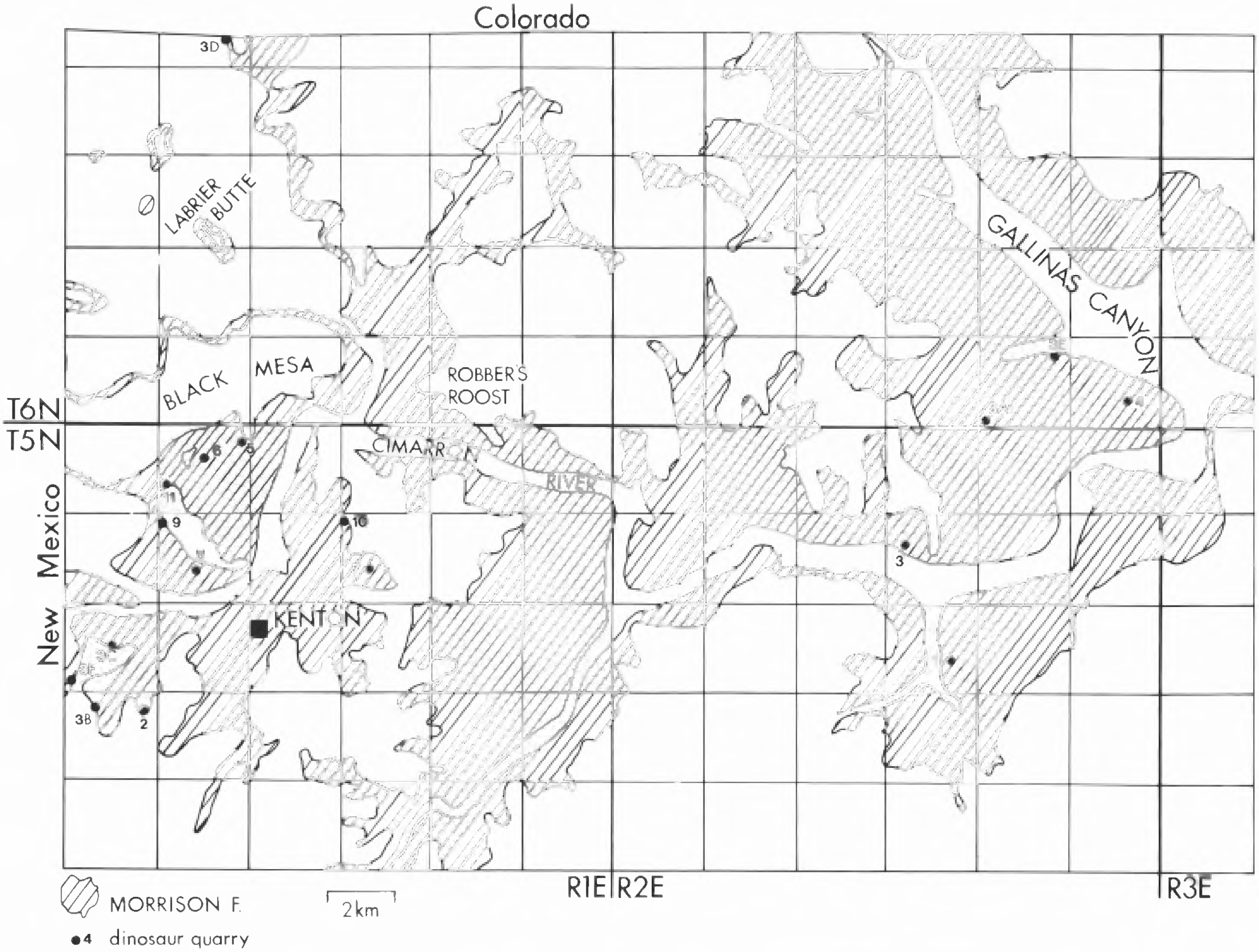


FIGURE 2. Distribution of Morrison dinosaur quarries in Cimarron County, Oklahoma. Numbers assigned to dinosaur quarries are our numbers in Table 2.

the last published map (Stovall, 1943, pl. 2) and, to a lesser extent, to the 1941 map described by West (1978). Six quarries fall between quarry 3 and quarry 4, and are given letter designations (Table 2).

May 1935–September 1938

Virtually all the excavation effort during this period was devoted to quarry 1, the original discovery. Work at this site started on 27 May 1935 and continued until April 1938 when work ceased "owing to the lack of sufficient bones" (Stovall and Shead, 1938, p. 9). The bones were found in a hard gray "shale" (claystone) layer containing many concretions of unknown composition, which occurred "throughout, but there are two distinct bands of layers three inches thick, occurring at about 16 inches below the top of the shale" (Stovall, 1938a, p. 18). The bone-bearing bed was 8.5 ft (2.6 m) thick and 6.75 ft (2 m) below the top of a low knoll. The quarry is still visible on Oklahoma Highway 64, 11.6 km east of Kenton (Lucas et al., 1987[b]). Since at least 1941, a concrete replica of an *Apatosaurus* femur has marked the quarry site (Stovall, 1941, p. 9). The present route of the metalled highway follows that of the road where the bonebed was found during construction. Initial excavations were on the south side of the knoll where the bone-bearing bed cropped out, but it was soon necessary to excavate to the north under the knoll, necessitating the removal of much overburden. By 1938 more than 100 tons of overburden had been removed (Stovall and Shead, 1938). Extensive blasting was carried out both to remove overburden and to fracture the bone-bearing bed (Stovall and Shead, 1938; Stovall, 1938a, p. 4, fig. 2). Five men worked at the quarry under the direction of Crompton R. Tate, who had "several years of experience collecting in the area" (Stovall and Shead, 1938) and who had reported the initial finds to Stovall. The bones in quarry 1 were white and generally excellently preserved. Several small groups of bones were articulated, and others were closely associated (Stovall, 1938a, b). The majority of the recovered bones are sauropod postcrania (Fig. 3) representing several individuals, with rare cranial and tooth fragments also present. Enough material was recovered to mount a right hind limb of *Apatosaurus* which is still on exhibit at the Stovall Museum of Science and History in Norman, Oklahoma (Fig. 10A). A left hind limb of a large dinosaur named *Saurophagus maximus* was much photographed in the quarry (e.g., Ray, 1942, p. 36; Fig. 4), although it apparently was not found articulated. Other dinosaur postcranial material was recovered, and a few isolated teeth were found scattered through the quarry. Some of the postcranial material represented a stegosaur and a camptosaur. Much of the material from quarry 1 appears to have been collected in blocks of rock in plaster jackets (Ray, 1941), although some, such as the *Saurophagus* material, was apparently prepared in situ. No quarry maps are known to have been made for quarry 1. Stovall (1938a) stated that 3,500 bones were recovered from quarry 1, and an unknown number of unidentifiable fragments were also found (Stovall, 1938a; Ray, 1941).

A number of other localities were found during this time period in Cimarron County. Stovall (1938a) mentions that "bones have been

FIGURE 3. One of the early discoveries at quarry 1 was a left femur of *Apatosaurus* being supported by R. B. Shead (left) and J. W. Stovall (right) in Kenton. Photograph courtesy of the Stovall Museum of Science and History, University of Oklahoma.

discovered at six other locations. These locations have been tested but have not proved very productive" (Stovall, 1938a, p. 37). Only five additional localities are indicated on the maps of this period (Stovall, 1938a, pl. 10; 1938b, fig. 1). It is now clear that there were nine additional quarries or prospects (numbers 2, 3, 3A–F, 4 in Table 2). No material from these other sites, with one exception, was described by Stovall (1938a, b), which, together with the above quote, suggests that most of them were not fully excavated. The exception is the *Stegosaurus* femur (Stovall, 1938a, pl. 8, fig. 13; 1938b, fig. 3, no. 13) from "locality #3" (quarry 3A, Table 2, Fig. 2). In the revised quarry numbering scheme adopted by Stovall and Shead (1941b), the quarries from the second phase of excavations start with the number five, indicating that only two of the earlier localities, apart from quarry 1, warranted quarry numbers.

In early 1938 it became obvious that few bones remained in quarry 1, although 152 boxes were recovered between December 1937 and April 1938 (Stovall and Shead, 1938). "Successive scouting trips failed to provide other suitable bone deposits" (Stovall and Shead, 1938, p. 9). Crompton Tate, in late 1937 and 1938 (Tate, 1937, 1938), with termination threatened on 9 May 1938, wrote to archeologist Forrest E. Clements at the University of Oklahoma pleading for support: "I hope so MUCH MUCH MUCH that you can take over this work" (Tate, 1938, p. 1). However, Clements was not able to take over the crew (Clements, 1938), and the men were discharged on 9 May 1938.

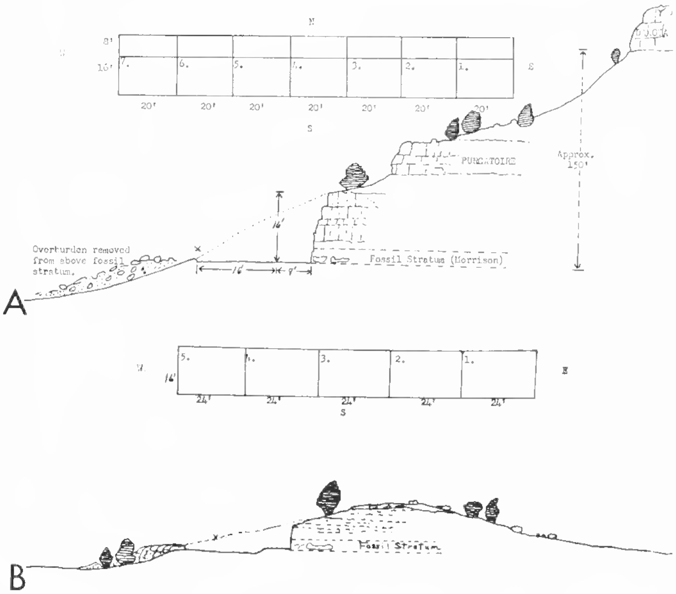
December 1939–February 1942

In December 1939, unit 3 was reconstituted under the leadership of Tate, although "only three suitable men were available" (Stovall and Shead, 1940a, p. 7). The crew was set to work on the newly discovered quarry 5 which lay 3.3 km north of Kenton (Stovall and Brown, 1954, p. 330). This phase of excavation was much better documented than the previous phase, and quarterly reports were written from 10 June 1940 until the end of the program. Detailed maps were drawn at the quarry sites, showing the location of all collected materials in 16×24 ft blocks. These charts were drawn at a scale of 0.75 inches to 1 ft and divided into 1 ft squares. Unfortunately, most of these maps have been lost, although several of the keys for collating the maps have been preserved (Fig. 5). No cleaning or restoration of bones was carried out by this crew (Stovall and Shead, 1940a). Material that was collected was taken to Kenton where it was stored until a truckload was accumulated, and then a vehicle from Norman was sent to collect a load (Stovall and Shead, 1940a).

Quarry 5 is located on the side of an isolated hill south of Black Mesa. The bone-bearing bed is a gray "shale" (claystone) near the base

FIGURE 4. Right hind limb of *Saurophagus maximus* in quarry 1: A, J. W. Stovall measuring the femur. B, Wann Langston, Jr., later professor of geology at the University of Texas at Austin (left), J. W. Stovall (center) and William Price (right) examine the *Saurophagus* material. C, View of entire hind limb of *Saurophagus*. Photographs courtesy of the Stovall Museum of Science and History, University of Oklahoma.

of the hill (Fig. 5A). Excavation of the quarry required the removal of huge quantities of overburden, and within six months Stovall and Shead (1940a) reported the removal of hundreds of cubic yards of rock. By the time quarry 5 was abandoned in mid-1941, the back wall was more than 9 m tall, and the width of the quarry was at least 73 m (Stovall and Shead, 1940b, 1941a, b; Fig. 6). Blasting was not used at this quarry because of damage to bones and problems with safety regulations. Stovall and Shead (1940b) were at pains to point out how safe their operations were and how quarry 5 had been approved by state safety inspectors. A thick sandstone lens overlay the bonebed, but a pervasive fracture pattern allowed workers to use crowbars and hammers to break up this bed (Stovall and Shead, 1940b, 1941a). It is amazing that a crew usually consisting of only five men (Stovall and Shead, 1940b, c, 1941a) could remove so much rock. In a three-month period between December 1940 and March 1941, the quarry was extended by 107 m^2 with the average overburden being 3 m thick (Stovall and Shead, 1941a). Quarry 5 was finally abandoned in early mid-1941 because of a combination of four factors: (1) unit 3 lost its foreman and was reduced to four men; (2) the backwall of the quarry was more than 9 m tall,



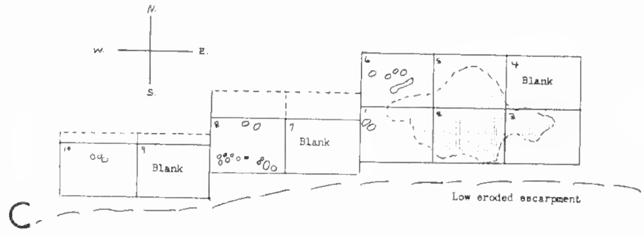


FIGURE 5. Cross sections and plans for quarries 5 and 6: A, Cross section through quarry 5 and key for collating quarry maps (Stovall and Shead, 1940b). The quarry maps are incorrectly labeled and should be 16 ft by 24 ft (Stovall and Shead, 1940c). "X" marks the point of the initial discovery of bones. B, Cross section through quarry 6 and key for collating quarry maps (Stovall and Shead, 1940c). "X" marks the location of the first discovery of bones. C, "Excavation chart" for quarry 6 showing location of individual bones and of areas of bone concentrations (hatchured) within the 16 ft by 24 ft quarry-map areas (Stovall and Shead, 1940c).

FIGURE 6. Overview of quarry 5, probably during "visitation week" of 20–25 May 1940. Photograph courtesy of Stovall Museum of Science and History, University of Oklahoma.

and huge quantities of overburden had to be removed to extend the quarry; (3) the number of bones in the bone-bearing layer was decreasing and (4) bones had been found elsewhere in more accessible units (Stovall and Shead, 1941b).

In quarry 5 "the bones were disarticulated and considerably scattered with little evidence to show that a complete skeleton might be assembled" (Stovall and Shead, 1940c, p. 7). Some of the specimens were in good shape, but the majority were broken and distorted by pressure. "This was especially true of the vertebrae" (Stovall and Shead, 1941b, p. 6). One of the few articulated elements from this quarry was a string of seven sauropod caudal vertebrae (Stovall and Shead, 1940a, p. 4). A large percentage of the bones from this quarry were assigned to *Diplodocus* (Stovall and Shead, 1940a). Some bones were prepared at the quarry (Fig. 7a), but many were taken out in blocks which contained "several small bones and fragments" (Stovall and Shead, 1940b).

Quarry 6 was excavated in a knoll a few hundred m from quarry 5. The slope of the face of the knoll was less than the slope at quarry 5, and hence excavation did not require the removal of so much overburden (Fig. 5b). The maximum depth of bones at quarry 6 was 1.8 m (Stovall and Shead, 1940c), and matrix was softer than at quarry 5 (Stovall and Shead, 1940b). This quarry was excavated from mid-1940 to early 1941, during which time "some of our best specimens" were collected (Stovall and Shead, 1940c, p. 5). Unfortunately, the bone occurrences were very localized (Fig. 5c). Prize finds from this quarry included a 1.8-m-long *Apatosaurus* femur and a 1.4-m-long scapula (Stovall and Shead, 1940c). Apparently most material was sauropod postcrania assignable to *Apatosaurus* (Fig. 7b).

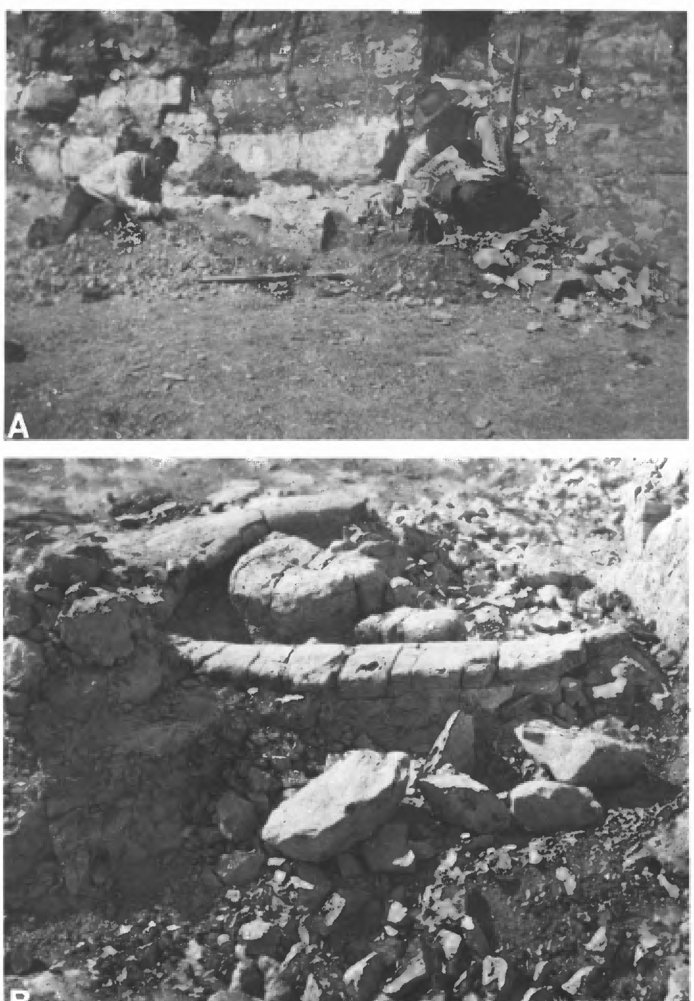


FIGURE 7. Excavation of bones from quarries 5 and 6: A, Two workers in quarry 5 (photograph Q13-8-J). B, *Apatosaurus* vertebra and ribs uncovered in quarry 6. Photographs courtesy of Stovall Museum of Science and History, University of Oklahoma.

It is unclear what excavation "quarry 7" referred to, although it was probably the locality 2.5 km west of Kenton (quarry 3C, Fig. 2, Table 2) mentioned by Stovall and Shead (1940c). This locality consisted of two bones in a "shale" with very little overburden (Stovall and Shead, 1940c). Apparently no bones were collected from quarry 7 (Stovall and Shead, 1940c).

Quarry 8 was located on the side of a small hill 2.5 km northwest of Kenton. As at the other quarries in Cimarron County, the bones were found in a gray "shale." However, the type of material recovered from quarry 8 was very different. Quarry 8 was dominated by crocodilian remains that included a staggering 1,142 teeth in addition to at least 300 other bones including strings of 2–3 articulated vertebrae and two beautifully preserved skulls (Stovall and Shead, 1941b, c, d, 1942; Mook, 1964). This quarry also produced a number of turtle carapace and plastron fragments and limb bones and rare fish vertebrae and scales. Quarry 8 was discovered in mid-1941 when the number of men available for unit 3 was declining and fluctuating between one and four (Stovall and Shead, 1941b, c, d, 1942). Because of the small size of the fossils and small volume of overburden, this quarry received most attention during late 1941 and early 1942. Eventually the backwall of this quarry reached 3 m (Stovall and Shead, 1941d).

Quarry 9 was 150 m north of quarry 8 on the steep side of a small butte (Stovall and Shead, 1941b). Well-preserved *Apatosaurus* bones occurred in a red clay, the only occurrence of bones in a matrix other than gray "shale." It appears that quarry 9 was only worked briefly in mid-1941 because of the labor shortage (Stovall and Shead, 1941b, d).

Quarry 10 contained a number of limb bones exposed on a flat surface northeast of Kenton (Stovall and Shead, 1941b). Because of a shortage of personnel, there was no intention to excavate this site, but in the winter of 1941–1942 some bones were fully exposed. A small excavation produced a femur, a tibia and a fibula and revealed a shallow bonebed that was never further excavated (Stovall and Shead, 1942).

A large femur exposed several hundred m west of quarry 5 was designated quarry 11 (Stovall and Shead, 1941b). This bone apparently was never collected, even though there was little overburden, because WPA funding ceased in early 1942.

Apart from the body fossils in Cimarron County, Stovall also found an important dinosaur-trackway locality in the bed of the Cimarron River east of Kenton (Stovall and Shead, 1940b; Stovall, 1943). Two sets of sauropod trackways, the longest 12 m long, were excavated between 10 October and 9 November 1940 (Stovall and Shead, 1940c). The trackways were split into 55 blocks, each 10 to 15 cm thick, placed on boards and covered with burlap and plaster. Originally these tracks were to have been put on display at the University of Oklahoma (Stovall and Shead, 1940c). Langston (1974, p. 97) noted that a "short sauropod trackway was removed from the bed of the Cimarron River . . . and installed on the campus of the University of Oklahoma but it apparently was subsequently destroyed by vandals." However, Stovall and Shead (1941b, p. 15) note that between 9 May and 5 June unit 3 "prepared dinosaur tracks for Oklahoma Panhandle A and M College," which probably refers to one of the sauropod trackways. Therefore, it is likely that at least some of the sauropod tracks were saved.

The trackways occurred on a mud-cracked surface. Stovall and Shead (1940b) thought that these were the first sauropod tracks to be found in North America, but two years earlier R. T. Bird had discovered sauropod trackways in the Lower Cretaceous of the Paluxy River valley in Texas (Bird, 1939, 1985; Farlow, 1987). On 23 March 1942, WPA project 65-1-65-2652 was suspended indefinitely because of the national emergency, and all excavation of Morrison bones from Cimarron County ceased (Stovall and Shead, 1942).

Stratigraphic relationships of the quarries

There have always been substantial problems in correlating the Morrison Formation east of the Front Range and Sangre de Cristo Mountains with the Morrison Formation on the Colorado Plateau. These difficulties arise partly from paucity of work in the High Plains, but mainly from the lack of laterally continuous facies.

Several lines of evidence suggest that the Morrison Formation exposed in Cimarron County is equivalent to the complete Morrison section exposed farther west in New Mexico and Colorado. At the base of the sequence the "brown-silt member" (=Ralston Creek Formation=Bell Ranch=Wanakah Formation) of the Morrison is directly correlatable into New Mexico and Colorado by lithology and position below the "agate-bed" (Stovall, 1938a; Cooley, 1955; Baldwin and Muehlberger, 1959; West, 1978; Abbott, 1979). The upper Morrison in the Cimarron Valley is similar to the upper Morrison in eastern New Mexico in containing abundant volcanic ash (Mankin, 1958; Abbott, 1979; Hunt, 1986b) and a kaolinite/mixed-layer montmorillonite-illite clay association (Abbott, 1979).

Stovall (1938a, b, 1943) believed that most of his dinosaur quarries occurred at similar stratigraphic horizons. He measured a number of stratigraphic sections in the Morrison Formation, but was unable to identify many "marker beds" to correlate between sections. Hence, he wrote of a locality near the Colorado border, "the bone layer is stratigraphically similar to all of the others and, like them, cannot be placed exactly in the section" (Stovall, 1938b, p. 595). In 1943 he was more vague and wrote that one quarry "and perhaps others" were stratigraphically equivalent (Stovall, 1943, p. 63).

West (1978) recognized a lower fluvial, a middle lacustrine and an upper fluvial unit in the Morrison of Cimarron County. Utilizing a limestone-sandstone couplet within the lacustrine interval, West (1978) was able to correlate lithostratigraphically a number of Stovall's quarries. The quarries range from 7 m (quarry 5) to as much as 76 m (quarry 1) above the couplet (West, 1978, p. 45; Fig. 8). The more western quarries 5, 6, 8 and 3D (Table 2) are at essentially the same stratigraphic level, whereas the more eastern quarries such as 1 and 4 are stratigraphically higher, but also occur within a narrow stratigraphic interval (West, 1978).

Taphonomy

Without the original quarry maps and field notes of the excavations, no detailed analysis can be made of the taphonomy of the quarries. However, some conclusions can be drawn from the available evidence.

The vast majority of bones was found in gray "shale." This lithologic association was so pervasive that Stovall and Shead (1941b) suspected that *Apatosaurus* bones found in a red clay must have slumped from a higher bed of gray "shale." The bones are usually very light gray (N8) or white (N9), with the matrix being light bluish gray (5 B 7/1). The color of the bones distinguishes them from material from all other Morrison quarries (J. McIntosh, written commun., 1985). A few bones were found in a sandstone near quarry 8 (Stovall and Shead, 1941d), and West (1978) reported finding bone in sandstone. The majority of the large quarries (quarries 1, 5, 6 and 10) consisted of bonebeds or laterally continuous associations of bones with a sub-tabular geometry. Other quarries only contained two or three bones (?quarry 7, quarry 11). Quarries 1, 5, 8 and 10(?) contained a few articulated elements, usually vertebrae, and, in addition, quarry 1 produced associated partial skeletons (*Saurophagus, Apatosaurus*). All material from other quarries and the majority of the material from quarries 1, 5 and 8 consisted of disarticulated skeletal elements. Microvertebrate material (teeth, and bones of animals with body weights <25 kg) was rare or absent in all quarries except quarry 8. Quarry 8 is the only important Morrison locality to contain entirely the remains of small, non-dinosaurian animals. Bone preservation was apparently consistently good only in quarry 1 and the briefly worked quarry 9. Quarry 5 contained some well-preserved material, but most of it was fragmented (Stovall and Shead, 1941b). Quarry 6 also produced good material. It is implied in the WPA reports that preservation in the other quarries was less good.

Large dinosaur quarries have been excavated in fine-grained rocks in several places in the Morrison. These quarries contain either complete articulated specimens (Willow Springs) or accumulations of associated, but not articulated, skeletons (Cleveland-Lloyd). Bone is generally excellently preserved in these quarries. Quarry 1 is similar in some ways to the Cleveland-Lloyd quarry (Hunt, 1986a), but at Kenton associated skeletons are not complete and carnosaur remains are in the minority. Quarry 5 differs from the Cleveland-Lloyd type of deposit in that the bones are unevenly distributed and most are poorly preserved. The fact that material is disarticulated and damaged suggests scavenging, weathering and/or hydraulic transport. The fine-grained nature of the enclosing sediments does not preclude movement by water (cf. Cleveland-Lloyd: Hunt, 1986a). The lack of recognition of carnivore damage to bones suggests that bone damage and dispersal were caused by water. Stovall (1938b, p. 595) speculated on the taphonomy of quarry 1, noting that:

> The unbroken condition of the bones indicates that no marked disturbances have affected them. The fact that they are disarticulated, and in the main, undistorted indicates that they were disturbed only by streams of water and possibly by flesh- or carrion-feeding animals. The large size of many of the bones would require a stream of considerable force to move them. Their perfect condition, their degree of concentration, and the fact that an occasional two or three bones are normally articulated suggest that they were moved only a few feet at the most.

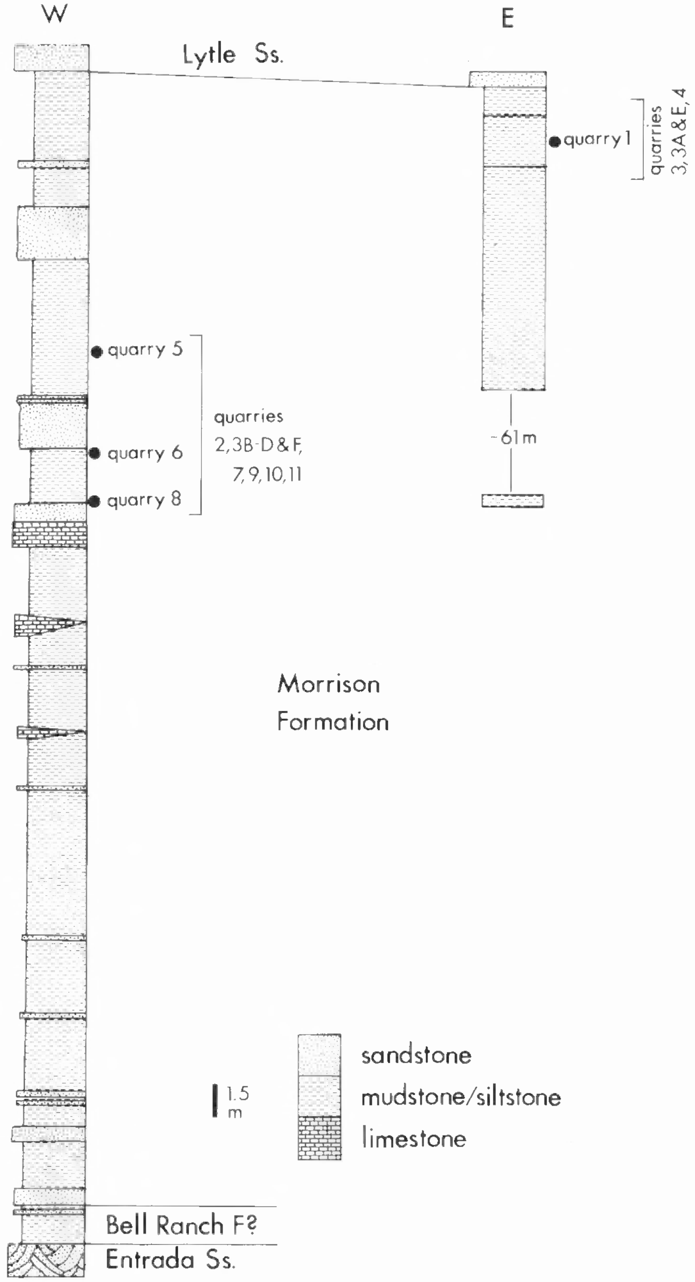


FIGURE 8. Stratigraphic distribution of selected dinosaur quarries in the Morrison Formation of Cimarron County, Oklahoma (adapted from Stovall [1938a, b] and West [1978]).

A tentative scenario for the formation of the bone deposits, based on the sparse evidence presented above, is as follows. Dinosaur carcasses lying on floodplain surfaces were subject to aerobic decay. Disarticulated elements were then moved by flood events into hollows or depressions on the floodplain where they were buried by flood-derived muds.

The origin of quarry 8 was obviously unique. This quarry is dominated by material derived from within or near bodies of water (crocodile, turtle, fish). The vast number of teeth, possibly of the same taxon, in one location suggests both hydraulic sorting and perhaps a catastrophic death (desiccation of water source?). This material may have been moved from a dried lake or stream bed by a later flood.

Dinosaur remains are rare in the Morrison of northeastern New Mexico (Hunt and Lucas, 1984; Lucas and Hunt, 1985) and, therefore, it is surprising that so much material was found in Cimarron County. Although part of the explanation lies in the amount of work carried out by the WPA crew, it is likely that the very thick Morrison of Cimarron County (Abbott, 1979, fig. 6) is the result of exceptional depositional rates which would favor bone preservation. The quarries in both eastern and western Cimarron County all are in identical lithologies and exhibit similar taphonomic characteristics. In addition, all quarries are near the top of the Morrison Formation, and the quarries in the eastern and western areas both are located within short stratigraphic intervals. However, the eastern quarries lie at the top of a much thicker Morrison section than the western quarries. The thinning of the Morrison has been interpreted as due to an angular unconformity (Stovall, 1938a, b, 1943), but the taphonomic evidence suggests that the thickening trend may be depositional. It is extremely unlikely that identical taphonomic conditions would have been repeated in both areas such that all localities would ultimately lie near the top of the Morrison after a period of uplift and erosion.

How many bones?

Although the collection of fossil vertebrates at the Stovall Museum of Science and History is not well organized, it is clear that many estimates of the number of bones collected from Kenton are greatly in error. All reports agree that the number of bones collected from quarry 1, and a small number collected from other quarries until 1938, totaled around 3,500 (Stovall, 1937, 1938a; Ray, 1941; Young, 1986). Examination of a random sample of Morrison bones preserved at the Stovall Museum suggests that a large proportion of them were collected prior to 1938, as indicated by their field numbers.

In contrast, there is much disagreement about the number of bones that were collected after 1938. Branson (1954) wrote that Stovall estimated the total number of bones collected from Kenton at 15,000. Stovall (1943, p. 70) estimated that about "6,000 bones have been excavated and prepared." Utilizing these figures, it appears that from 3,500 to 11,500 bones may have been collected after 1938. These numbers can be checked against the WPA reports which indicate that 425 bones were collected from Kenton from September 1938 to June 1940 (Stovall and Shead, 1940a). From June 1940 to February 1942, unit 3 at Kenton collected 589 "dinosaur bone blocks," 393 alligator and turtle bones and 1,142 crocodilian teeth, having removed a staggering 1,749.5 cubic yards of overburden (Stovall and Shead, 1942, p. 6). From this material, unit 1 at Norman prepared 1,766 large dinosaur bones, 7,490 small dinosaur bones, 2 crocodilian skulls, 450 crocodilian bones and bone fragments and 576 crocodilian teeth (Stovall and Shead, 1942, p. 7). Thus, the WPA reports suggest that a minimum of 9,681 dinosaur bones were collected from 1938 to 1942 in addition to about 450 crocodilian bones and 576 crocodilian teeth. Other material, including some 600 crocodilian teeth, must have been collected but not prepared at the time of cessation of the WPA project. Several considerations suggest that the WPA reports may have inflated the actual bone counts, most probably by including unidentifiable bone scraps among their lists of bones. First, there was an obvious incentive to show that the largest numbers of boxes were being processed at Norman, as this was the raison d'être of unit 1. Second, if the WPA reports are to be believed, more than 9,000 bones were collected between 1940 and 1942, which added at most two (maybe zero) new dinosaur genera to the faunal list of the area (Stovall, 1943). Third, the WPA numbers indicate that the excavation rate at Kenton rose from 47.3 dinosaur bones per month (September 1938–June 1940) to 462.8 bones per month, not counting quarry 8 (June 1940–February 1942), even though the number of men in unit 3 decreased during this time interval. Although the above evidence could suggest that the later quarries were rich in small dinosaur bones, the WPA field reports from Kenton suggest that the majority of the bones from the later quarries were poorly preserved bones of large dinosaurs (Stovall and Shead, 1941b). In addition, the diagrams from quarries 5 and 6 suggest that these quarries contained mainly large bones and bone fragments (Stovall and Shead, 1940c, pp. 7 and 8).

In summary, the apparent abundance of bones from quarry 1 together with the evidence from the WPA reports as to later excavations suggest

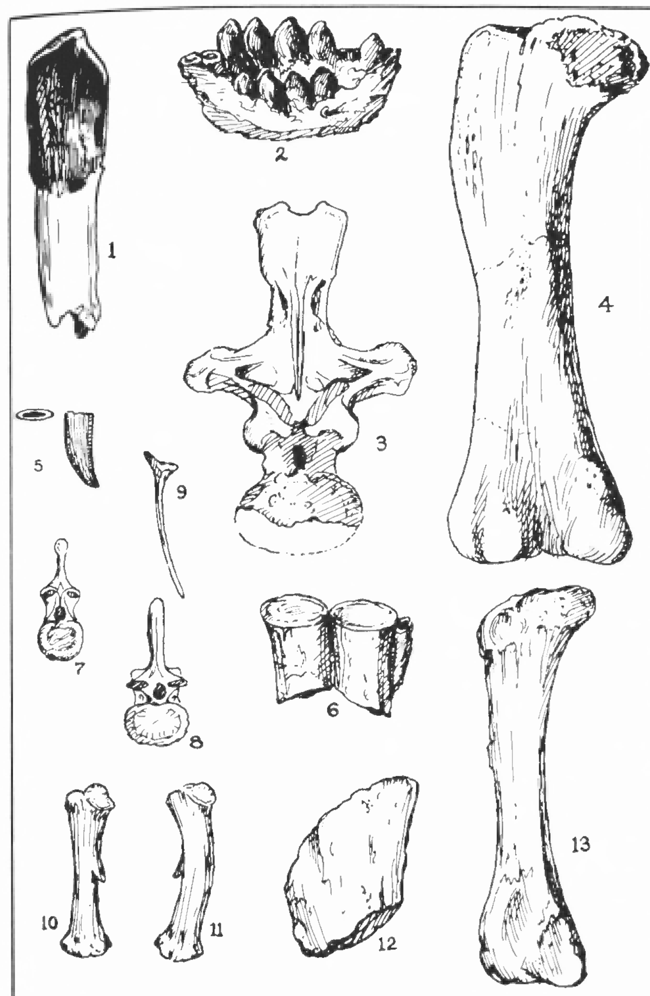


FIGURE 9. Stovall's (1938b) figure 3 with revised taxonomy in brackets: "(1) An individual tooth of *Brontosaurus excelsus* Marsh [*Camarasaurus*] length 13 cm. (2) A fragment of the right mandible of *B. excelsus* Marsh [*Camarasaurus*], length 35 cm, depth 23 cm. (3) A dorsal vertebra of *B. excelsus* Marsh [*Camarasaurus*], greatest length 130 cm. (4) The left femur of *B. excelsus* Marsh [*Camarasaurus*], length 178 cm. (5) A fragment of tooth of *Ceratosaurus*? Marsh [indeterminate], length 5.1 cm. (6) A fragment of the fused metatarsals of *Ceratosaurus*? Marsh [*Ceratosaurus*], size of fragment 10.2×15.3 cm. (7) A small cervical vertebra of *Ceratosaurus*? Marsh [*Ceratosaurus*?], length 8.9 cm. (8) A dorsal vertebra of *Ceratosaurus*? Marsh [*Ceratosaurus*?], length 12.4 cm. (9) A rib of *Ceratosaurus*? Marsh [*Ceratosaurus*?], length 32.5 cm. (10) Front view of the left femur of *Camptosaurus*? Marsh [*Camptosaurus*], length 69 cm. (11) A side view of the left femur of *Camptosaurus*? Marsh [*Camptosaurus*], length 69 cm. (12) A dorsal plate [caudal spine] of *Stegosaurus* Marsh [*Stegosaurus*], greatest length 38 cm. (13) A femur of *Stegosaurus* Marsh [*Stegosaurus*], length 113.5 cm."

that Stovall's (1943) estimate of 6,000 bones is probably the most accurate estimate of the number of bones, identifiable at least as to element if not taxon, collected from near Kenton. Circumstantial evidence, including the reports of the poor quality of material collected after mid-1940, suggests that the actual number of bones might have been considerably less than 6,000.

Disposition of the collection

The majority of the Morrison vertebrate remains from Cimarron County are currently housed in the Stovall Museum of Science and History at the University of Oklahoma, Norman. This important collection is in a state of considerable disarray (J. McIntosh, written commun., 1985; W. Langston, written commun., 1985; J. Zidek, oral commun., 1986, 1987). Since Stovall's death in 1953 the collection has been moved at least 10 times, and virtually all accompanying documentation has been lost (J. Zidek, oral commun., 1987). There are none of the original data cards, field-note books or quarry maps at Norman. Many records were lost when drawers slid out of a wooden filing cabinet transported on a flatbed pickup during one of the many moves of the collection and during one of Oklahoma's many wind storms (J. Zidek, oral commun., 1987).

Most specimens only carry a field identification number which is usually in the form of K-number-number. West (1978) deduced that a field number such as K-184-1-35 refers to Kenton (K)- quarry 1 (1), specimen 841 (841), 1935 (35). In some cases the initials of a member of unit 3 may substitute for the K (West, 1975). However, it is probable that there is no indication of the quarry number in the field number, for K-953-35 would otherwise indicate a ninth quarry being excavated in 1935. In the case of the *"Goniophilis stovalli"* skull, the field number does include the quarry number, but in this case it is underlined, e.g., K8 219-41 (West, 1975). Presumably the bones were numbered sequentially each year and keyed to a ledger or card file that is now lost. A few specimens have field designations that include letters, e.g., K-px#9. Some specimens also have a catalogue number, but there is no file containing these numbers. A small number of dinosaur and crocodilian specimens as well as the only five surviving quarry maps, for quarry 8, are at the Vertebrate Paleontology Building, Balcones Research Center, University of Texas, Austin (West, 1978; W. Langston, written commun., 1986; J. Zidek, oral commun., 1986).

Taxonomic notes on specimens

We have made no systematic study of the dinosaur material at the Stovall Museum of Science and History. However, certain taxonomic judgments can be based on published descriptions and illustrations.

Dinosaur material from near Kenton was described by Stovall (1938a, b) and illustrated by Stovall (1938a, pl. 8; 1938b, fig. 3) and Stovall and Shead (1940a, pp. 26, 47). Stovall used two different versions of a plate of drawings of bones from Kenton (Stovall, 1938a, pl. 8; 1938b, fig. 3). The earlier figure (Stovall, 1938a, pl. 8) was obviously drawn by a less skilled artist than the later version (Stovall, 1938b, fig. 3). However, some differences between the figures appear to be significant, such as the loss of half the centrum in the *Apatosaurus* vertebra (no. 3 in both figures). The later figure (Stovall, 1938b, fig. 3; Fig. 9) appears more anatomically correct than the earlier version (of the *Stegosaurus* femur), and we take it to be a more accurate representation of the material.

Stovall believed that much of the material from quarry 1 was assignable to *Apatosaurus* (=*Brontosaurus*) (Fig. 9, nos. 3, 4). Most of the material from this quarry does belong to *Apatosaurus*, including a dorsal vertebra (Fig. 10F), an articulated right hind leg (Fig. 10A) and a cervical vertebra (Fig. 10D), which are comparable with material assigned to *Apatosaurus* (Ostrom and McIntosh, 1966, pls. 14, 21, 71). Stovall's illustration (Stovall, 1938a, pl. 8, fig. 4; 1938b, fig. 3, no. 4) is presumably a poor representation of the latter femur (Fig. 9).

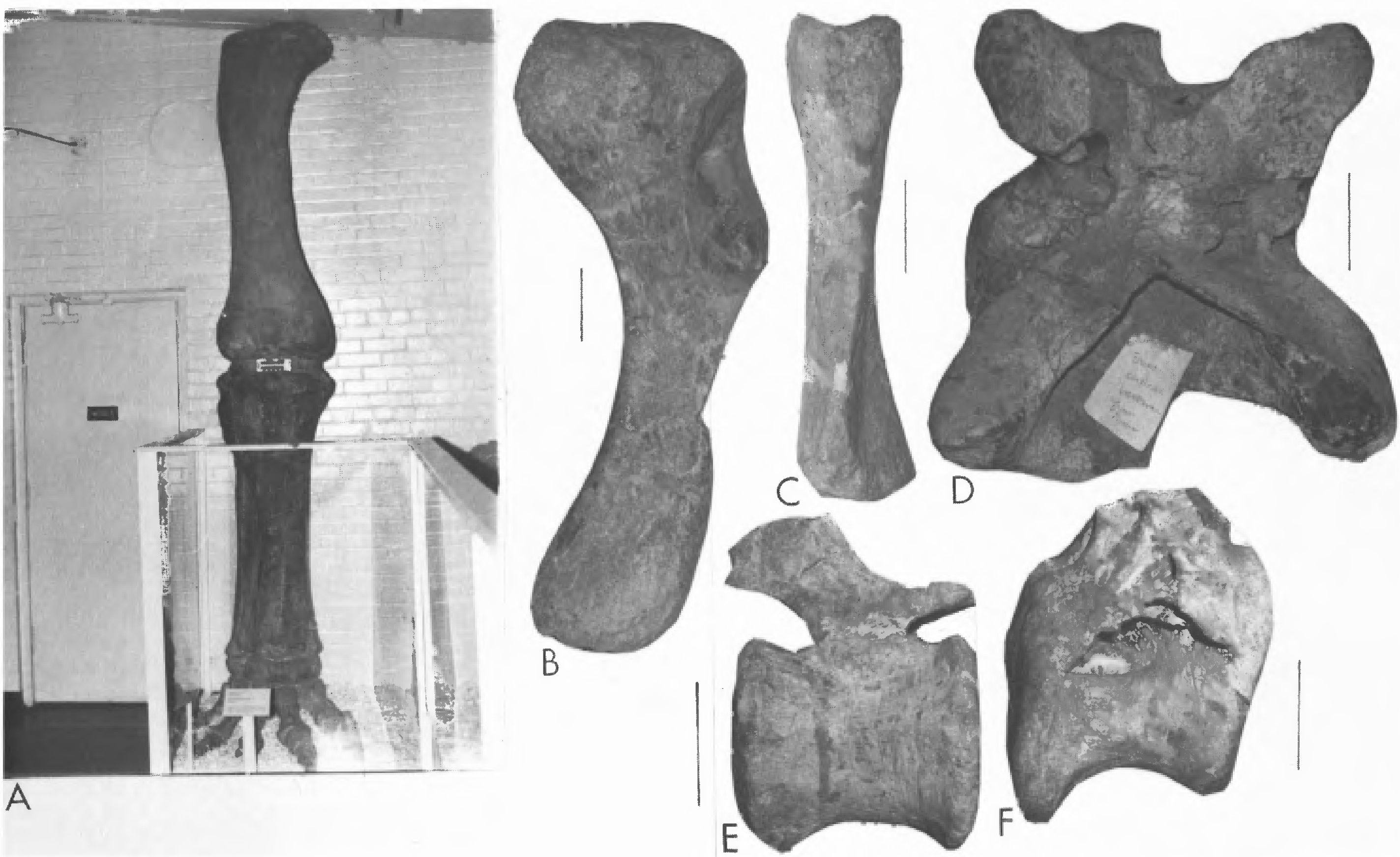


FIGURE 10. Selected dinosaur material from the Kenton quarries preserved in the Stovall Museum of Science and History: A, Left hind limb of *Apatosaurus*. B, Left pubis of *Apatosaurus*, K-17746-36. C, Left radius of sauropod, K-1841-35. D, Cervical vertebra of *Apatosaurus*, K-px#9. E, Mid-caudal vertebra of *Camarasaurus*, K-x-36. F, Centrum of mid-dorsal vertebra of *Apatosaurus*, K-86-35 9+6. Scale bars are 10 cm long.

A left femur in the collection of the Stovall Museum of Science and History also represents *Apatosaurus* (Fig. 10B).

The dental material assigned to *Apatosaurus* included an individual tooth and a fragmentary right dentary (Stovall, 1938b, fig. 3, nos. 1, 2; Fig. 9, nos. 1, 2). However, it is now realized that cranial material once assigned to *Apatosaurus* actually belongs to *Camarasaurus* (Ostrom and McIntosh, 1966; McIntosh and Berman, 1978). Thus, the tooth and dentary fragment should be assigned to *Camarasaurus*. The isolated tooth is virtually identical to isolated teeth of *Camarasaurus grandis* from Wyoming (Ostrom and McIntosh, 1966, pl. 7, nos. 3, 8), and the dentary is comparable with material of *Camarasaurus* (Ostrom and McIntosh, 1966, pl. 6, no. 4). A caudal vertebra is also assignable to *Camarasaurus* (Fig. 10E). Stovall did not recognize *Camarasaurus* from any of the quarries.

Two other sauropod taxa were reported from Kenton, *Diplodocus* from quarry 5 and *Atlantosaurus* from an indeterminate quarry (Stovall and Shead, 1940a; Stovall, 1943). Unfortunately, no material of either of these taxa was illustrated. Caudal vertebrae from quarry 5 (Stovall and Shead, 1940a) are very different from those of *Diplodocus* (Hatcher, 1901, pl. 9). Stovall (1943) mentioned a new genus of small sauropod from quarry 1, but this specimen was never described and cannot now be located (J. McIntosh, written commun., 1985).

Carnosaur material from Kenton was assigned to three taxa: *Allosaurus* (=*Antrodemus*), *Ceratosaurus*? and *Saurophagus maximus* (Stovall, 1943). Identification of *Ceratosaurus* is best supported by fragments of fused metatarsals (Stovall, 1938b, fig. 3, no. 6; Fig. 9, no. 6). Unfortunately, these elements are so poorly illustrated that it is impossible to discern their identity. If these elements are metatarsals and are fused, then this is strong evidence for the presence of *Ceratosaurus* (Gilmore, 1920, pls. 24–25), although the type of this genus may have pathological metatarsals (J. Madsen, oral commun., 1985). Vertebrae of *Ceratosaurus* are poorly illustrated (Stovall, 1938b, fig. 3, nos. 7, 8; Fig. 9, nos. 7, 8), but the cervical vertebra is certainly closer to *Ceratosaurus* (Gilmore, 1920, pl. 20) than *Allosaurus* (Madsen, 1976, pls. 12–15). The isolated tooth assigned to *Ceratosaurus* (Stovall, 1938b, fig. 3, no. 5; Fig. 9, no. 5) is not identifiable as illustrated, although isolated teeth of *Ceratosaurus* are distinguishable from those of *Allosaurus* (J. Madsen, oral commun., 1985). Similarly, the rib assigned to ?*Ceratosaurus* (Stovall, 1938b, fig. 3, no. 9; Fig. 9, no. 9) appears undiagnostic.

Saurophagus maximus was named on material from quarry 1, including most of a right hind limb (Fig. 4) and a manus claw (Ray, 1941). This taxon has been ignored by most workers on the Morrison Formation (e.g., Dodson et al., 1980), apparently because it was not believed to have been named properly. However, Ray's (1941) paper on *Saurophagus* meets all the criteria of availability, and more, of the *International Code of Zoological Nomenclature* (International Commission on Zoological Nomenclature, 1985) in that the taxon has a properly constructed generic and trivial name, a holotype, a diagnosis, and that the report was published in a widely distributed journal. The diagnosis of *S. maximus* read as follows: Diagnosis – "Larger in total body size, size of hands and arms and has a less specialized arrangement of metatarsals than smaller carnivores of the Jurassic. Compared to *Tyrannosaurus*, *Saurophagus* is more massive in proportion to its height and has arms more than twice as long" (Ray, 1941, p. 38). Its holotype is a right tibia in the Stovall Museum of Science and History ("bone no. 4666"). Its type locality and horizon is quarry 1, Cimarron County, Oklahoma (Stovall, 1938b, fig. 1, no. 1), upper Morrison Formation.

We have not examined the *Saurophagus* material, most of which is currently housed at the Balcones Research Center, University of Texas at Austin, but we suspect that it may represent a large individual of *Allosaurus*. However, this species should no longer be ignored. It should be properly studied and its taxonomic status resolved.

No material of *Allosaurus* was ever illustrated and thus we cannot evaluate the validity of this identification. Similarly, material of "small unidentified carnivorous dinosaurs" and "small carnivore teeth" (Stovall, 1943, p. 70) were never illustrated.

Stegosaurus material from Kenton included a dorsal plate from quarry 1 (Stovall, 1938b, fig. 3, no. 12; Fig. 9, no. 12) and a right? femur from quarry 3A (Stovall, 1938b, fig. 3, no. 13; Fig. 9, no. 13). The dorsal plate is essentially unrecognizable from the illustration. If it does represent *Stegosaurus*, it is probably a proximal fragment of a caudal spine (Ostrom and McIntosh, 1966, pl. 57). The femur compares favorably with femora assigned to *Stegosaurus* (Ostrom and McIntosh, 1966, pls. 46, 47).

The last dinosaur taxon recognized by Stovall from Kenton was *Camptosaurus*? (Stovall, 1938a, b), identified from a left femur (Stovall, 1938b, fig. 3, nos. 10, 11; Fig. 9, nos. 10, 11). The poor illustration indicates a specimen comparable in size and morphology to the femur of *Camptosaurus* illustrated by Gilmore (1909, fig. 33).

Other vertebrate material from the Kenton quarries was identified as small fish, turtle and crocodile. One of the two crocodilian skulls collected from quarry 8 was described by Mook (1964) as a new species, *Goniopholis stovalli* (Fig. 11). Since goniopholid taxonomy is in disarray and *G. stovalli* resembles *G. felix* and *G. gilmorei* "in having the supratemporal fenestrae separated from the posterior border of the cranial table by a considerable space" (Mook, 1964, p. 286), the specimen from Kenton should be re-examined. Langston (in Mateer, 1981) suggested that all *Goniopholis* specimens from North America may be assignable to *Eutretaurasuchus*.

In summary, the dinosaurs from the Kenton quarries are *Apatosaurus*, *Camarasaurus*, *Atlantosaurus*, *Diplodocus*, *Allosaurus*, *Ceratosaurus*, *Saurophagus maximus*, *Stegosaurus* and *Camptosaurus* and unidentified small carnivorous forms. Non-dinosaur vertebrates are *Goniopholis stovalli*, a fish and a turtle. *Apatosaurus*, *Diplodocus*, *Goniopholis*, the fish and the turtle are known from the stratigraphically lower western quarries, whereas *Apatosaurus*, *Camarasaurus*, *Stegosaurus*, *Saurophagus*, *Ceratosaurus* and *Camptosaurus* were recovered from the stratigraphically higher, eastern quarries. The stratigraphic distributions of other taxa are not known.

OTHER CONTRIBUTIONS TO THE STRATIGRAPHY AND PALEONTOLOGY OF THE CIMARRON VALLEY

Besides his work on the Morrison Formation, Stovall made important contributions to the stratigraphy and paleontology of the Triassic and Cretaceous strata in the Cimarron Valley. Stovall's (1943; also see Schoff and Stovall, 1943) stratigraphy of Mesozoic strata exposed in the Oklahoma portion of the Cimarron Valley much improved on the earlier work of Rothrock (1925), who previously studied the area in detail (Fig. 12). While Stovall was studying the Mesozoic stratigraphy of the area, his field assistant, Donald E. Savage, later professor of paleontology at the University of California, Berkeley, found "an almost

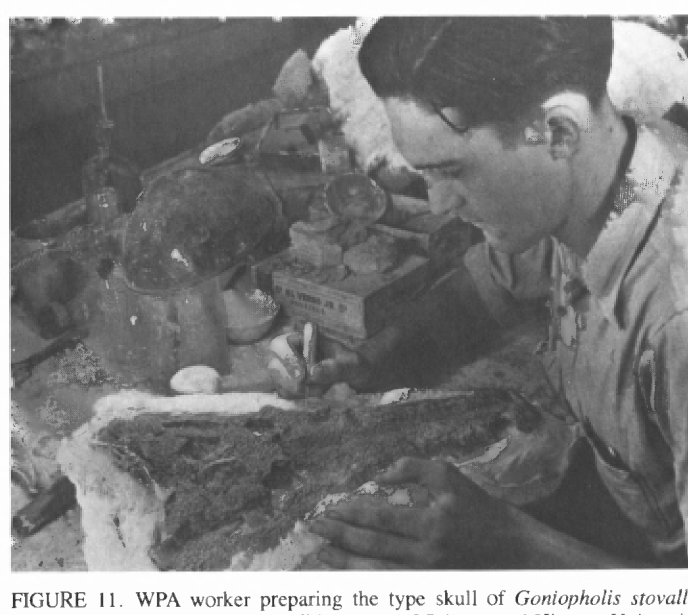


FIGURE 11. WPA worker preparing the type skull of *Goniopholis stovalli*. Photograph courtesy of the Stovall Museum of Science and History, University of Oklahoma.

ROTHROCK	STOVALL		1987		AGE	
not recognized	Graneros-Greenhorn beds	Colorado Gr.	Bridge Creek M.	Greenhorn F.	CENOMANIAN	CRETACEOUS
			Hartland M.			
			Lincoln M.			
			upper m.	Graneros Shale		
			Thatcher M.			
			lower m.			
Dakota Formation	upper sandstone	Dakota Ss.	Romeroville S	Dakota Group	ALBIAN	
	middle shale		Pajarito F.			
	lower sandstone		Mesa Rica S.			
Purgatoire Formation	Kiowa Sh. M.	Purgatoire F.	Glencairn F			
	Cheyenne S. M.		Lytle S.			
	Morrison Formation		Morrison F		Tth Kim Oxf	JURASSIC
			Bell Ranch F. / EXETER M.		Clv	
	Exeter S.		Entrada S.			
	Sheep Pen S.	Dockum Group	Sheep Pen S.		NORIAN	TRIASSIC
Morrison F.	Sloan Canyon Formation		Sloan Canyon F			
Red Beds			Travesser F			
			COBERT CANYON S. BED			
			Baldy Hill F.		Crn	

FIGURE 12. Stratigraphic nomenclature of Mesozoic strata in the Cimarron Valley, Oklahoma, of Rothrock (1925), Stovall (1943) and that currently in use (from Kauffman et al. [1977], Kues and Lucas [1987] and Lucas et al. [1987a, b]).

complete phytosaur skull and associated bones of the post-cranial region" (Stovall, 1938a, p. 7). In 1939 the two of them described this material as *Machaeroprosopus* [=*Rutiodon*] sp. (Stovall and Savage, 1939). The material consisted of a nearly complete skull, partial lower jaws and numerous dermal scutes. The skull is further illustrated by Stovall and Shead (1938, fig. 18).

The skull was collected from Sloan Creek in Union County, New Mexico, north of its crossing by NM Highway 325. Using locality information and a measured section at the quarry (Stovall and Shead, 1939, table 2), we were able to relocate the site (Lucas et al., 1987[a]). No excavation pit is visible, but quantities of highly weathered plaster still remain. Stovall and Savage (1939) thought that the skull came from the Sloan Canyon Formation, but recent work indicates that the locality is in the uppermost Travesser Formation (Lucas et al., 1987[a]).

Stovall and Savage (1939) assigned the skull to *Rutiodon*, noting its similarity to *R. tenuis*. The specimen was not well enough described or illustrated to allow a definite reassessment of its taxonomic position. The skull, originally catalogued into the University of Oklahoma collection, is now at the Royal Ontario Museum (W. Langston, oral commun., 1986), and we have been unable to examine it. The most interesting feature of this skull is the dorsal concealment of the superior temporal fenestrae by overhanging postorbital bars, an "advanced feature" in phytosaurs (Gregory, 1957; Long and Ballew, 1985). This skull has long been considered to represent the same species as a specimen collected by J. T. Gregory from the Redonda Member of the Chinle Formation at Porter Ranch, Quay County, New Mexico (Gregory, 1957; Colbert and Gregory, 1957; Gregory, 1972; Long and Ballew, 1985; Lucas et al., 1985). Both skulls have concealed superior temporal fenestrae. However, the Travesser skull is distorted, and Stovall and Savage (1939, p. 759) noted that the skull's "posterior part was rolled under toward the left side" which casts doubt on interpretations of the morphology of this part of the skull. Obviously a new study of this skull is required.

Near the Travesser phytosaur site Stovall and Savage (1939, table 2) noted the first occurrence of Triassic unionid bivalves and gastropods from the Cimarron Valley. These specimens occur in an intraformational conglomerate of the upper Travesser Formation.

Stovall (1943) also reported the first vertebrate fossils from what is now recognized as the Cobert Canyon Sandstone Bed of the Baldy Hill Formation (Lucas et al., 1987[a]). These specimens, collected by Bloesch in 1941, included "the right jaw of a phytosaur, and a portion of the interclavicle of the amphibian *Buettneria* [=*Metoposaurus*]" (Stovall, 1943, p. 50). The discovery of these Triassic fossils in the Cimarron Valley was significant because earlier workers, notably Rothrock (1925), had been confused as to the extent of the Triassic system in the area. Indeed, Darton (1928) identified the strata which produced Stovall and Savage's (1939) phytosaur skull as Morrison Formation of Jurassic age (cf. Lucas et al., 1987[a]).

Stovall not only collected vertebrate fossils from the Jurassic rocks of the Dry Cimarron. He also made a large collection of invertebrates and plants from the Morrison Formation (Stovall, 1943). West (1979) later noted that ostracodes are common in lacustrine lithosomes of the Morrison in Cimarron County. Wedel made extensive ostracode collections in Cimarron County, representing about 60 species in about 25 genera (Stovall, 1943). Unfortunately, this collection was never described. The material Stovall collected and had identified by Harris is very significant since invertebrate remains are rare in the Morrison Formation (Dodson et al., 1980). Stovall's (1943) collection included two species of charophytes, nine species of ostracodes, two species of gastropods and one species of bivalve. We have been unable to locate this collection.

Stovall also made extensive collections of fossils from rocks of Cretaceous age. Most of these specimens were of marine invertebrates and included *Inoceramus*, "*Trigonia*," and "*Gryphaea*" from the Glencairn Formation, ?*Pecten* or ?*Exogyra* from the Pajarito Formation and *Inoceramus* from the Graneros Shale (Stovall, 1938a, 1943). The collection of these taxa helped to establish the age relationships of these units (Kues and Lucas, 1987). Stovall (1938a, 1943) also first noted petrified wood in the Lytle and Mesa Rica formations.

Stovall described the first occurrences of several groups of marine vertebrates from the Cretaceous of the Cimarron Valley. Several fossil fish were reported from the Mesas Rica Sandstone south of Kenton. "They were badly damaged while being removed. Most of the fragments have been lost, and those seen by the writer were too incomplete for identification beyond the fact that they are teleosts about seven inches in length" (Stovall, 1938a, p. 26). In the Graneros Shale, Stovall (1938a) found "occasional shark teeth of an unidentified genus" and the humerus of a plesiosaur.

Finally, Stovall made important discoveries in Pleistocene rocks of Cimarron County. He found, but did not collect, "a more or less completely articulated skeleton of an elephant" (Stovall, 1938a, p. 31) and a femur of "*Elephas columbi*" in terrace gravels. An Indian-occupied cave produced two molars of "*Equus complicatus*," a *Camelus* cannon bone and phalanx and remains of *Bison bison*. These were first occurrences for Cimarron County.

HIS LATER LIFE

Following the end of WPA support for his endeavors in the Cimarron Valley in 1942, Stovall conducted little more research in the area. However, he still listed the geology of the area as his principal interest (Cattell, 1949). WPA-sponsored excavations had provided him with a wealth of research material which he continued to study (e.g., Stovall and Langston, 1950), although he never did describe *Saurophagus* or the "new" small sauropod from quarry 1 (Stovall, 1943, p. 70). The last publication on the WPA collections appeared in 1966, 13 years after Stovall's death (Stovall et al., 1966).

In 1946 Stovall suffered a serious heart attack from which he never fully recovered. "He chose, however, to continue an active and fruitful career rather than to sit quietly and take no chances" (Branson, 1954, p. 156). Stovall continued to go on collecting expeditions, and on such a trip in Wyoming in 1953 he became gravely ill. He flew back to Norman and died on 24 July 1953.

ACKNOWLEDGMENTS

We thank J. McIntosh, J. Zidek and W. Langston, Jr. for providing unpublished information about Stovall's collection of Morrison dinosaurs. J. Droke, collections manager at the Stovall Museum of Science and History, allowed access to the archives of the museum and provided copies of archival photographs. B. S. Kues and J. Zidek reviewed an earlier version of this paper.

REFERENCES

Abbott, M. M., 1979, A basic evaluation of the uranium potential of the Morrison Formation of northwestern Cimarron County, Oklahoma and adjoining areas of New Mexico and Colorado [M.S. thesis]: Stillwater, Oklahoma State University, 92 pp.

Baldwin, B. and Muehlberger, W. R., 1959, Geologic studies of Union County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 63, 171 pp.

Berman, D. S. and McIntosh, J. S., 1978, Skull and relationships of the Upper Jurassic sauropod *Apatosaurus* (Reptilia, Saurischia): Bulletin of the Carnegie Museum of Natural History, no. 8, 35 pp.

Bird, R. T., 1939, Thunder in his footsteps: Natural History, v. 43, pp. 254–261, 302.

Bird, R. T., 1985, Bones for Barnum Brown: Fort Worth, Texas Christian University Press, 225 pp.

Branson, C. C., 1954, Memorial to John Willis Stovall: Proceedings of the Geological Society of America, Annual Report for 1953, pp. 155–158.

Cattell, J., ed., 1949, American men of science (8th ed.): Lancaster, The Science Press, v. 2, 836 pp.

Colbert, E. H. and Gregory, J. T., 1957, Correlation of continental Triassic sediments by vertebrate fossils: Geological Society of America Bulletin, v. 68, pp. 1456–1467.

Clements, F. E., 1938, Letter to Crompton R. Tate dated 7 May: Unpublished letter on file at the Stovall Museum of Science and History.

Darton, N. H., 1928, "Red beds" and associated formations in New Mexico with an outline of the geology of the state: U.S. Geological Survey, Bulletin 794, 356 pp.

Dodson, P., Behrensmeyer, A. K., Bakker, R. T. and McIntosh, J. S., 1980, Taphonomy and paleoecology of the dinosaur beds of the Jurassic Morrison Formation: Paleobiology, v. 6, pp. 208–232.

Farlow, J. O., 1987, Lower Cretaceous dinosaur tracks, Paluxy River Valley, Texas: Waco, South Central Section of the Geological Society of America and Baylor University, 109 pp.

Gilmore, C. W., 1909, Osteology of the Jurassic reptile *Camptosaurus*, with a revision of the species of the genus, and descriptions of two new species: Proceedings of the U.S. National Museum, v. 36, pp. 197–302.

Gregory, J. T., 1957, Significance of fossil vertebrates for correlation of Late Triassic continental deposits of North America: Report of the 20th Session of the International Geological Congress, 1956, section II, pp. 7–25.

Gregory, J. T., 1972, Vertebrate faunas of the Dockum Group, Triassic, eastern New Mexico and west Texas: New Mexico Geological Society, Guidebook 23, pp. 120–123.

Hatcher, J. B., 1901, *Diplodocus* Marsh, its osteology, taxonomy and probable habits, with a restoration of the skeleton: Memoirs of the Carnegie Museum, v. 1, pp. 1–64.

Hunt, A. P., 1986a, Taphonomy of the Cleveland-Lloyd quarry, Morrison Formation (Late Jurassic), Emery County, Utah: a preliminary report: North American Paleontological Convention IV, Abstracts with Programs, p. 21.

Hunt, A. P., 1986b, The Morrison Formation in eastern New Mexico—stratigraphy and correlation with central New Mexico: New Mexico Geology, v. 8, p. 69.

Hunt, A. P. and Lucas, S. G., 1984, Rarity of dinosaurs in the Upper Jurassic Morrison Formation, New Mexico: Geological Society of America, Abstracts with Programs, v. 16, p. 225.

International Commission on Zoological Nomenclature, 1985, International code of zoological nomenclature third edition: London, International Trust for Zoological Nomenclature, 338 pp.

Kauffman, E. G., Hattin, D. E. and Powell, J. D., 1977, Stratigraphic paleontologic and paleoenvironmental analysis of the Upper Cretaceous rocks of Cimarron County, northwestern Oklahoma: Geological Society of America, Memoir 149, 150 pp.

Kues, B. S. and Lucas, S. G., 1987, Cretaceous stratigraphy and paleontology of the Dry Cimarron Valley, New Mexico, Colorado and Oklahoma: New Mexico Geological Society, Guidebook 38.

Langston, W., Jr., 1974, Nonmammalian Comanchean tetrapods: Geoscience and Man, v. 8, pp. 77–102.

Long, R. and Ballew, K., 1985, Aetosaur dermal armor from the Late Triassic of southwestern North America, with special reference to material from the Chinle Formation of Petrified Forest National Park: Museum of Northern Arizona, Bulletin 54, pp. 45–68.

Lucas, S. G. and Hunt, A. P., 1985, Dinosaurs from the Upper Jurassic Morrison Formation in New Mexico: New Mexico Journal of Science, v. 25, pp. 1–12.

Lucas, S. G., Hunt, A. P. and Bennett, S. C., 1985, Triassic vertebrates from east-central New Mexico in the Yale Peabody Museum: New Mexico Geological Society, Guidebook 36, pp. 199–203.

Lucas, S. G., Hunt, A. P. and Hayden, S. N., 1987[a], The Triassic system in the Dry Cimarron Valley, New Mexico, Colorado and Oklahoma: New Mexico Geological Society, Guidebook 38.

Lucas, S. G., Hunt, A. P., Kues, B. S. and Holbrook, J., 1987[b], First-day road log, from Clayton to Seneca, Moses, Mexhoma, Kenton, Wedding Cake Butte, Travesser Park, Clayton Lake and back to Clayton: New Mexico Geological Society, Guidebook 38.

Mankin, C. J., 1958, Stratigraphy and sedimentary petrology of Jurassic and pre-Graneros Cretaceous rocks, northeastern New Mexico [Ph.D. dissertation]: Austin, University of Texas, 208 pp.

Mateer, N. J., 1981, The reptilian megafauna from the Kirtland Shale (Late Cretaceous) of the San Juan Basin, New Mexico; *in* Lucas, S. G., Rigby, J. K., Jr. and Kues, B. S., eds., Advances in San Juan Basin paleontology: Albuquerque, University of New Mexico Press, pp. 49–75.

Mook, C. C., 1965, New species of *Goniopholis* from the Morrison of Oklahoma: Oklahoma Geology Notes, v. 24, pp. 283–287.

Ostrom, J. H. and McIntosh, J. S., 1966, Marsh's dinosaurs: the collections from Como Bluff: New Haven, Yale University Press, 388 pp.

Ray, G. E., 1941, Big for his day: Natural History, v. 38, pp. 36–39.

Rothrock, E. P., 1925, Geology of Cimarron County, Oklahoma: Oklahoma Geological Survey, Bulletin 34, pp. 1–92.

Stanton, T. W., 1905, The Morrison Formation and its relations with the Comanche Series and the Dakota Formation: Journal of Geology, v. 13, pp. 657–669.

Stovall, J. W., 1932, The Jurassic in Oklahoma: Science, v. 76, pp. 122–123.

Stovall, J. W., 1935, Two fossil grizzly bears from the Pleistocene of Oklahoma: Journal of Geology, v. 43, pp. 208–213.

Stovall, J. W., 1937, Advance notes on the geology of the Cimarron Valley of western Oklahoma: Proceedings of the Oklahoma Academy of Science, v. 17, pp. 78–79.

Stovall, J. W., 1938a, Geology of the Cimarron River Valley in Cimarron County, Oklahoma [Ph.D. dissertation]: Chicago, University of Chicago, 60 pp.

Stovall, J. W., 1938b, The Morrison of Oklahoma and its dinosaurs: Journal of Geology, v. 46, pp. 583–600.

Stovall, J. W., 1940, *Megalonyx hogari,* a new species of ground sloth from Gould, Oklahoma: American Journal of Science, v. 238, pp. 140–146.

Stovall, J. W., 1941, The Mesozoic rocks of the Oklahoma Panhandle: Oklahoma City, Oklahoma City Geological Society, 30 pp.

Stovall, J. W., 1943, Stratigraphy of the Cimarron Valley (Mesozoic rocks): Oklahoma Geological Survey, Bulletin 64, pp. 43–132.

Stovall, J. W. and Brown, H. E., 1954, The principles of historical geology: Boston, Ginn and Company, 472 pp.

Stovall, J. W. and Johnston, C. S., 1934a, Hypertrophy in the jaw of an Oklahoma proboscidean: American Midland Naturalist, v. 15, pp. 622–624.

Stovall, J. W. and Johnston, C. S., 1934b, *Tapirus haysii* of Oklahoma: American Midland Naturalist, v. 15, pp. 92–93.

Stovall, J. W. and Langston, W., Jr., 1950, *Acrocanthosaurus atokensis,* a new genus and species of Lower Cretaceous Theropoda from Oklahoma: American Midland Naturalist, v. 43, pp. 696–728.

Stovall, J. W. and McAnulty, W. N., 1939, Cyprinodontidae from the Pliocene in Roger Mills County, Oklahoma: American Midland Naturalist, v. 22, pp. 749–752.

Stovall, J. W. and Savage, D. E., 1939, A phytosaur in Union County, New Mexico, with notes on the stratigraphy: Journal of Geology, v. 47, pp. 759–766.

Stovall, J. W. and Self, J., 1936, A new specimen of *Symbos* from Chickasha, Oklahoma: Journal of Mammalogy, v. 17, p. 422.

Stovall, J. W. and Shead, R. B., 1938, Report on WPA project 465-65-3-146 serial number S-189, work project number 4143: Unpublished report on file at the University of Oklahoma Library, 33 pp.

Stovall, J. W. and Shead, R. B., 1940a, Report on WPA paleontological project, official project number 665-65-3-89, work project number 5353: Unpublished report on file at the University of Oklahoma Library, 49 pp.

Stovall, J. W. and Shead, R. B., 1940b, Narrative quarterly report, WPA project number 65-1-65-2652, work project number 7100, excavation and preparation of fossil bones: Unpublished report on file at the University of Oklahoma Library, 23 pp.

Stovall, J. W. and Shead, R. B., 1940c, Second narrative quarterly report, WPA project number 65-1-65-2652, work project number 7100, excavation and preparation of fossil bones: Unpublished report on file at the University of Oklahoma Library, 18 pp.

Stovall, J. W. and Shead, R. B., 1941a, Third narrative quarterly report, WPA project number 65-1-65-2652, work project number 7100, excavation and preparation of fossil bones: Unpublished report on file at the University of Oklahoma, 18 pp.

Stovall, J. W. and Shead, R. B., 1941b, Fourth narrative quarterly report, WPA project number 65-1-65-2652, work project number 7100, excavation and preparation of fossil bones: Unpublished report on file at the University of Oklahoma Library, 19 pp.

Stovall, J. W. and Shead, R. B., 1941c, Fifth narrative quarterly report, WPA project number 65-1-65-2652, work project number 7100, excavation and preparation of fossil bones: Unpublished report on file at the University of Oklahoma Library, 16 pp.

Stovall, J. W. and Shead, R. B., 1941d, Sixth narrative quarterly report, WPA project number 65-1-65-2652, work project number 7100, excavation and preparation of fossil bones: Unpublished report on file at the University of Oklahoma Library, 15 pp.

Stovall, J. W. and Shead, R. B., 1942, Seventh narrative quarterly report, WPA project number 65-1-65-2652, work project number 7100, excavation and preparation of fossil bones: Unpublished report on file at the University of Oklahoma Library, 16 pp.

Stovall, J. W., Price, L. I. and Romer, A. S., 1966, The postcranial skeleton of the giant Permian pelycosaur *Cotylorhynchus romeri:* Museum of Comparative Zoology, Bulletin 135, pp. 1–30.

Tate, C. R., 1937, Letter to Dr. Forrest E. Clements dated 2 October: Unpublished letter on file at the Stovall Museum of Science and History.

Tate, C. R., 1938, Letter to Dr. Forrest E. Clements dated 20 April: Unpublished letter on file at the Stovall Museum of Science and History.

West, E. S., 1978, Biostratigraphy and paleoecology of the lower Morrison Formation of Cimarron County, Oklahoma [M.S. thesis]: Wichita, Wichita State University, 61 pp.

Young, N. G. B., 1986, Not a stoplight in the county: Boise City, Boise City News Consultants, 52 pp.

Shallow canyon cut by Ute Creek in upper Cenozoic basalt about 21 km north of Abbott. View is N5°W upstream. Here the creek is about 10 km downstream from its headwaters. The channel is shallow and well defined. Juniper trees are common on the canyon walls but are absent on the grassy mesa aove. Several large cottonwood trees are present in the tributary canyon at left. Camera station is in NE1/4 sec. 13, T26N, R25E. Altitude about 2,073 m. W. Lambert photograph No. 86L110. 29 December 1986, 2:07 p.m., MST.