Stratigraphy, paleontology, and depositional systems of the Eocene Cub Mountain Formation, Lincoln County, New Mexico--A preliminary report

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Stratigraphy, paleontology, and depositional systems of the Eocene Cub Mountain Formation, Lincoln County, New Mexico—a preliminary report

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Introduction

Bodine (1956) first used the name Cub Mountain Formation to refer to "Laramide" strata that lie above the coal-bearing Mesaverde Group and below the volcaniclastic and volcanic rocks of the Sierra Blanca basin in western Lincoln County, New Mexico (Fig. 1). Although it was then clear that the age of the Cub Mountain Formation must be Late Cretaceous and/or early Tertiary, no precise age data were available. This resulted in varied age assignments and differing interpretations of the stratigraphic relationships of the Cub Mountain Formation to nearby "Laramide" units. Furthermore, no precise information on the depositional environments, provenance, and evolution of the Cub Mountain depositional basin has been published. In this paper we present a preliminary effort to determine the stratigraphy, age, depositional environments, and provenance of the Cub Mountain Formation near its type section.

Previous studies

Prior to 1956, strata of the Cub Mountain Formation either were included in the Upper Cretaceous Mesaverde Group or apparently were not recognized (e.g., Campbell, 1907; Wegemann, 1914; Sidwell, 1946; Allen and Jones, 1951). Bodine (1956, p. 8) introduced the term Cub Mountain Formation and mapped its distribution in the vicinity of Capitan. Although he indicated that the formation name was for Cub Mountain south of Carrizozo, Bodine did not designate or describe a type section for the Cub Mountain Formation. (A footnote inadvertently omitted from Bodine's article would have credited the concept of the Cub Mountain Formation to R. H. Weber and explained that proper definition of the unit was forthcoming in an article by Weber.) Nevertheless, Bodine (1956, p. 9) presented evidence that at least 100 m of strata are missing between the Cub Mountain Formation and underlying Mesaverde Group. Although he noted that the Cub Mountain Formation could be as old as Late Cretaceous or as young as Miocene, Bodine (1956, p. 10) concluded that "apparently, the Cub Mountain formation is another Tertiary intermountain deposit, similar to the Baca formation of Socorro County, the Galisteo formation of north-central New Mexico, and possibly the McRae formation of south-central New Mexico." Griswold (1959, p. 12) noted the similarity of the Cub Mountain Formation to the Baca Formation of west-central New Mexico and assigned it an "early Tertiary" age. Lochman-Balk (1964, p. 58) listed a "latest Upper Cretaceous(?) (sic) - Eocene(?)" age for the Cub Mountain Formation, and Kelley and Thompson (1964, p. 120) equated the Cub Mountain and McRae formations (also see Thompson, 1964, 1966, 1972) and assigned them a "Laramian and Paleocene" age.

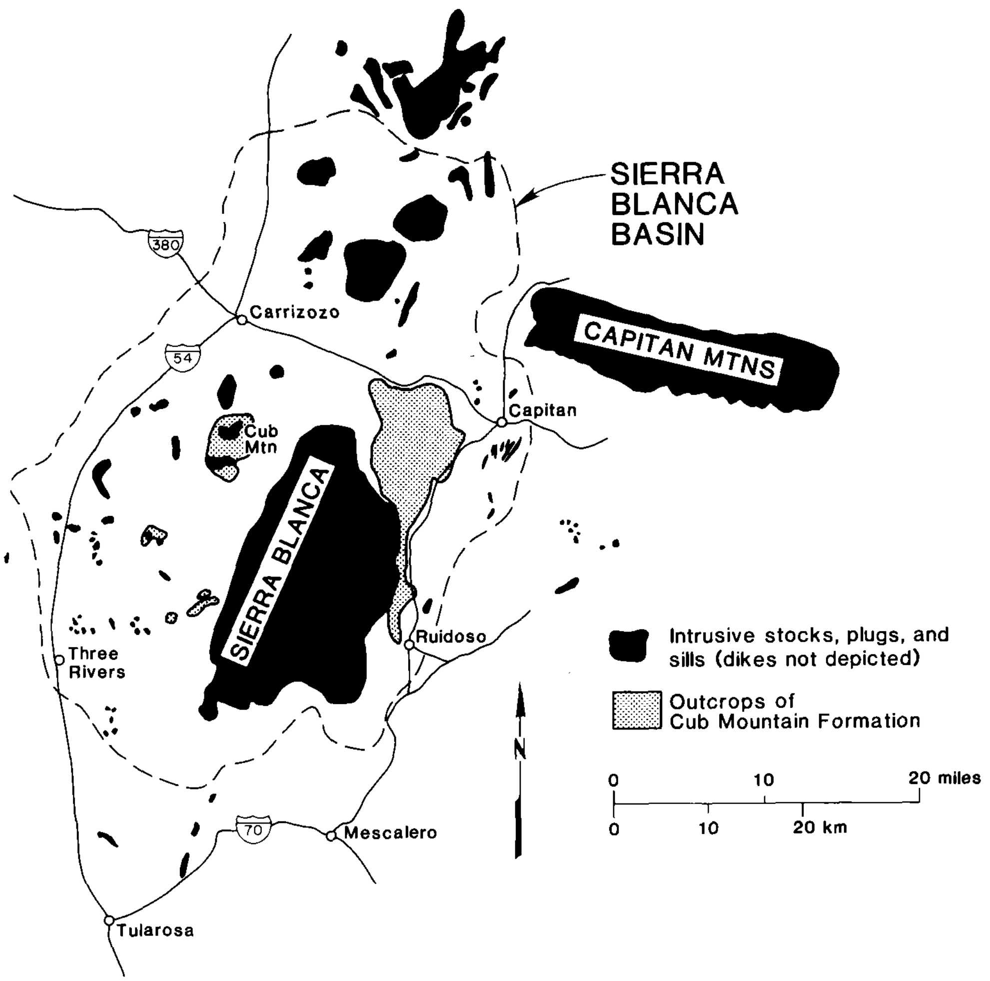


FIGURE 1—Outcrops of the Cub Mountain Formation and intrusive igneous rocks in vicinity of Sierra Blanca basin (modified from Dane and Bachman, 1965).

Weber (1964, p. 105) designated and described a type section of the Cub Mountain Formation in Sanders Canyon between Cub and Chaves Mountains (Fig. 2), from the SW1/4SW1/4, sec. 16 to the SW1/4SW1/4, sec. 24, T9S, R10E. According to Weber (1964), the Cub Mountain type section is about 730 m of light-colored arkosic sandstone interbedded with dominantly red mudrock and minor conglomerate consisting of pebbles of quartzite, silicic volcanic rocks, chert, granite, and petrified wood. He also noted volcanic debris in the upper part of the Cub Mountain Formation and suggested it might provide a basis for dividing the Cub Mountain into two members, a lower, nonvolcanic member and an upper, volcanic member. Weber (1964, p. 106) very tentatively correlated the Cub Mountain with the Eocene Baca Formation.

In the two decades that followed Weber's (1964) article, very little work was done on the Cub Mountain Formation. Thompson (1966, p. 17–19) argued on a lithologic basis for identity of the Cub Mountain Formation and the McRae Formation in the Elephant Butte area of Sierra County. He also mapped

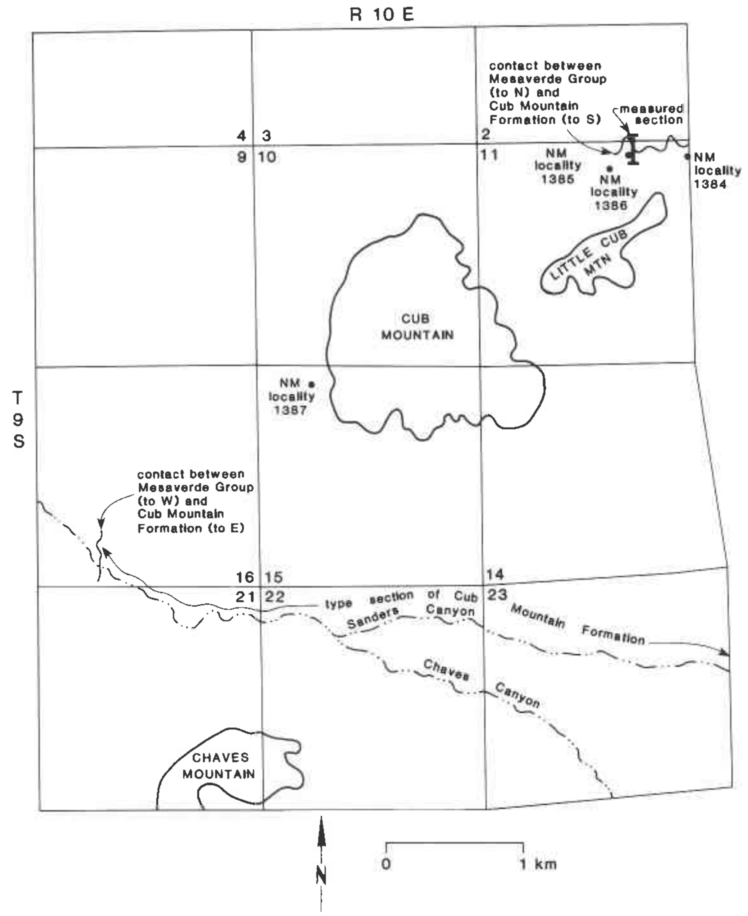


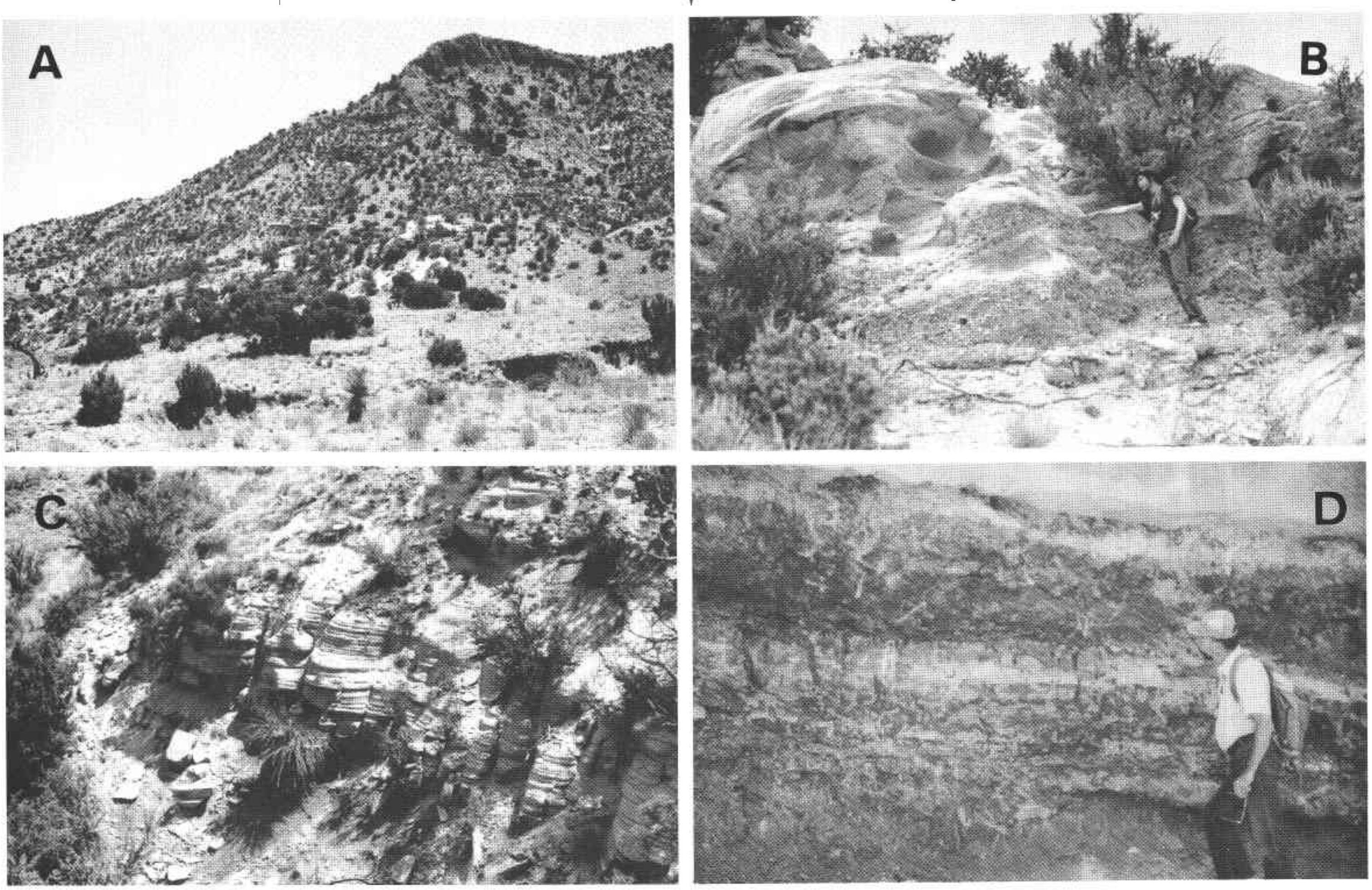
FIGURE 2—Location of fossil localities, measured stratigraphic section and Cub Mountain–Mesaverde Group contact in the Chavez Canyon–Little Cub Mountain area.

the distribution of the "McRae Formation" in the Sierra Blanca–Cub Mountain area (Thompson, 1966, fig. 1). Kelley (1971, p. 29) assigned the Cub Mountain Formation a Paleocene age, although in his map (pl. 1) of the Ruidoso–Capitan area he denotes a Cretaceous–Tertiary age (as "TKCM"). Lucas and Ingersoll (1981) and Chapin and Cather (1981) assigned an Eocene age to the Cub Mountain Formation based, again, on its similarity to the Baca Formation. However, Allen and Kottlowski (1981, p. 22) indicated a Cretaceous–Paleocene age. Smith et al. (1985) assigned a middle Eocene–early Oligocene age to the Cub Mountain Formation.

Stratigraphy and depositional environments

We examined two stratigraphic sections of the Cub Mountain Formation, one partial and one complete, during June, 1987. The partial section is located on the northern flank of Little Cub Mountain (Fig. 3A); the complete

FIGURE 3—Some outcrop photographs of the Cub Mountain Formation. **A,** Overview of section on northern flank of Little Cub Mountain. **B,** Basal conglomerate of Cub Mountain Formation near Little Cub Mountain (Unit 5 of measured section in Figure 4). **C,** Interbedded sandstone and mudstone at the stratigraphic level of vertebrate-fossil occurrences at NM localities 1384, 1385 and 1386 (sandstone outcrop is about 5 m thick). **D,** Root traces and burrows in red mudstone exposed in Chaves Canyon.



section is exposed along Chaves and Sanders Canyons (Fig. 2). At both sections, the Cub Mountain Formation disconformably overlies strata of the Upper Cretaceous Mesaverde Group. Although no angular unconformity is apparent locally, Kelley and Thompson (1964) and Kelley (1971) noted that the Cub Mountain Formation oversteps progressively older Cretaceous units to the east. The basal contact is exposed in Chaves Canyon in the SW1/4, sec. 16, T9S, R10E and north of Little Cub Mountain in the NE1/4, sec. 11, T9S, R10E (Fig. 2). A basal conglomeratic sandstone (Fig. 3B) marks the upsection change from drab mudstone, sandstone, and rare pebbly sandstone of the Mesaverde Group to the coarser sandstone, variegated red mudstone, and conglomerate of the Cub Mountain Formation (Fig. 4).

No precise lithologic definition of the Cub Mountain Formation has been published. Perhaps because of ambiguities in its definition, Arkell (1983, 1986) extended the term Cub Mountain to include beds mapped as Mesaverde Group by Weber (1964) and Thompson (1966). Our work supports assignment of these beds to the Mesaverde Group because of their lithologic similarity to Mesaverde exposures to the west and their dissimilarity to the coarser grained, more brightly hued beds that overlie them. In our view, Arkell's (1983) basal unit and lower part of the main body of the Cub Mountain Formation are correlative with the Mesaverde Group and are separated from superjacent Tertiary strata by an unconformity.

The Cub Mountain Formation is about 730 m thick (Weber, 1964), although the upper part of the section in Sanders Canyon may be repeated by faulting. Estimated average conglomerate:sandstone:mudstone ratio is about 5:70:25 in exposures near Cub Mountain, and the unit becomes finer grained upsection. Sandstone is the dominant lithology and mainly occurs as gray to pink tabular units that contain abundant horizontal and low-angle stratification and minor trough crossbedding (Fig. 3C). Conglomerate is largely restricted to the lower one-third of the formation and commonly occurs in scours in the basal portions of sandstone units (Fig. 3B). Pebbles are dominantly chert and quartzite with subordinant felsic volcanic, sandstone, siltstone, limestone and silicified wood clasts. Maximum clast size is about 10 cm. Mudstone units are tabular in shape and typically display variegated red coloration. Evidence of bioturbation in mudstones is common (Fig. 3D), and calcareous nodules of probable pedogenic origin were occasionally noted.

Stratification styles in the sandstone lithosome are similar to those described by McKee et al. (1976) for modern flood deposits of ephemeral Bijou Creek, Colorado. Interbedded mudstones presumably accumulated in vegetated flood basins and ponds adjacent to aggrading channel complexes. Overall, facies characteristics are quite similar to those of distal-fan deposits of the Eocene Baca Formation (Cather and Johnson, 1984, 1986), al-

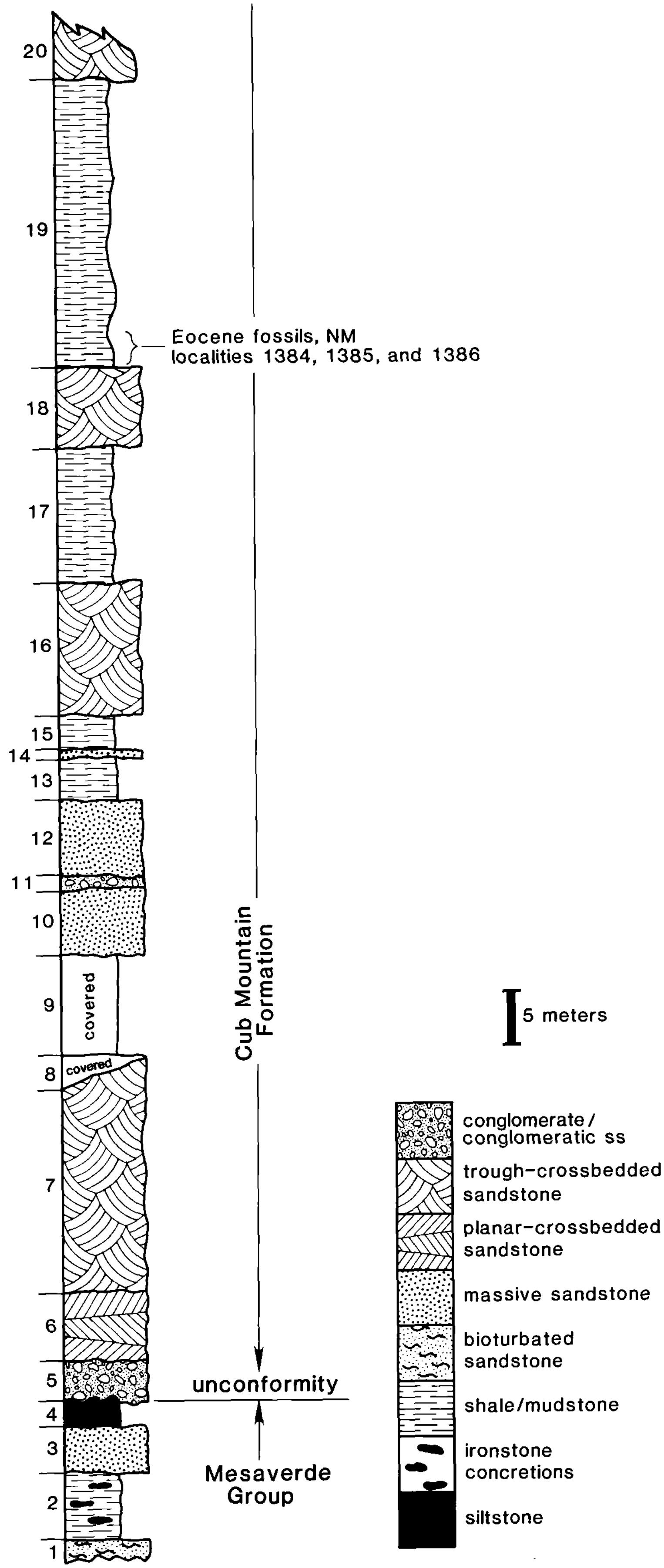


FIGURE 4—Measured stratigraphic section of the lower part of the Cub Mountain Formation on the northern slope of Little Cub Mountain. See Figure 2 for location of section and Table 1 for description of lithologic units.

though the Cub Mountain Formation contains significantly more mudstone.

The upper contact of the Cub Mountain Formation is defined by the first upsection occurrence of abundant volcaniclastic detritus. Although poorly exposed in Sanders Canyon and its tributaries, the contact appears to be conformable, with interbedding of volcanic and nonvolcanic sandstone and mudstone occurring over a stratigraphic interval of at least several tens of meters.

Paleontology and correlation

We collected fossil bone from the Cub Mountain Formation at four localities (Fig. 2): 1) NM locality 1384 in the NE1/4SE1/4 NE1/4 NE1/4NE1/4, sec. 11, T9S, R10E; 2) NM locality 1385 in the NE1/4SE1/4NE1/4NW1/4 NE1/4, sec. 11, T9S, R10E; 3) NM locality 1386 in the SW1/4SW1/4NE1/4NW1/4NE1/4, sec. 11, T9S, R10E; and 4) NM locality 1387 in the NW1/4SW1/4NW1/4NE1/4NW1/4, sec. 15, T9S, R10E. NM localities 1384, 1385 and 1386 are within about 0.5 km of strike in the same interval of grayish-red mudstone, 94–98 m above the base of the Cub Mountain Formation (Fig. 4; Table 1). NM locality 1387, which only produced unidentifiable bone fragments, is in similar mudstone on the southwestern flank of Cub Mountain about 3 km southwest of the other localities.

Four identifiable vertebrate fossils, of unquestionable Eocene age, were collected at these localities. Three of these are turtles. NMMNH (New Mexico Museum of Natural History) P–3601 from locality 1386 consists of ventral fragments of the right third and fourth peripherals articulated with a fragment of the hyoplastral buttress, the distal part of a posterior peripheral, and four costal fragments. NMMNH P–3602 from locality 1385 is a fragment of the medial part of a hypoplastron and a peripheral 7 fragment. Both of these specimens pertain to *Baptemys* sp.

Two of the costal fragments exhibit ripple-like ornamentation, and one of them is crossed by the sinusoidal tract of a pleural sulcus. The fragment of plastron and the associated peripherals (Fig. 5A) are tightly articulated with the hyoplastral buttress extending onto the third peripheral. The marginal 4–5 sulcus is finely incised and irregular. The axillary scale extends just lateral to the peripheral–plastral suture, and the area covered by the scale is inflated ventrally. The free edge of the posterior peripheral fragment is bluntly acute. The fine texture of the external bone surfaces, where undamaged, is smooth.

Only two species of *Baptemys* are recognized here as valid: *Baptemys garmanii* (Cope, 1872) (= *Baptemys tricarinata* Hay, 1908, and *Dermatemys costilatus* Cope, 1872) and *Baptemys wyomingensis* Leidy, 1870 (= *B. fluviatilis* Hay, 1908). The two taxa are distinguished on the basis of size, ornamentation of the carapace (carinae), and expansion of the plastral lobes and bridges. Although the Cub Mountain fragments are fully consistent with assignment to the genus *Baptemys*, they are not clearly diagnostic at the species level. Size approximates that of large *B. garmanii*. In Wyoming, where the best samples are known, there is a general increase in size through time. The Cub Mountain material agrees well in size with that of *B. garmanii* and an undescribed taxon from the Cathedral Bluffs Member of the Wasatch Formation of Wyoming that is intermediate in morphology between *B. garmanii* and *B. wyomingensis*. The sculpture of the shell agrees best with that of the intermediate taxon. The genus *Baptemys* is presently known to range

TABLE 1—Measured stratigraphic section of part of the Mesaverde Group and Cub Mountain Formation north of Little Cub Mountain in the E1/2 NE1/4 NW1/4NE1/4, sec. 11, T9S, R10E, and the SE1/4SE1/4SW1/4SE1/4, sec. 2, T9S, R10E, Lincoln County. Strata dip about 15° to south-southeast. Colors are those of Goddard et al. (1948). Section measured by S. G. Lucas and P. Sealey during June 1987 using Brunton compass and 1.5–m staff.

Unit	Lithology	Thickness (m)
	Cub Mountain Formation (Eocene)	
20	Sandstone, same color and lithology as unit 18.	not measured
19	Mudstone, grayish-red (10 R 4/2), slightly calcareous. Fossils (NM localities 1384, 1385, and 1386) occur in lower 3.3 m, upper 18 m much covered by colluvium.	24.4
18	Sandstone, pale-red (10 R 6/2), weathers to grayish-red (10 R 4/2), quartzose, medium-grained, well-sorted, subrounded to rounded, hematitic. Multiple scour surfaces divide beds with low-angle, large-scale, arcuate crossbeds and planar beds with a thin (0.3 m) lenticular (~3 m of strike) bed of limestone pebble conglomerate like unit 11 in middle.	7.6
17	Sandy mudstone, variegated grayish-red (5 R 2/4 and 10 R 4/2), medium light gray (N 6), light bluish-gray (5 B 5/1), calcareous; much covered by colluvium.	12.8
16	Sandstone, very pale orange (10 YR 8/2), quartzose, fine to very coarse grained, poorly sorted, rounded, noncalcareous; trough crossbeds.	12.2
15	Shale, light olive-gray (5 Y 6/1), weathers olive-gray (5 Y 4/1), noncalcareous, much covered; some mudstone like unit 19.	3.0
14	Sandstone, grayish orange-pink (5 YR 7/2), weathers to pale-brown (5 YR 5/2), quartzose, fine-grained, well-sorted, subrounded to rounded, hematitic, noncalcareous; platey weathering of beds.	0.6
13	Mudstone, grayish-red (10 R 4/2), noncalcareous.	3.6
12	Sandstone, same color and lithology as unit 10.	6.7
11	Conglomerate: matrix is pale yellowish orange (10 YR 8/6); clasts are light gray (N 6), matrix supported. Maximum clast size is about 1 cm. Clasts are limestone, siltstone, and chert; matrix is quartzose, fine- to medium-grained, poorly sorted, subangular to subrounded sandstone, slightly calcareous, massive.	0.9
10	Sandstone, white (N 9) and very light gray (N 8), quartzose, medium- to coarse-grained, poorly sorted, subrounded, noncalcareous, hematitic, massive.	6.1
9	Covered.	9.1
8	Covered. Lower 0.9 m is sandstone like unit 7.	3.0
7	Sandstone, pale yellowish-orange (10 YR 8/6) and grayish-orange (10 YR 7/4), weathers pale-brown (5 YR 5/2), quartzose, fine-grained, poorly sorted, subrounded, hematitic, slightly calcareous, trough crossbedded; some carbonaceous material on beds.	18.3
6	Sandstone, pale yellowish-orange (10 YR 8/6) and dark yellowish-orange (10 YR 6/6), weathers pale yellowish-brown (10 YR 6/2), quartzose, medium- to coarse-grained, moderately sorted, subangular to subrounded, noncalcareous, hematitic; planar crossbeds, some thin (3 cm) gravel beds, scour surfaces.	6.4
5	Conglomerate and sandstone. Conglomerate is clast supported; clasts are dominantly quartzite pebbles as much as 12 cm in diameter (minor chert and felsic volcanics). Sandstone is same lithology as unit 7, grayish-orange (10 YR 7/4), weathers moderate-brown (5 YR 4/4); clasts are dark yellowish orange (10 YR 6/6), light gray (N 8) medium light gray (N 6) and medium gray (N 5).	4.0
	disconformity	
	Mesaverde Group (Upper Cretaceous)	
4	Siltstone, light greenish-gray (5 GY 8/1 and 5 G 8/1), noncalcareous; some ironstone concretions like unit 2.	2.4
3	Sandstone, pale yellowish-orange (10 YR 8/6) and grayish-orange (10 YR 7/4), quartzose, fine- to coarse-grained, poorly sorted rounded, hematitic, noncalcareous, massive, friable.	4.2
2	Shale, medium light gray (N 6), weathers yellowish-gray (5 Y 8/1), noncalcareous; contains ironstone concretions that are moderate brown (5 YR 3/4), dusky yellowish brown (10 YR 2/2), noncalcareous.	6.4
1	Sandstone, very light gray (N 8), weathers moderate-brown (5 YR 4/4), quartzose, noncalcareous, bioturbated.	0.2

from the late Graybullian through Bridgerian (Hutchison, 1980). *Baptemys garmanii* is known from the later Graybullian through Lostcabinian, the intermediate taxon from earliest Bridgerian (Bridger A and Cathedral Bluffs Member of the Wasatch Formation), and *B. wyomingensis* from middle to late Bridgerian (Bridger B–E).

NMMNH P–3603 from locality 1385 is fragments of peripherals (6), costals (2), epiplastra (3) and other bones (8) of a turtle we identify as *Echmatemys* sp. The epiplastral fragments (Fig. 5B, C) have extensive overlap of the gular scales medially on the dorsal surface. Thickened lateral gular projections enclose a depressed trough medially on the dorsal side, but this trough is not reflected ventrally. The hypoplastral fragments show that the humeral–pectoral sulcus lies posterior to the entoplastron, and that there is a thick and nonkinetic suture between the hyo- and hypoplastron. Other fragments show that the plastral buttresses rise vertically from the plastron and are set medial to the margins of the plastral lobes (Fig. 5D). The pleural-marginal sulcus lies above the proximal suture of peripheral 11. The plastral scales overlap extensively the dorsal margins of the plastral lobes. The single proximal fragment of either costal 3 or 5 indicates the presence of an octagonal neural in the neural series and lacks any indication of swelling at the pleural–vertebral margin. The fragments indicate a plastral length of as much as approximately 23 cm.

The broad plastra with thickened gular projections, extensive overlap of the plastral scales dorsally, especially on the medial part of the epiplastron, post-entoplastral position of the humeral–pectoral sulcus, vertical and medial position of the plastral buttresses, and dorsal position of the posteriormost marginal scales are consistent with or diagnostic of the common Eocene batagurid *Echmatemys*. The systematics of the species within this genus are in need of extensive revision. The Bridgerian species are clearly over split. In the Wyoming sections where the genus is most extensively known and abundant, there is a general increase in size through time. The Cub Mountain material appears to lie in the size range of later Wasatchian to earliest Bridgerian *Echmatemys* in the Wyoming sections. The Wasatchian species from Wyoming, moreover, are characterized by a swelling of the costal bones just lateral to the vertebral–pleural sulcus that is lacking from the Bridgerian and Uintan species (as in the Cub Mountain taxon). This swelling, however, may be absent or only weakly developed in the San Jose Formation *E. lativertebralis* (Cope, 1875). The posterior placement of the humeral–pectoral sulcus is generally typical of the Wasatchian species, whereas it typically overlaps the entire plastron of the Bridgerian species. In species from the Cathedral Bluffs Member of the Wasatch Formation, however, the modal condition resembles that of the Wasatchian species. *Echmatemys* in North America is characteristic of and limited to the Eocene. The combination of characters in the Cub Mountain *Echmatemys* in comparison with the standard sequence in Wyoming and Utah indicates a late Wasatchian or earliest Bridgerian age.

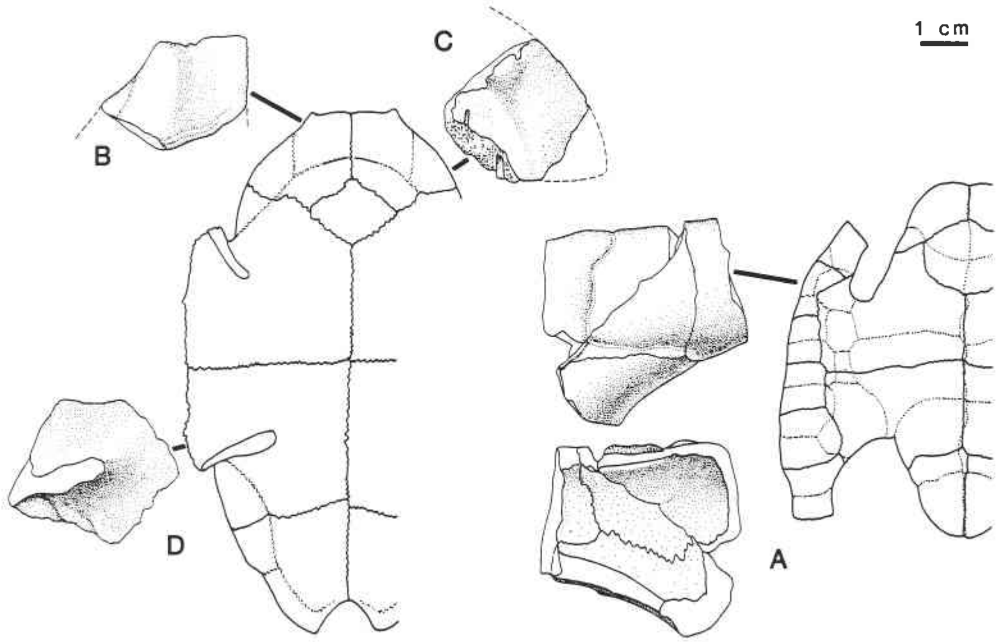


FIGURE 5—Fossil turtles from the Cub Mountain Formation. **A,** *Baptemys* sp., NMMNH P–3601, ventral and dorsal views of part of right axillary region compared to ventral view of plastron of *B. wyomingensis*. **B–D,** *Echmatemys* sp., NMMNH P–3602, 3603, dorsal views of right and left epiplastral fragments (**B, C**) and left hypoplastral fragment (**D**) compared to a dorsal view of a late Wasatchian *Echmatemys* from Wyoming. Scale line refers only to Cub Mountain specimens.

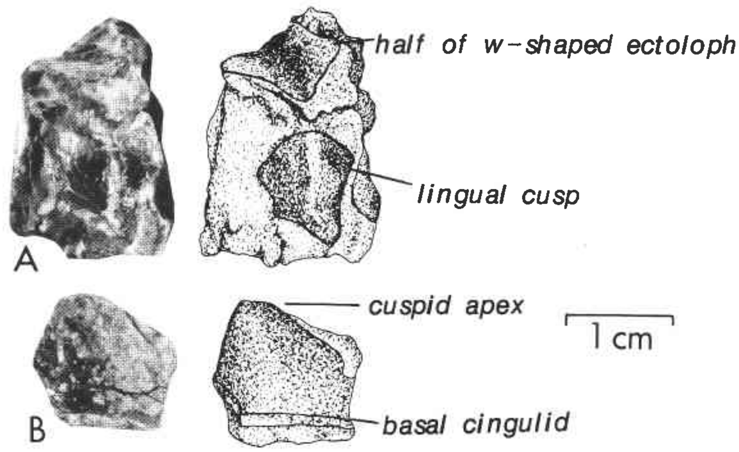


FIGURE 6—NMMNH P–3604, fragments of brontothere(?) molars from the Cub Mountain Formation. **A,** occlusal view of upper molar fragment preserving part of w-shaped ectoloph and a lingual cusp. **B,** lateral view of lower molar(?) cuspid fragment.

NMMNH P–3604 is two fragments of a mammalian upper cheek tooth from locality 1384 (Fig. 6). These fragments represent a bunolophodont tooth with at least one low, blunt lingual cusp and a shallow w-shaped ectoloph labially. The minimum width of this tooth is 20 mm, and parts of its enamel are finely lineated. Clearly, this is the tooth of a relatively large mammal. Overall closest similarity is to upper molars of *Palaeosyops* and *Manteoceras* (sensu Osborn, 1929) grade brontotheres. These are Bridgerian taxa, and a brontothere of similar grade is known from the Baca Formation in the Carthage area of Socorro County (Lucas et al., 1982).

Thus, the fossil evidence from the Cub Mountain Formation indicates, without question, an Eocene age. More precisely, a latest Wasatchian or early Bridgerian age, about 50 ± 2 Ma, is probably indicated. This age is consistent with radiometric-age data ☞

on dikes and dike swarms that post-date Cub Mountain deposition. Moore and Foord (1986, p. 31) recently reported K/Ar age-determinations of 47.7 ± 2.9 Ma provided by R. F. Marvin of the U.S. Geological Survey on alkali-gabbro and monzo-gabbro dikes and dike swarms in the Sierra Blanca vicinity.

Paleocurrents and provenance

Paleoflow during deposition of the Cub Mountain Formation, as shown by pebble imbrication and parting-step lineation, was northeasterly in the study area (Fig. 7). Because the study area is located in the western part of the Sierra Blanca basin, paleoflow was roughly tangential to the present basin margin. These data indicate that Eocene drainage in the Sierra Blanca basin was not centripetal, which supports the concept that synclinal downwarping of the basin *postdated* deposition of the Cub Mountain Formation (Kelley and Thompson, 1964; Kelley, 1971).

Most detrital components of Cub Mountain sandstones and conglomerates were derived from older sedimentary sources. Quartzite, chert, and subordinant felsic volcanic pebbles dominate conglomerates in the study area; pebbles of these lithologies occur in trace amounts in the underlying Mesaverde Group and are common in conglomerate beds of the Ash Canyon Member of the Crevasse Canyon Formation (Wallin, 1983) to the southwest. Other pebble varieties (limestone, sandstone, siltstone, silicified wood) in the Cub Mountain Formation were clearly derived from Mesozoic and Paleozoic sedimentary units. Although Weber (1964) reports minor granitic clasts in the Cub Mountain Formation, none were noted during the present study.

Preliminary petrographic analysis of three sandstones indicates a dominance of sedimentary rock fragments in the lithic fraction. Contributions from crystalline basement rocks appear to be minimal. Minor but persistent amounts of volcanic rock fragments, plagioclase, and biotite are present throughout the Cub Mountain Formation. However, as noted above, this material may have been recycled from the underlying Mesaverde Group. Provenance of the Cub Mountain Formation thus can be only loosely constrained at present; source terranes were to the southwest and consisted primarily of older sedimentary rocks. At least two potential source regions can be postulated.

The Rio Grande uplift (Fig. 8) of Seager and Mack (1986) was a northwest-trending, late Laramide uplift in south-central New Mexico that shed clastic detritus (Love Ranch Formation) mostly during Eocene time. Sediments were transported both to the southwest into the Potrillo basin and northeast into the Love Ranch basin. Deposits of the Love Ranch basin become markedly finer toward the northeast, in the direction of the Sierra Blanca basin. Clast types are locally variable and include Mesozoic, Paleozoic, and Precambrian lithologies (Seager, 1981; Seager and Mack, 1986).

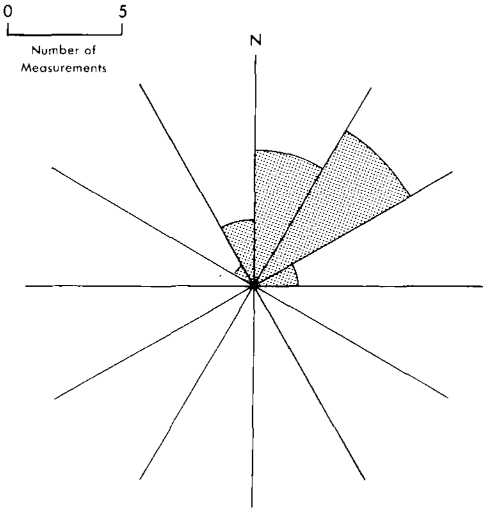


FIGURE 7—Paleocurrent-rose diagram based on 20 measurements of pebble imbrication and parting-step lineation from the Cub Mountain Formation in Chaves Canyon–Little Cub Mountain area.

An alternative source region for the Cub Mountain Formation is the Tularosa uplift (Fig. 8; Herrick, 1904, p. 75; Eardley, 1962, p. 399; Kottlowski et al., 1956, p. 73; Chapin and Cather, 1981), a poorly documented and controversial uplift that may have collapsed to form the present Tularosa Basin. With the exception of Mesozoic units penetrated by three wells in the extreme northeastern part of the Tularosa Basin near Three Rivers (King and Harder, 1985), borehole and outcrop data indicate poorly consolidated Quaternary to Tertiary(?) sediments directly overlie Permian strata throughout the eastern part of the basin. Where absent, Mesozoic sedimentary units may have been stripped during broad upwarping, possibly during the Late Cretaceous or early Tertiary. Alternatively, these units may have been eroded during late Tertiary crustal extension (W. R. Seager, oral comm. 1988). At present, the Tertiary structural development of the Tularosa Basin area is poorly understood, primarily due to lack of borehole and seismic data on the White Sands Missile Range, in the critical western part of the basin.

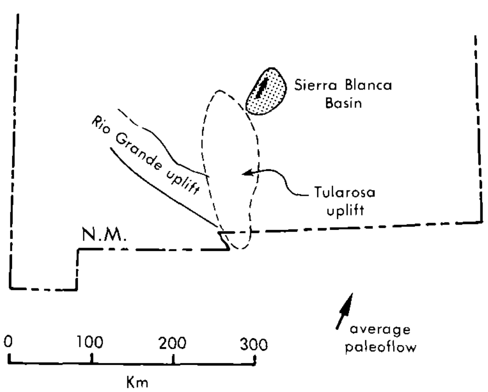


FIGURE 8—Laramide paleogeographic map showing Sierra Blanca basin, average paleoflow in the study area, and postulated source areas for the Cub Mountain Formation.

Summary

Near its type locality, the Cub Mountain Formation is as much as 730 m of interbedded sandstone, mudstone, and minor conglomerate that were deposited by northeast-flowing braided streams. Fossil vertebrates collected about 100 m above the base indicate an Eocene age (near the Wasatchian–Bridgerian boundary, about 50 ± 2 Ma). Lithologic and paleocurrent data for the Cub Mountain Formation suggest derivation from source terranes to the southwest that exposed dominantly older sedimentary rocks. Potential source regions include the Laramide Rio Grande and Tularosa uplifts although further study is needed to better constrain the provenance of the Cub Mountain Formation.

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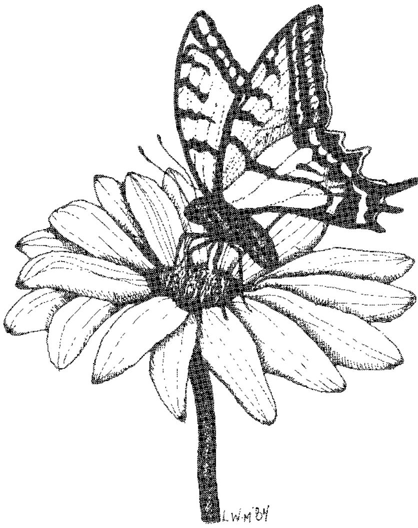
New Mexico Geological Society
Spring Meeting

The New Mexico Geological Society will hold its annual spring meeting on Friday, April 7, 1988 in Macey Center at the New Mexico Institute of Mining and Technology, Socorro, New Mexico. This meeting promotes the dissemination of the results of recent research on the geology of New Mexico. The morning sessions cover geophysics/petrology/structural geology and stratigraphy/sedimentology/paleontology. The afternoon sessions cover geochemistry/economic geology and hydrology/environmental geology. Registration materials are available from Virginia T. McLemore, New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico 87801, (505) 835–5521.

Fall Field Conference

The New Mexico Geological Society will hold its 40th annual field conference in the Acoma–Grants–Zuni–Gallup area of west-central New Mexico from September 29 to October 1, 1989. Several stops on this bus tour will emphasize the southeastern Colorado Plateau as a zone of tectonic transition where Laramide strike–slip faults and monoclinal uplifts have partially collapsed in response to late Cenozoic extension and magmatism. Other stops will address advances in Jurassic, Cretaceous, and Tertiary stratigraphy; the relationship of coals to basement structures and shore lines; and the recognition of paleoweathering zones. Stops at the scenic Acoma and Zuni Pueblos will allow for brief shopping sprees and cultural enrichment. The conference will convene at, and return to Albuquerque, just prior to the AAPG Rocky Mountain Section meeting. For additional information contact co-chairmen Orin Anderson (505/835–5122) or Richard Chamberlin (505/835–5310) at the New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico 87801.



Frank Wayne Campbell
(1947–1988)

Frank W. Campbell was born on May 31, 1947 in Long Beach, California, the son of Paul and Zella Campbell. He came to New Mexico Institute of Mining and Technology to study geology and graduated with a BS degree in 1971, the same year he married Sue Lynn Rose. They moved to Rapid City, South Dakota where Frank attended the South Dakota School of Mines. He received an MS degree in geology there in 1975. Job openings in geology were scarce at that time, so Frank and Sue moved back to California, where he operated a pet shop and indulged his love of tropical fish.

In 1978, when there was an increased interest in coal in New Mexico, the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) had three openings for coal geologists. Frank applied, along with many others, and was hired to fill one of these positions. His projects included the mapping and stratigraphic interpretation of coal outcrops in the Fence Lake–Salt Lake coal field; he set up and directed the drilling program in this field. Frank has been one of the principal investigators in the NMBMMR's four-year study of the quality and quantity of New Mexico strippable coals.

Beginning in the early 1980's Frank developed a coal analytical laboratory at the NMBMMR capable of determining heating values, proximate and ultimate analyses, forms of sulfur, ash-fusion temperatures, water-soluble alkalies, major oxides, and trace-element composition of coals. He was the first professional staff member to routinely use a personal computer for his work. At a time when PCs were not in use in the Bureau, he bought one himself and installed it in his office. Frank's scientific accomplishments are evident through his many published papers and open-file reports. At the time of his death publication was imminent of GM–62, *Geology and coal resources of Fence Lake 1:50,000 quadrangle, New Mexico,* a compilation by Frank of eight 1:24,000-scale quadrangles in west-central New Mexico.

Frank loved science fiction, military history, classical music, and opera. But his most important interest away from his job was his family. He adored his wife Sue and their two children, Elizabeth Katie born in 1975 and Paul Clayton born in 1981.

Frank Campbell died on December 3, 1988. Throughout the years and final months of his illness he showed us all how to laugh in spite of pain and how to live in spite of dying. He was a shining example of quiet courage.

—*Lynn Brandvold*