Origin and stratigraphy of historic dinosaur quarries in the Upper Cretaceous Fruitland Formation of the Fossil Forest Research Natural Area, northwestern New Mexico

Adrian P. Hunt and Spencer G. Lucas

2003, pp. 383-388. https://doi.org/10.56577/FFC-54.383

in:

Geology of the Zuni Plateau, Lucas, Spencer G.; Semken, Steven C.; Berglof, William; Ulmer-Scholle, Dana; [eds.], New Mexico Geological Society 54 th Annual Fall Field Conference Guidebook, 425 p.
https://doi.org/10.56577/FFC-54

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

New Mexico Geological Society Guidebook, 54th Field Conference, Geology of the Zuni Plateau, 2003, p. 383-388.

ORIGIN AND STRATIGRAPHY OF HISTORIC DINOSAUR QUARRIES IN THE UPPER CRETACEOUS FRUITLAND FORMATION OF THE FOSSIL FOREST RESEARCH NATURAL AREA, NORTHWESTERN NEW MEXICO

ADRIAN P. HUNT AND SPENCER G. LUCAS
New Mexico Museum of Natural History, 1801 Mountain Road NW, Albuquerque, NM 87104-1375

Abstract.—Five dinosaur quarries in the upper part of the Fruitland Formation in the Fossil Forest Research Natural Area were almost certainly collected by Charles H. Sternberg in the 1920s and probably yielded the holotypes of *Pentaceratops sternbergi* and *Parasaurolophus cyrtocristatus*, among other fossils. We divide the Fruitland Formation into two members, named here, a lower Neh-nah-ne-zad Member characterized by thick coal beds and an upper Fossil Forest Member that lacks such coal beds. The vertebrate fauna of the Fruitland Formation is mostly from the Fossil Forest Member.

INTRODUCTION

The Fossil Forest Research Natural Area (RNA) is located in San Juan County, New Mexico and preserves an important Late Cretaceous Lagerstätten. The area derives its name from a large fossil stump-field, but there are also significant macro- and micro-vertebrate localities as well as localities that yield plant compressions and invertebrate fossils (Hunt, 1984, 1991). The Fossil Forest RNA includes portions or all of secs. 13 -14, 22-24, 16, T23N, R12W, San Juan County, New Mexico (Fig. 1).

A large channel-form sandstone body within the Fossil Forest RNA includes five large excavation pits (Fig. 2). These are presumed to be historic dinosaur quarries because: 1) there is dinosaur or bone debris at all localities: (2) there is highly weathered burlap and plaster at three of the localities; and (3) the sandstone contains abundant dinosaur specimens. The channel-form sandstone was termed the "Dinosaur Graveyard" by Hunt (1984), following the informal nomenclature of collectors from 1979-1986. Wolberg and coauthors (e.g, Hall et al., 1988) termed this the "horseshoe channel," which they, in interesting contrast to the name, interpret to be a crevasse splay, a conclusion that runs counter to a decade of sedimentologic studies that demonstrate it to be of in-channel origin (Hunt, 1984, 1991, 1992).

The purposes of this paper are to document the five historic dinosaur quarries, to discuss their origin and stratigraphic position and to discuss the stratigraphy and taphonomy of the upper Fruitland-lower Kirtland Formation interval.

REDISCOVERY OF THE HISTORIC QUARRIES

The Fossil Forest area was re-discovered in 1977 by a paleontological survey team, including one of us (SGL) that evaluated the paleontology of BLM lands in the San Juan Basin that might be impacted by coal development (Kues et al., 1977). Kues et al. (1977, p. 207) noted localities of vertebrate, invertebrate and plant fossils in the Fossil Forest area as well as "an old excavation ([locality] 809) where apparently part of a dinosaur skeleton was removed many years ago."

Subsequently, starting in 1979, the New Mexico Bureau of Mines and Mineral Resources (now New Mexico Bureau of Geology and Mineral Resources) and the U. S. Bureau of Land Man-

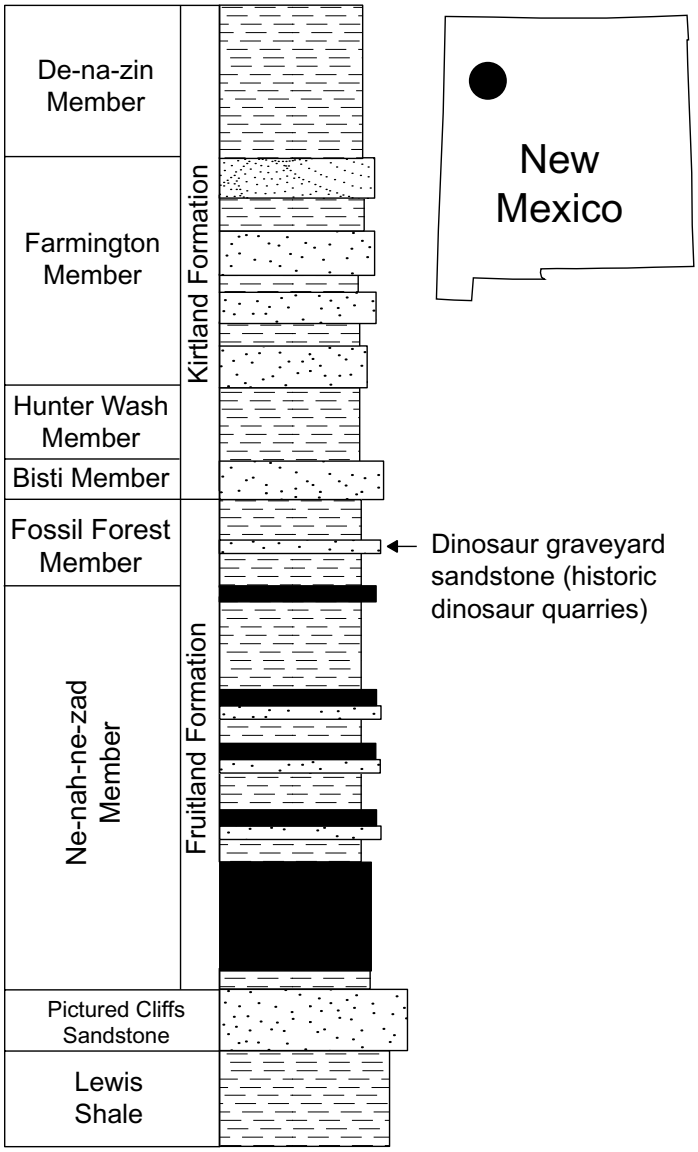

FIGURE 1. Index map and general stratigraphy of Fruitland and Kirtland formations showing location of historic dinosaur quarries in the Fossil Forest RNA.

FIGURE 2. Historic dinosaur quarries in the "Dinosaur Graveyard sandstone" in the Fossil Forest RNA, San Juan County, New Mexico. All localities are in the Fossil Forest Member of the Fruitland Formation. Note the thin carbonaceous bed above the quarries that is a significant marker bed in the area. A. Quarry 1 (NMMNH locality 5367). B. Quarry 2 (NMMNH locality 5368). C. Quarry 3 (NMMMNH locality 5369). D. Quarry 4 (NMMNH locality 5370). E. Quarry 5 (NMMNH locality 5371). F. *In situ* dinosaur bone in the floor of Quarry 2 (NMMNH locality 5368).

agement initiated a multi-disciplinary study of the Fossil Forest area that was never completed, although several component reports were produced (Hunt, 1984, 1990, 1992; Rigby and Wolberg, 1987; Wolberg et al., 1988a,b; Hunt and Lucas, this volume).

Hunt's (1984) portion of the Fossil Forest project was to evaluate the litho- and magneto-stratigraphic, sedimentologic and taphonomic context of the fossil localities. Hunt (1984, fig. 38; 1991, fig. 2) discussed the five historic quarries in some detail and illustrated Quarry 3 (see numbering scheme below).

Wolberg et al. (1988, p. 15) stated that there were about 12 historic quarries in the Fossil Forest RNA: (1) three-five from 1915-1930; (2) two-three from the middle part of the century; and (3) at least four quarries from the early-mid 1970s. Our studies, which started in 1977 and have continued to the present day, can only substantiate the presence of five historic quarries in the Fossil Forest RNA, all of which substantially predate the 1970s.

Hunt (1984) first speculated on the origin of the Fossil Forest quarries. Subsequently, three principal candidates have been suggested as excavators of the historic quarries (Hunt, 1984, 1991; Wolberg et al., 1988; Hunt et al., 1992; Sullivan and Williamson, 1999): Charles H. Sternberg, J. Willis Stovall and the U. S. National Museum.

THE QUARRIES

There are five historic quarries preserved in the Fossil Forest RNA that we document below (Fig. 2). However, there are several other quarries, some also in the Dinosaur Graveyard sandstone, that have been excavated in the Fossil Forest area since 1979. All five quarries are preserved in the upper portion of a well-indurated sandstone significantly above wash level. Lithology and topography favor the recognition of these quarries. One quarry, in a well-indurated sandstone that was excavated in 1979 and which occurs on a virtually flat surface on the bank of an arroyo, is now virtually undetectable. Thus, it is highly probable that other historic quarries existed in less-indurated lithologies or in flatter terrane. Hunt (1984) compared the weathering of the Fossil Forest localities with quarries of known age (University of Kansas quarries from the early 1960s) in similar stratigraphic and sedimentologic contexts in the upper Fruitland Formation at Hunter Wash. He concluded that the Fossil Forest quarries were probably several decades old.

The largest quarry, which we designate Quarry 1 (NMMNH locality 5367; Kues et al., 1977 locality 809; Fig. 2A) is 7 m wide by 4 m deep with a highwall of 1 m. There is bone debris in and around this quarry as well as highly-weathered plaster. This is locality 809 of Kues et al. (1977, p. 146), who reported ceratopsian fossils from this location.

Quarry 2 (NMMNH locality 5368; Figs. 2B, F) also yields abundant bone debris and some old plaster. This quarry is 3.5 m wide by 3 m deep with a highwall of 0.75-1 m. Large fragments of bone are downhill from the excavation, and there is in-situ material on the quarry floor (Fig. 2F), including an ossified tendon of a hadrosaur.

Quarry 3 (NMMNH locality 5369; Hunt, 1991, fig. 2; Fig. 2C) contains abundant bone debris as well as several in-situ elements immediately below the concretion under the person in Figure 2C. The quarry is 5 m wide by 1 m deep with a highwall of 0.75 m and was illustrated by Hunt (1984, fig. 38; 1991, fig. 2).

Quarry 4 (NMMNH locality 5370; Fig. 2D) contains a limited amount of bone debris. The quarry is 3.5 m wide by 2.5 m deep by 1 m high.

Quarry 5 (NMMNH locality 5371; Fig 2E) is another very large quarry that is 6 m wide by 2 m deep with a high wall of 1.25 m. There was some excavation of the floor of this quarry in the 1980s, and there is still significant in-situ dinosaur bone.

It should be noted that the sandstone matrix in these quarries is well indurated, and excavations in the 1980s principally involved power tools. There is obviously a relationship between the age of these quarries and the importance of the specimens which they yielded. Older hand excavations of such size and scope would only have been conducted for significant specimens.

STERNBERG QUARRIES?

Charles H. Sternberg (1850-1943) was one of the greatest dinosaur collectors of all time (Lucas, 1997). He collected numerous vertebrate fossils for institutions across the country and abroad. In 1921, when he was 71 years old, Sternberg was hired by Dr. Carl Wiman to collect vertebrate fossils from the Cretaceous of the San Juan Basin for the University of Uppsala, Sweden (Sternberg, 1932; Hunt et al., 1992). This expedition can be reconstructed in some detail, principally because of a series of letters from Sternberg to Wiman that are preserved in Uppsala, and details in one volume of his autobiography (Sternberg, 1932; Hunt et al., 1992). In 1922, Sternberg returned to the San Juan Basin to work "on my own account" (Sternberg, 1932, p. 253) and collected specimens that he sold to other institutions.

Following Hunt (1984), there has been a consensus among most authors that Charles Sternberg collected in the Fossil Forest (Wolberg et al., 1988; Hunt, 1991; Hunt et al., 1992; Sullivan and Williamson, 1999). The following specimens were collected by Sternberg in 1922 and are potentially from the Fossil Forest:

1. AMNH (American Museum of Natural History) 6325 is the holotype skull of *Pentaceratops sternbergi* (Osborn, 1923). This specimen was collected from "9 miles northeast of Tsaya," and the Fossil Forest lies 7.65 miles at a bearing of 46.5° from the original, now abandoned Tsaya Trading Post (Osborn, 1923; Hunt, 1984, 1991). There are only grassy plains 9 miles NE of Tsaya and , so it appears highly probable that the holotype of *Pentaceratops sternbergi* derives from the Fossil Forest area.

2. Lull and Wright (1942) list a *Kritosaurus ischium* (AMNH 4982) and metapodial (AMNH 4983) at the AMNH as also having been collected 9 mi NE of Tsaya (Hunt, 1984, 1991; Sullivan and Williamson, 1999).

3. The holotype skeleton of *Parasaurolophus cyrtocristatus* (FMNH [Field Museum of Natural History] P27393) was collected by Sternberg and described by Ostrom (1961, 1963) as a new species. Ostrom (1961, p. 575) identified the locality as "near Coal Creek, eight miles southeast of Tsaya, McKinley County." Field notes indicate that Ostrom reported the county name incorrectly (Wolberg et al., 1988), which clears up one problem with this locality information. However, a second problem is that a

locality eight miles SE of Tsaya would be in the Menefee Formation (Santonian-early Campanian), which is too old to yield *Parasaurolophus* (Sullivan and Williamson, 1999). As noted above, the Fossil Forest is almost exactly 8 miles *NE* of Tsaya, so it is likely, as suggested by several authors, that Sternberg's locality was misreported and that FMNH P27393 is actually from the Fossil Forest (Wolberg et al., 1988; Hunt and Lucas, 1992; Sullivan and Williamson, 1999). It is worth noting that a marginal note on Sternberg's field notes at the FMNH indicates that "Sternberg's scrawl is practically illegible" (Wolberg et al., 1988, p. 15).

Sternberg (1932) discussed his expeditions to the San Juan Basin in one of his two autobiographies. However, Wolberg et al. (1988) rightfully note that Sternberg's (1932) writing is confused and sometimes contradictory. However, it is intriguing that he wrote (Sternberg, 1932, p. 210-211) "my best specimen, a *Pentaceratops* skull seven and one-half feet long, and the complete skeleton of a duckbilled dinosaur, were discovered in this formation. This is the only formation where the stumps of trees attached to their own roots stood erect among all the evidences of their past history around them." Given that the only reasonably complete hadrosaur skeleton that Sternberg collected from the San Juan basin was the holotype of *Parasaurolophus cyrtocristatus,* that this specimen was probably collected near the holotype of *Pentaceratops sternbergi*, as discussed above, and that the Fossil Forest area is characterized by multiple standing stumps, it is easy to believe that this passage refers to the Fossil Forest area.

OR STOVALL QUARRIES?

In 1940-1941, J. Willis Stovall (1891-1953) of the University of Oklahoma collected vertebrate fossils from the San Juan Basin. Wann Langston Jr. is the main source of information about these collecting trips (Langston in Kues et al., p. 374-378; Langston, 1989). In 1940, Stovall collected with Don Savage (later professor at the University of California, Berkeley) a specimen assigned field number 40-VIII-1 to 7, which was a partial ceratopsian skeleton that was collected "5 miles south of Wood Ranch" (Langston in Kues et al., p. 376). Apparently there were no other specimens from this area. About 50 years later this specimen was finally prepared, described and mounted and it includes the longest skull of any known terrestrial vertebrate (Lehman, 1988). Langston reviewed unpublished notes and deduced that this specimen (now OMNH [Oklahoma Museum of Natural History]10165) was collected five miles south of the Wood Ranch headquarters, which Wolberg et al. (1988) located in the SE1/4 NW1/4 sec. 36, T24N, R12W. Thus, the locality should be in sec. 25 T23N, R12W, where there are no outcrops. However, the next section north (sec. 24 T23N, R12W) contains the historic quarries under discussion, encompasses extensive outcrops and is highly fossiliferous. It is worth noting, in considering that Stovall may have been 20% in error in his distance estimation, that Langston (in Kues, 1977, p. 374) noted that "in those days the badlands were pretty much trackless wastes and one was never sure exactly where one was."

There is another complication to this story. Langston (in Kues et al., 1977, p. 376) mentions that he could not locate specimen 40-VIII-1 to 7 and that Stovall collected another ceratopsian skeleton in 1941 (specimen IX-1-41 to IX-44-41). This specimen is the second best from the San Juan Basin and is in a "highly carbonaceous flaky shale containing plant fragments and much fossil resin." (Langston in Kues et al., 1977, p. 377) This second specimen is from north of Wood Ranch. The matrix of OMNH 10165 is "carbonaceous shale with red resinous nodules" (Lehman, 1998, p. 895). The similarity of the matrix and the fact that Langston could not locate the more southerly specimen in 1977 suggests that the specimen described by Lehman (1998) may be from north of Wood Ranch. Regardless of the provenience of OMNH 10165, it is clear that in 1940 Stovall did collect in the area of the Fossil Forest and could be the excavator of one of the historic quarries.

OR SMITHSONIAN QUARRIES?

Wolberg et al. (1988) noted that one of Gilmore's (1916) U. S. National Museum hadrosaur localities was from 30 mi S of Farmington and 4 mi E of the Reservation boundary and that this corresponds to the Fossil Forest area. However, the Fossil Forest is closer to 35 mi S of Farmington. It is possible that the specimen is from the Fossil Forest RNA because it is clear that Bauer and Reeside, who collected the specimens described by Gilmore (1916), measured stratigraphic sections in this area (Hunt, 1984). However, Bauer and Reeside did not conduct large excavations, so they would not be responsible for any of the quarries.

There is circumstantial evidence that Gilmore's locality is not in the Fossil Forest. Charles Sternberg met J. B. Reeside in 1921 at the Ojo Alamo Trading Post (Sternberg, 1932; Hunt et al., 1992). Reeside told Sternberg about the geology and fossil localities in the San Juan Basin, and Sternberg acknowledged that much of his collecting success was due to the geologist (Sternberg, 1932; Hunt et al., 1992). If Reeside had collected in the Fossil Forest, it is highly unlikely that he wouldn't have seen the abundance of fossils. However, Sternberg did not collect in the Fossil Forest until the 1922, which suggests that Reeside had not told him about the rich fossil deposits, presumably because he had not seen them.

Gilmore himself collected in the San Juan Basin in 1929, but he was disappointed at the fossil content of the Cretaceous rocks in this area and obviously did not collect in the Fossil Forest (Hunt et al., 1992)

OTHER CANDIDATES

Wolberg et al. (1988) suggested that Charles Sternberg's son George, who was also a prominent dinosaur collector, may have revisited some of his father's localities, but we know of no evidence to back-up this assertion or any specimens that might have resulted from this collecting. The only evidence of Sternberg collections made in the San Juan Basin after 1922 is the reference of Gilmore (1935) to turtles collected in 1923, which we believe is a typographical error. Even if it is not in error, the quarries in the Fossil Forest produced specimens far larger than turtles.

IMPORTANCE OF RECOGNIZING ORIGIN OF QUARRIES

Circumstantial evidence strongly suggests that most of the historic quarries in the Fossil Forest were produced by Charles Sternberg, with possibly one the work of J. Willis Stovall. This is of paleontological importance because it now appears that several dinosaur specimens, including two holotypes (*Pentaceratops sternbergi; Parasaurolophus cyrtocristatus*) were collected in the Fossil Forest. This is also of biostratigraphic importance as we can now demonstrate the two holotypes are probably from the upper member of the Fruitland Formation.

STRATIGRAPHIC POSITION OF FOSSILS FROM THE FOSSIL FOREST AND SUBDIVISIONS OF THE FRUITLAND FORMATION

Clemens (1973) noted that University of Kansas localities microvertebrate localities in Hunter Wash were restricted to a narrow stratigraphic interval in what he considered to the lower Kirtland Shale, but which are in the upper Fruitland Formation of current usage (Hunt and Lucas, 1992). Subsequently, Hunt (1984; 1991; Hunt and Lucas, 1992) demonstrated that, indeed, the majority of fossil vertebrates within the Fruitland-Kirtland sequence are restricted to what is now considered (*sensu* Hunt and Lucas, 1992) the upper portion of the Fruitland Formation. This interval is between the top of the highest coal greater than 1 m in thickness and the base of the Bisti Member of the Kirtland Formation. The stratigraphy of this interval was documented in detail within the Fossil Forest RNA by Hunt (1984), who measured 28 stratigraphic sections. Note that the B sandstone of Hunt (1984) is the basal sandstone of the Bisti Member. The short stratigraphic sequence represented within the Fossil Forest area can be correlated to more extensive exposures in Hunter Wash to the north by correlating the base of the Bisti Member, the highest thick Fruitland coal and a succession of volcanic ashes (Hunt, 1984). Therefore, all of the historic dinosaur quarries in the Fossil Forest RNA are from a thin interval in the uppermost Fruitland Formation, as indeed are most of the other localities subsequently collected there.

This fossiliferous interval is lithologically distinct from the lower portion of the Fruitland Formation principally because it lacks economic coals and consists of rocks deposited in better-drained paleoenvironments (Hunt, 1984; 1992). We name this upper interval of the Fruitland Formation the Fossil Forest Member. The type area is secs. 14, 23 and 24, T23N, R12W. Its type section extends from the SW ¼ NE ¼ sec. 23, T23N, R12W to SW ¼ NW ¼ sec. 24. The Fossil Forest Member is documented by more than a dozen sections in Hunt (1984, Appendix 1, plate 2). The base of the unit is defined as the highest coal greater than 30 cm thick in the Fruitland Formation. It is overlain in its type area by the Bisti Member of the Kirtland Formation and is underlain by the coal-bearing member of the Fruitland Formation that we name below. At its type section, the Fossil Forest Member is about 12 m thick. It is up to at least 25 m thick in other areas. The Fossil Forest Member is distinguished from the lower part of the Fruitland Formation by an absence of thick coal (30 cm or more thick), less carbonaceous shale, less sideritic concretions, and colors of mudrocks indicative of better drainage (green rather than gray). This member is also characterized by a diverse fossil assemblage. It will be important to establish the exact fauna that has been recovered from this member. Previously, many fossils have merely been listed as coming from the upper Fruitland-lower Kirtland.

We name the lower, coal-bearing member of the Fruitland Formation, the Ne-nah-ne-zad Member for the Chapter of the Navajo Nation on whose land the type section is located. The type section is the lower portion of the Bauer's (1916) type section of the Fruitland Formation and is described in detail by Bauer and Reeside (1921, p. 168-169). The base of the Fruitland is the first shale or coal above the massive sandstone of the Pictured Cliffs Sandstone. Locally, *Ophiomorpha*-bearing sandstones of the Pictured Cliffs intertongue with the Ne-nah-ne-zad Member. On the San Juan River, the Ne-nah-ne-zad Member is 13 m thick. Elsewhere, such as in Cottonwood Arroyo, the member is three times as thick and in southern Colorado it can be four times as thick (e. g., Bauer and Reeside, 1921, pl. 22). The Ne-nah-ne-zad Member is conformably overlain by the Fossil Forest Member and is distinguished from the Fossil Forest Member by the presence of thick coals and carbonaceous shales, large channel sandstones and abundant sideritic concretions. Diverse evidence, including paleomagnetic data, radioisotopic dates and biostratigraphic correlation demonstrate that the Fruitland Formation is of Campanian age (Hunt and Lucas, 1992).

REFERENCES

Bauer, C. M., 1916, Contricbutions to the geology and paleontology of San Juan County, New Mexico. 1. Stratigraphy of a part of the Chaco River Valley: U. S. Geological Survey, Professional Paper 98, p. 271-278.

Bauer, C. M. and Reeside, J. B. Jr., 1921, Coal in the middle and eastern parts of the San Juan County, New Mexico: U. S. Geological Survey, Bulletin 716G, p. 155-237.

Gilmore, C. W., 1916, Vertebrate faunas of the Ojo Alamo, Kirtland and Fruitland Formations: U. S. Geological Survey, Professional Paper 98Q, p. 279-308.

Gilmore, C. W., 1935, On the Reptilia of the Kirtland Formation of New Mexico with descriptions of new species of fossil turtles: Proceedings of the U. S. National Museum, v. 83, p. 159-188.

Hall, J. P., 1991, Lower vertebrate paleontology of the upper Fruitland Formation, Fossil Forest area, New Mexico and implications for Late Creatceous terrestrial biogeography [M.S. thesis]: Lawrence, University of Kansas, 125 p.

Hall, J. P., Wolberg, D. L. and West, S., 1988, Dinosaur skin impressions from the Fruitland Formation (Campanian-Maastrichtian) of the Fossil Forest, San Juan Basin, San Juan County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 122, p. 23-27.

Hunt, A. P., 1984, Stratigraphy, sedimentology, taphonomy, and magnetostratigraphy of the Fossil Forest area, San Juan County, New Mexico; [M. S. thesis]: Socorro New Mexico Institute of Mining and Technology, 359 p.

Hunt, A. P., 1991, Integrated vertebrate, invertebrate and plant taphonomy of the Fossil Forest area (Fruitland and Kirtland formations: Late Cretaceous), San Juan County, New Mexico, USA.: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 88, p. 85-107.

Hunt, A. P., 1992, Sedimentology of a fossiliferous fluvial system, Fruitland and Kirtland formations (Late Cretaceous), Fossil Forest area, San Juan County, New Mexico: New Mexico Geological Society, Guidebook 43, p. 47-50.

Hunt, A. P. and Lucas, S. G., 1992, Stratigraphy, paleontology and age of the Fruitland and Kirtland formations (Upper Cretaceous), San Juan Basin, New Mexico: New Mexico Geological Society, Guidebook 43, p. 217-239.

Hunt, A. P., Lucas, S. G. and Mateer, N. J., 1992, Charles H. Sternberg and the collection of Late Cretaceous vertebrate fossils from the San Juan Basin, New Mexico: New Mexico Geological Society, Guidebook 43, p. 241-250.

Kues, B. S., Froehlich, J. W., Schiebout, J. A. and Lucas, S. G., 1977, Paleontological survey, resource assessment, and mitigation plan for the Bisti-Star Lake area, northwestern New Mexico: Unpublished report to the U. S. Bureau of Land Management, Albuquerque, New Mexico, October 31, 1977, 1519 p.

Langston, W. Jr., 1989, A history of vertebrate paleontology at the University of Oklahoma: Unpublished Report, Oklahoma Museum of Natural History, 92 p.

Lehman, T. M., 1998, A gigantic skull and skeleton of the horned dinosaur *Pentaceratops sternbergi* from New Mexico: Journal of Paleontology, v. 72, p. 894-906.

Lucas, 1997, Dinosaurs: The textbook, second edition: Dubuque, William C. Brown, 292 p.

Osborn, H. F., 1923, A new genus and species of Ceratopsia from New Mexico: Amewrican Museum Novitates, no. 93, 3 p.

Ostrom, J. H., 1961, A new species of hadosaurian dinosaur from the Cretaceous of New Mexico: Journal of Paleontology, v. 35, p. 575-577.

Ostrom, J. H., 1963, *Parasaurolophus cyrtocristatatus,* a crested hadrosaurian dinosaur from New Mexico: Fieldiana, Geology, v. 14, p. 143-168.

Rigby, J. K. Jr. and Wolberg, D. L., 1987, The therian mammal fauna (Campanian) of quarry 1, Fossil Forest study area, San Juan Basin, New Mexico: Geological Society of America, Special Paper 209, p. 51-80.

Sternberg, C. H., 1932, Hunting dinosaurs in the bad lands of the Red Deer River, Alberta, Canada: Privately published, 261 p.

Sullivan, R. M. and Williamson, T. E., 1999, A new skull of *Parasaurolophus* (Dinosauria: Hadrosauridae) from the Kirtland Formation of New Mexico and a revision of the genus: New Mexico Museum of Natural History and Science, Bulletin 15, 52 p.

Wolberg, D. L., West, S. Hall, J. P. and Zidek, J., 1988a, Probable caddisfly (Trichoptera: Insecta) larval cases from the Fruitland Formation (Campanian-Maastrichtian) of the Fossil Forest, San Juan County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 122, p. 29-31.

Wolberg, D. L., Hall, J. P., Bellis, D., Chavez, W. X., Anderson, O., Moro, R. and Gil, A., 1988b, Regional historic, stratigraphic, and paleontologic framework of the Late Cretaceous (Campanian-Maastrichtian) Fossil Forest locality near Split Lip Flats, San Juan Basin, San Juan County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 122, p. 7-21.