

DINOSAUR TRACKS NEAR COMANCHE, TEXAS

Claude C. Albritton, Jr.

One of the most remarkable displays of dinosaur tracks found in Texas was that which until recently could be seen three miles south of Comanche at Lake Eanes (Fig. 1, locality 8). This lake is an artificial one, formed by a dam which was built across Mercer Creek in May, 1925. Heavy rains which fell during October of the following year caused the lake to overflow and a great volume of water to pass over the spillway at the north end of the dam. As constructed, the spillway was floored with flat-lying of Cretaceous clay. In the course of flooding the clay was stripped away, and when the waters subsided several hundred and fifty dinosaur tracks were visible on an underlying stratum of mud-cracked limestone. Mr. Elbert Stewart caretaker at the reservoir, was the first to see and report the tracks, which in time became well known to local geologists. The late Dr. Robert T. Hill mentioned them in an article written for the Dallas Morning News, and more recently Mr. Wilson Straley has given a brief but entertaining account of them in a popular magazine.

In the company of Professor J. D. Boon the writer visited Lake Eanes late in 1939. There they found that, thanks to the vigilance of Mr. Stewart, the tracks had been protected from mutilation by collectors and souvenir hunters. The following spring a class in field geology from Southern Methodist University mapped the tracks and collected the data presented here. Those largely responsible for this work are Messrs. E. F. Blakemore, Jr., C. M. Gaffield, R. B. McConnell, and Laurence Stephens. Miss Connie Shannon and Miss Dorothy Stewart have been most helpful in assembling the bibliography.

At the time of mapping there were 101 tracks as well as a number of formless impressions or other vestiges of

tracks. Many had been destroyed by erosion since the time of their exposure. This natural process of destruction has continued until at present there are only a few tracks remaining.

As the footprints are impressed in a stratum of the Glen Rose formation, there is nothing novel regarding their general horizon in the Cretaceous section. "Bird tracks" in the Glen Rose had been known to residents of nearby Somervell County long before Shuler described and correctly interpreted their origin in 1917. Nor were the tracks near Comanche of the deep, cleanly impressed sort that would have provided spectacular displays for museums. There are certain features of the Comanche locality, however, which make it one of especial interest to the paleontologist and stratigrapher.

Stratigraphy

Bed rock exposed in the spillway at Lake Eanes consists of thin layers of limestone, clay, shale and fine sandstone belonging to the Glen Rose formation of Lower Cretaceous age (Fig. 2). The beds are approximately horizontal and aggregate some 38 feet in thickness. It is impossible to state at this time what part of the entire formation is here represented, nor is it known where this section lies with respect to the base of the next youngest Cretaceous formation, the Paluxy. It is, however, certain that the Glen Rose becomes thinner toward the northwest and that it disappears by virtue of this thinning a few miles west of Comanche. The exposure at Lake Eanes may thus represent the larger part of the entire formation in this area.

Clay is the most common rock type. It is both calcareous and gritty, containing considerable silt and fine sand. Some of the clay beds are fossiliferous, with numerous ostracods and gryphaeate pelecypods. Most of the clay beds appear to be internally massive, though some are laminated and others have shaly parting.

Limestone accounts for approximately 45% of the thickness of the section. All of it is relatively impure, and there are all transitions from argillaceous limestone to calcareous clay and shale. Some of the units are massive,

others are flaggy, and some are coquinitic. Most of the beds contain fossils, although rudistids and large orbitoline Foraminifera such as *abound* in some parts of the Glen Rose are lacking. Small exogyrate or gryphaeate pelecypods are locally abundant, and a large species of *Protocardia* is common at several levels. Molds of gastropod shells occur in many layers, and worm borings are generally abundant. A single fragment of ammonite shell found in one of the limestone beds is worth reporting in view of the rarity of these

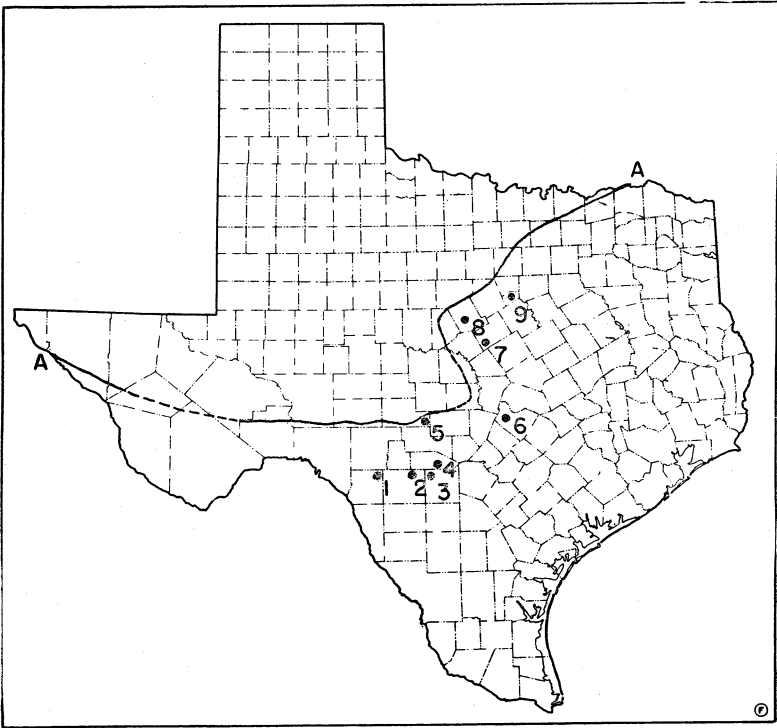


Figure 1.—Map of Texas, with black dots indicating areas where dinosaur tracks in the Glen Rose formation have been reported. 1—northeastern Kinney County; 2—northeastern Uvalde County; 3—northwestern Medina County; 4—southern Bandera County near Tarp-ley; 5—southeastern Kimble County; 6—western Travis County; 7—southern Hamilton County; 8—Comanche County, Lake Eanes; 9—Somervell County, various localities near Glen Rose. All localities except number 8 are listed by Adkins (1932, p. 320). Line A-A marks the northern margin of the Glen Rose limestone belt (from Adkins, 1932, p. 300, Fig. 16).

fossils in the Glen Rose. Doubtful impressions of plants, possibly fucoids, were seen on the weathered surface of one bed. Vertebrate remains include scattered fish teeth and dinosaur tracks, the latter of which were observed only in the mud-cracked limestone to be described in following paragraphs.

Whereas fine sand is scattered through many of the clayey and limy beds, whole layers of sandstone are uncommon, although a few thin strata are found near the top of the section.

Details of the local stratigraphy are given in the following section.



Figure 2.—Spillway at Lake Eanes, viewed toward the northwest. The ledge at the level of the man's head is unit 20 of the accompanying stratigraphical section. The mud-cracked limestone that bears the dinosaur tracks overlies this unit and formerly covered the flat part of the spillway in the background.

**Stratigraphic Section, Beds of Glen Rose Formation Exposed
in Spillway at Lake Eanes**
(Descending Order)

	Thickness in feet
40. Buff-weathering nodular limestone with brown clay partings; contains molds of pelecypod and gastropod shells; upper boundary indefinite, grading into soil	0.50
39. Mottled gray and brown clay	0.50
38. Nodular limestone with gray and brown clay partings; limestone contains numerous shell fragments, including those of exogyrate pelecypods	0.50

37. Brownish sandy and calcareous clay with local thin partings of nodular limestone.....	1.50
36. Thin-bedded nodular limestone with partings of clay; rock contains tubular borings up to $\frac{1}{4}$ in. across; grades into calcareous sandstone toward base.....	1.25
35. Alternating thin beds of flaggy limestone and brownish clay.....	1.50
34. Brown clay with local thin partings of calcareous sandstone; poorly exposed.....	1.16
33. Resistant fossiliferous limestone, locally a shell breccia.....	0.50
32. Nodular limestone with thin partings of brown clay; molds of large pelecypods abundant.....	1.00
31. Impure nodular and flaggy limestone traversed by tubular borings up to $\frac{1}{2}$ inch across; unit thins toward southeast....	1.00
30. Buff to brownish calcareous clay with local thin interbeds of impure limestone.....	1.75
29. Resistant gray, flaggy, crystalline limestone; unfossiliferous toward top; toward bottom coquinitic with small pelecypod and gastropod shells.....	1.00
28. Fossiliferous brownish calcareous clay with shaly partings....	0.40
27. Impure crystalline limestone; upper 4 inches massive and unfossiliferous; remainder thin-bedded and coquinitic with thin clay partings.....	1.33
26. Brown calcareous clay with shells.....	0.60
25. Flaggy impure coquinitic limestone.....	0.25
24. Brown clay with thin interbeds of impure dense crystalline limestone.....	1.75
23. Brown sandy clay with thin interbeds of sandy limestone and calcareous sandstone; poorly exposed.....	2.00
22. Impure buff limestone, with mud-cracks, small tubular borings, and dinosaur tracks.....	0.06
21. Buff clay with shaly partings.....	0.17
20. Buff impure limestone with shell fragments concentrated toward top; conspicuously jointed.....	0.83
19. Light gray sandy shale with pelecypod shells.....	2.50
18. White limestone, locally nodular and with scattered small concretions of pyrite or marcasite; contains <i>Pecten</i> and other pelecypods.....	0.40
17. Thinly laminated grayish shale with limonite stains; contains <i>Pecten</i>	0.60
16. Crumbly grayish shaly limestone with pelecypod shells.....	1.00
15. Fossiliferous white limestone with gastropods and pelecypods. A single unidentifiable fragment of an ammonite shell was collected from this bed.....	0.40
14. Brown clay stained with limonite.....	0.75
13. Gray to buff limestone with numerous tubular borings.....	1.60

12. Gray shale.....	0.40
11. Gray, thin-bedded limestone with limonite stains.....	0.30
10. Brown clay with limonite stains.....	0.90
9. Gray limestone with fucoids (?) and gastropod shells.....	0.30
8. Gray calcareous clay with limonite stains.....	0.70
7. Gray shaly limestone with fucoids (?).....	1.30
6. Gray clay with shells of pelecypods and gastropods.....	1.17
5. Gray limestone with clay partings; contains small concretions of pyrite or marcasite, tubular borings, pelecypod shells, and fish teeth.....	1.40
4. Brownish laminated clay.....	2.30
3. Jointed gray limestone with numerous tubular borings and shells of pelecypods and gastropods.....	0.50
2. Calcareous brown clay.....	0.90
1. Fossiliferous limestone.....	1.00
Total thickness exposed.....	37.97

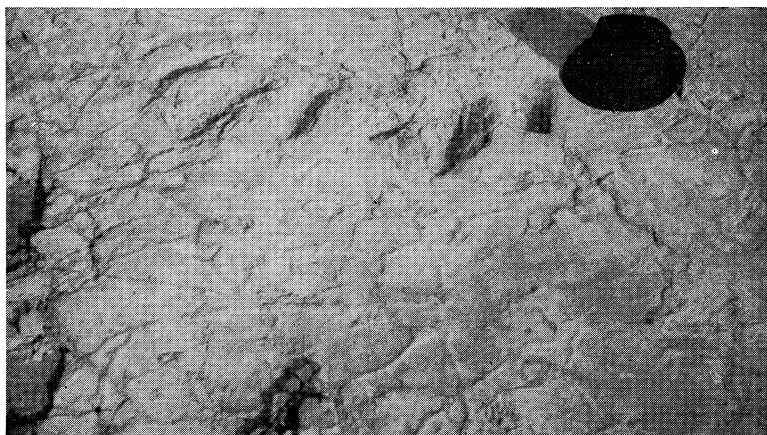


Figure 3.—Mud-cracked limestone with two dinosaur tracks. These belong to different trails and were not formed by a single animal standing at rest, as this picture might suggest.

The track-bearing layer is a buff, flaggy limestone which averages less than an inch in thickness. The rock is laminated and breaks readily into thin plates along surfaces of bedding that are slightly undulatory. A sample from this layer consisted of about 70% by weight of calcium carbonate. The insoluble residue included particles of clay, silt, and fine sand, with the clay and silt fractions

predominating. Larger clastic particles were of angular quartz, and there seemed to be very few grains of heavy minerals.

Much of the calcium carbonate in this layer is in the shells of ostracods and Foraminifera. The concentrate from a small sample of the rock yielded seven species of ostracods as well as a number of large foraminiferal tests both calcareous and arenaceous. Larger shells, such as those of pelecypods and gastropods, appear to be lacking.

In addition to containing the dinosaur tracks, this layer is characterized by mud cracks and tubular borings (Figs. 3, 5). Mud cracks divide the stratum into irregular polygons, some of which measure as much as a foot across. The surfaces of the polygons are relatively flat except near the margins where they curve upward toward the bordering cracks. These cracks are filled in large part with impure limestone so similar in texture and color to the track-bearing stratum itself that the downward extensions of the fillings are difficult or impossible to observe. The fillings stand in slight relief above the bordering surfaces of the polygons. Where dinosaur tracks occur, these are impressed on the mud-cracked surface so as to obliterate the cracks. As no cracks cut across the footprints, it is evident that the development of polygons was completed before the dinosaurs walked across.

The stratum is perforated by small tubular borings which are from 2 to 3 millimeters in diameter. These are mostly inclined at high angles with the bedding, the upper surface of which they intersect as circular or elliptical openings. Some, however, run parallel with the bedding in sinuous courses, suggesting, as Straley (1942) has observed, that they were made by worms. The borings appear not only inside the mud polygons but also in the fillings between the polygons; they were probably formed in part before the cracking and in part after the filling of the cracks. The borings are filled with calcareous clay like that which overlies the stratum. As these fillings are softer than the rock in which they are set, they weather into small pits which give exposed surfaces pocked appearances.

Tracks and Trails

The tracks at Lake Eanes were made by dinosaurs that walked upright on their hind legs and which thus left no impressions of the forefeet. The footprints recall those of birds; they show impressions of three toes, of which the middle is longest. The terminations of the toe impressions are bluntly rounded, and there is no suggestion of sharp claws.

Tracks are impressed to various depths in the limestone. The shallower generally show marks of the toes only, with the deepest parts near the extremities. Impressions that are deeper than two inches generally show in addition to the toe prints the impression of a rounded heel, and a few have a suggestion of a short hallux claw directed backward (Fig. 5). Differences in depth of impression were due to lateral variations in the softness of the substratum at the time the tracks were made, as indicated by the fact that along the trail of a single dinosaur some prints are impressed considerably more deeply than others. As the questionable impressions of the hallux occur only in the deeper tracks, it is evident that in normal gait and on relatively firm ground the dinosaurs supported their weight mostly on three toes and thus had feet that were functionally if not structurally tridactyl.

As the shallower impressions generally lack heel-prints and as the deeper tracks tend to be blurred and rather indistinct, it was not possible to determine the dimensions of the dinosaurs' feet with any great degree of accuracy. A track that appeared to be near average size measured 21 inches long and 15 inches wide.

The length of stride could be determined more satisfactorily. Most of the dinosaurs covered between 4 and 5 feet of distance with each step. However, some of the strides were as small as 3.5 feet, whereas one set of tracks indicated a stride near 10 feet. There appeared to be no necessary relationship between size of track and length of pace. Indeed, what must have been one of the largest dinosaurs, to judge by the size of his footprint, took steps

of far less than average length. It was not to be determined whether this mincing gait reflected corpulence, old age, or a certain caution gained by past experience with mud flats.

The variation in length of pace along a given set of tracks is small, amounting to a few inches in most instances and only seven inches in an extreme case.

In plan the tracks are aligned in trails which are straight or only very slightly curved. Most of the trails have from two to five tracks exposed or left preserved, although one showed 13 tracks. Several of the trails could be traced for 40 feet, and one was followed for twice this distance. There were a number of single tracks, isolated from the others by the erosion of intervening portions of the track-bearing stratum, that could not be referred with certainty to any of the trails.

The plan of the trails is shown on the accompanying map, where the individual tracks are shown very nearly to scale. The general absence of tracks on the southern part of the spillway is due to the fact that the track-bearing stratum had been eroded from this area at the time the map was made. On the northern part of the spillway, where the stratum was intact, the tracks are grouped along belts which seem to have marked preferred paths of travel. Data on the various trails are summarized in Table 1. Trail and track numbers entered in the left column of this table were not included on the map because they would have obscured the patterns formed by the tracks themselves. The trails, however, are numbered in the order of their appearance from west to east, so that little effort is required to correlate the information jointly given by the map and table.

The map shows that the trails are for the greater part aligned northwest. Most of the dinosaurs were travelling northwest, several were travelling southeast, and only a few were moving in other directions. In some cases the tracks were so blurred or so badly eroded that it was impossible to discover the direction of progress; these tracks are shown on the map as dark elliptical areas. Figure 4

shows graphically the orientation of the trails, and emphasizes the preferred directions of movement.

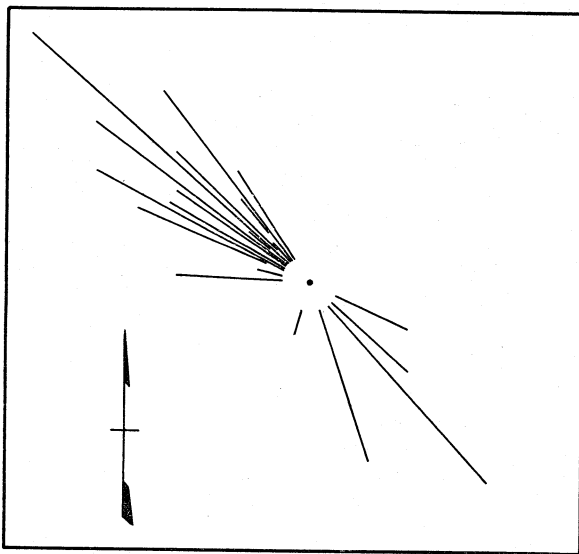


Figure 4.—Diagram showing alignment of dinosaur trails at Lake Eanes. Each of the radiating lines shows the direction of one or more trails with respect to true north as indicated by the arrow in the lower left corner. The length of each radiating line is in direct proportion to the number of tracks bearing in the direction of the line.

It may be conservatively estimated that the tracks were made by not less than 30 individuals. So far as may be judged by the similarity in the shape of the tracks, they may well have been made by a single species of dinosaur here represented by individuals of different ages and sizes.

In their general form the tracks near Comanche are like those in the Glen Rose limestone of Somervell County which Shuler has tentatively assigned to Hitchcock's genus *Eubrontes*. This generic name was first applied to tracks in the Triassic rocks of the Connecticut Valley, where an elaborate system of classifying dinosaur tracks has evolved from the studies of Hitchcock and Lull into the science of ichnology. Lull has made it clear that the generic and specific names applied to tracks should be regarded as constituting a system of classification independent from that ordinarily used for the bones and other fossilized remains of these

animals. Only in rare instances has it been found possible to correlate skeletal remains with tracks, and, moreover, several species of dinosaurs might leave footprints which would be sufficiently alike to be included in a single "track-genus" or "track-species." Granting the expediency as well as the limitations of applying a binomial classification to tracks, there would seem to be no illogicality in classing Cretaceous footprints in Texas with an ichnite genus founded on Triassic tracks in Connecticut. Of the *Eubrontidae* Lull (1915, p. 194) observes that the apparent lack of a grasping hallux, heavy slow moving tread and blunt claws point to a herbivorous habit. However, he admits the possibility that *Eubrontes* might have belonged to an aberrant group of carrion feeders which "because of carrion feeding habits did not retain the raptorial claws of its predacious allies." He further believes that it would be necessary to observe the impression of the manus before reaching any conclusion regarding the eating habits of dinosaurs belonging to this genus.

In this connection Hill (1937) has made the curious observation that the dinosaurs that left their tracks at Lake Eanes were feeding on kelp. He further stated that impressions of this marine vegetation are to be seen on the track-bearing layer. Although what are probably the remains of marine algae are found in a limestone layer several feet below the track-bearing stratum, no such fossils are to be found at the horizon of the tracks. Evidently Hill mistook the raised fillings of the mud cracks for the stems of plants.

It is highly improbable that the dinosaurs were feeding at all when they made the tracks. Animals that are browsing do not follow straight paths, nor do they take uniform paces. The trails at Lake Eanes indicate that the dinosaurs were moving straight across and at steady pace toward destinations which lay beyond the present exposure of the mud-cracked stratum.

All of the tracks were impressed after the time of mud-cracking and before the time of deposition of the overlying clay. This interval was probably short, possibly only a

few hours in duration. Yet it is certain that not all the tracks were made at the same time, since in the most closely crowded groups some tracks run in one direction while others lead in the opposite direction. There is also some crossing of trails, but nowhere does one track actually intersect another. No conclusive evidence could be found to indicate whether the reptiles moved across the area singly, or in pairs or groups.

Although a careful search was made for them, no tail furrows could be found. Hill, however, reported such furrows, and Mr. Stewart stated that one or more could be observed in the southern part of the spillway, an area from which the track-bearing stratum had been stripped at the time of the author's visit. Straley noted tail marks in two places. One of these he interpreted as having been made by the animal's slapping the tail into the mud while making a turn, the other by a dinosaur that "reared back on his hind legs." The most that can be said on the basis of the writer's observations is that caudal traces did not invariably accompany the tracks, and that most of the dinosaurs walked with the tail held above the ground.

The tracks give considerable information on the physical state of the mud-cracked limestone at the time the dinosaurs walked across it. It appears that this stratum then existed as a relatively hard though still impressionable crust which in places overlay mud that was still quite soft. Where this softer substratum was lacking the tracks were impressed to depths of two inches or less. Where the softer substratum was present, the feet of the dinosaurs broke through the mud-cracked crust, forcing the mud beneath it away from the bottom of the foot and thereby uparching the crust around the peripheries of the tracks. Thus it is that around many of the cracks the mud-cracked limestone forms a small elevated rim that dips radially away from the sides. By the weight of the feet the mud remaining under the tracks was made more compact than that which was forced laterally aside. At certain stages in the erosion of the clay beds beneath the mud-cracked layer these compacted areas are left standing in relief,

indicating the points where tracks had once been in the bed above.

Around the more deeply impressed tracks there are tension tracks of two sorts that were produced by the impact of the feet. Generally there is an arcuate crack running tangent to the toes around the forward part of the track (Fig. 5). In addition there are radial cracks which diverge from the peripheries of the tracks and which if continued toward the tracks would intersect near their centers. These last are best developed around the rear parts of the tracks, from which some extend outward for as much as two feet.



Figure 5.—Deeply-impressed dinosaur track. The impression of the longest of the toes points upward and slightly toward the right in this picture. Note the pattern of mud-cracks which are filled with calcareous clay. Small pits scattered over the surface lead downward into tubular borings that were probably made by worms.

The conditions of origin of the mud-cracked layer and the sequence of events that it records may now be considered. The abundant shells of ostracods and Foraminifera that it contains indicate that the fine sedimentary particles that make this layer were deposited in marine waters. Manifestly these waters were quite shallow, and the bottoms they covered are to be classed as "mud-flat bottoms," as defined by Scott (1940, p. 1167-1168). The presence of mud cracks would seem to indicate that after the cal-

careous mud had been deposited it was bared to the atmosphere for a time, although it is conceivable in view of the findings of Moore (1914) and Twenhofel (1923) that the cracks opened while the bottom was still covered with shallow water. Under any circumstances the development of the mud cracks seems to have been an unusual episode in the local history of Glen Rose sedimentation. No other beds in the section show such cracks, and it is thus probable that extraordinary conditions were required to produce them. Such conditions might logically have been provided by strong and persistent winds blowing toward the sea and forcing the water off the shallowest parts of the near-shore area—a phenomenon that is today well exhibited during storms along the shores of the North Sea (Lüders, 1939, p. 326). These winds would have speeded the drying of the freshly exposed bottoms, so that mud cracks would have developed in a fairly short time. Subsequently the dinosaurs walked across the flat and impressed their tracks into the mud polygons. These animals may well have been taking a short cut from one point of land to another along a course that was ordinarily blocked or made less attractive by the presence of water. This might account for the facts that the trails run straight and mostly trend in a single direction. Some time after the reptiles had crossed, the waters returned and cracks and tracks alike were filled with mud and thus preserved.

Comparisons With Other Localities

Dinosaur tracks in the Glen Rose have been reported from a number of localities in Texas, but there has been little effort, other than that on the part of Adkins (1932, p. 320), to summarize and correlate the information that has accumulated. Figure 1 shows the distribution of nine track-localities in Texas.

In 1917 Shuler described eight dinosaur tracks that were found in the flat bottom of a ravine near Glen Rose, in Somervell County. These tracks each showed the impressions of three toes, and averaged about 16 inches long and 10 inches wide. In their general shape the tracks were simi-

**Table 1—Data on Dinosaur Tracks at Lake Eanes
(Compiled by C. M. Gaffield)**

Trail No.	No. Tracks	Progression	Stride	Remarks
1	1	N 75° W		Also 1 additional blurred track of uncertain direction.
2	4	?		Tracks obscure, may or may not be related.
3	1	?		Axis of track bears N 60° W.
4	1	?		Axis of track bears N 30° W.
5	6	N 60° W	6' 1" to 6' 5"	
6	3	N 66° W	5' 5" to 5' 7"	
7	5	N 55° W	5' 8"	One of these tracks may belong to another trail.
8	2	N 62° W	10'	
9	2	N 50° W	5' 5"	May be part of trail 10.
10	2	N 40° W	5' 10"	
11	3	S 66° E	4' 1" to 4' 4"	
12	7	S 42° E	5' 8" to 6' 2"	Formerly there were 9 tracks in this trail.
13	6	S 19° E	4' 10" to 5' 1"	
14	6	N 62° W	5' 1" to 5' 5"	
15	3	N 37° W	5' 2" to 5' 4"	
16	2	N 63° W	6' 7" ?	May not belong to same trail
17	1	N 87° W		
18	2	N 64° W	5' 4"	Also one heel print observed
19	3			Poorly preserved; not in sequence
20	1	N 45° W		
21	10	N 33° W to N 37° W	6' 0" to 6' 7"	Trail makes slight bend
22	6	N 52° W	5' 2" to 5' 8"	
23	3	N 87° W	9' 9" to 9' 11"	
24	3	N 42° W	3' 7" to 3' 10"	
25	3	N 53° W	4' 5" to 5' 7" ?	One track is blurred
26	4	N 33° W N 39° W	4' 5" to 4' 7"	May not all belong to same trail.
27	1	N 44° W		
28	2	?	?	
29	1	N 45° W		
30	3	S 15° W	4' 7" to 4' 9"	
31	1			
32	1	N 43° W		Associated with another indistinct impression.
33	4	S 49° E	?	Imperfect tracks, may not be related.
34	13	N 48° W	3' 4" to 4' 6"	

lar to those at Lake Eanes. Their spacing indicated a uniform stride of four feet and two inches. The track-bearing stratum was of limestone that contained approximately 75% calcium carbonate. Overlying this bed was a foot of shale which in turn was overlain by shell breccia. For the tracks Shuler proposed the name *Eubrontes ? titanopelopatidus*. As the limestone that bears the tracks shows no mud-cracks or any other evidence that the bottoms were emergent during the time the rock was formed, it must be supposed that the dinosaurs were wading in shallow water.

There are numerous other track localities in Somervell County, but perhaps the best known of them all is the one near the fourth crossing of the Paluxy river, about six miles west of Glen Rose. A large three-toed track has been taken from this locality and mounted in the bandstand at Glen Rose. Shuler (1935) described this example and assigned to it the name *Eubrontes ? glenrosensis*.

In 1934, twenty-six dinosaur tracks were exposed in the bed of the Paluxy near the fourth crossing. These were mapped and described by Shuler (1937). The tracks were all tridactyl, but showed such differences in the length of the toes and the angulation of the heels as to suggest that at least six dinosaurs belonging to three different species were there represented. The largest track measured 17 inches long and 16 inches wide; the smallest was only 8 inches long and 8 inches wide. Strides varied between 4 and 6 feet. Although the majority of the tracks pointed either northeast or southwest, there were a number pointing in other directions, and there was no such uniformity in alignment as was observed at Lake Eanes. There was nothing about the hard, fine-grained limestone which carried the tracks to indicate that it was ever exposed, even temporarily, to the atmosphere. As no caudal traces occurred with the tracks Shuler expressed the opinion that the tracks were made while the limy muds on the bottom were covered with water sufficiently deep to support the tails of the dinosaurs. These tracks have subsequently been destroyed by erosion.

A short distance downstream from the fourth crossing Bird (1939, 1941) found large sauropod tracks. These giant tracks, each some 38 inches in length, were taken up and distributed among several museums, a dozen of them going to the American Museum of Natural History. Impressed in the same layer with the sauropod tracks were those of the commoner tridactyl type. The trails run in various directions and are not straight except for short distances. The rock in which they are impressed is a limestone perforated by tubular borings similar in form to, but somewhat larger than, those in the mud-cracked layer at Lake Eanes. At the time the tracks were made the bottom was evidently under water, and Bird holds this to account for the absence of tail prints in the rock.

Wrather has reported numerous dinosaur tracks in the bed of Cottonwood creek, southern Hamilton County. Such tracks as could be examined were tridactyl, with lengths ranging from 8 to 20 inches. The stride at one place was estimated at four feet. The tracks were made by a number of dinosaurs moving in every direction. The rock in which the tracks were impressed is a limestone about one foot thick that is overlain by shales and coquinitic beds that carry a typical Glen Rose fauna. Wrather estimated that the stratum lay about 50 feet below the upper contact of the Glen Rose. He concurs with Shuler in supposing that the bottom was covered with shallow water at the time the tracks were impressed.

Tracks in northeastern Kinney County, some 35 miles northwest of Uvalde, have been described by Gould. These prints are in soft gray limestone exposed along the bed of an arroyo. Of the fifteen examples, six had an average length of 21 inches, an average width of 14 inches, and indicated a uniform stride of 5 feet and 3 inches. Apparently there are two and possibly three track-bearing layers in this area.

It is evident that dinosaur tracks are rather common primary features of some limestone beds in the outcropping section of the Glen Rose. At any locality, however, the tracks are confined to a single stratum or to a few strata

in the local section. Whether or not the horizons at which tracks occur are generally the same from county to county remains to be determined. As yet the stratigraphic positions of only a few of the track-bearing beds have been even approximately determined.

Both bipedal and quadrupedal dinosaurs have left their tracks in the Glen Rose. Tracks of the bipeds are by far the more abundant. They show the impressions of three toes, and range in length from 8 to 25 inches. The lengths of stride range between 3 and 10 feet. In general form the tracks appear to be allied with the track-genus *Eubrontes*, of which two species have already been named by Shuler. When these tracks are given systematic study, it is probable that several additional species will be recognized.

The giant footprints of the quadrupedal sauropods are best known from the fourth crossing of the Paluxy river in Somervell County, although Bird (1941) mentions a second locality at Bandera. At the fourth crossing they are associated with the commoner tridactyl tracks. Indeed, the parallelism of the two kinds of trails is in places so striking that Bird was led to suggest that the three-toed tracks belonged to carnivores stalking the larger sauropods.

All the tracks thus far described have been found in limestone that either contains or is associated with beds that contain marine fossils. With the exception of the Comanche locality, the tracks seem to have been made under water by dinosaurs that were wading. Thus the tracks show in a spectacular way that limestone may originate on bottoms normally covered with only a few feet or even inches of water and which under exceptional circumstances might become temporarily emergent.

To the writer's knowledge, no dinosaur bones have been found in the Glen Rose, although it is possible that the dinosaur tooth Hill found near Comanche came from this formation (Gould, 1929). The general absence of bones seems odd in view of the profusion of tracks. It may be that the dinosaurs in question actually spent little of their time in the water along the shores of the Glen Rose sea, but preferred for their normal habitat the "flat subsident, river and bayou, cycad-dinosaur-conifer forest land" that

lay to the west (Wieland, 1931). Possibly the water provided a medium of escape from the larger carnivorous reptiles of the day, and very likely many of the tracks were made by animals wading across from one point of land to another.

It is noteworthy in this connection that the dinosaur skeletons found in the beds of the Trinity group have come from mostly non-marine sands and shales into which the Glen Rose grades when traced along the surface toward the west and north. From the occurrence of such bones in the lower Trinity sands near Millsap, Texas, Hill (1887) named these beds the "Dinosaur sands." Other skeletal remains, probably from the Paluxy, have been reported from Irion County by N. H. Darton (Adkins, 1932, p. 320), and from a locality near Stephenville, Erath County, by Wieland (1931). The bone of a large sauropod was reported by Larkin in 1910 from cross-bedded sands of the Trinity group in Oklahoma. As yet there has not been sufficient study of these fossils to determine whether they can be correlated with the Glen Rose tracks.

Summary

Of the various localities in Texas where the footprints of dinosaurs have been observed in the Glen Rose formation, the one at Lake Eanes has displayed the greatest number of tracks and has afforded the most favorable conditions for their study. Until recently more than a hundred prints could be seen in the layer of mud-cracked limestone that formed the floor of the spillway. The tracks are all of the three-toed type that Shuler has elsewhere referred with some question to *Eubrontes*. They are mostly aligned in trails, the majority of which trend northwest or southeast.

It is suggested that the tracks were made during a brief interval when the waters along the Glen Rose shore had temporarily retired to a level below that of normal low tide, possibly owing to strong winds blowing off shore. Following the retreat of the waters the muddy bottom, rich in the shells of Foraminifera and ostracods and occupied by numerous worms, was dried to the extent that mud-cracks

formed. The dinosaurs, thirty or more in number and all bipeds, walked across the mud flat, possibly taking the shortest paths between two points of land that normally were separated by water. Subsequently the sea returned and filled the mud-cracks, worm borings and dinosaur tracks with mud. After this the deposition of clay, silt and shells in the shallow marine waters was resumed and went on for a time without further interruption.

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