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Stratigraphy and tectonic implications of Paleogene strata in the Laramide Galisteo Basin, north-central New Mexico

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Abstract

We exclude the lower 0-442 m from the Galisteo Formation and identify it as a new, unconformity-bounded stratigraphic unit, the Diamond Tail Formation. The Diamond Tail Formation is dominantly coarse-grained subarkosic to arkosic sandstone and conglomeratic sandstone with lesser amounts of drab, green, gray, and maroon mudstone. It crops out in north-central New Mexico in the Hagan Basin and the Madrid-Cerrillos-Galisteo area where it unconformably overlies Upper Cretaceous strata of the Mesaverde Group and is unconformably overlain by lower Eocene red-bed strata of the Galisteo Formation. The index fossil *Hyracotherium* sp. establishes the Wasatchian (late Paleocene-early Eocene) age of the upper part of the Diamond Tail Formation. The Diamond Tail Formation is tentatively correlated with the Cuba Mesa and Regina Members of the San Jose Formation and appears to record an early phase of Laramide trans-tensional subsidence in the Galisteo Basin.

Introduction

The boundary between Cretaceous and Paleogene rocks in north-central New Mexico has long been identified as the base of the Galisteo Formation. This boundary is a profound regional unconformity between rocks of Late Cretaceous and putative early Eocene age that has been interpreted to reflect a major pulse in Laramide tectonism. This pulse established the Laramide Galisteo Basin as a depocenter during Paleogene time. Here, we reinterpret the stratigraphic relationships of the lower part of the Galisteo Formation and modify previous concepts of the late Laramide evolution of the Galisteo Basin.

Previous studies

Stearns (1943) established the criteria used by subsequent workers to recognize and map the base of the Galisteo Formation in north-central New Mexico. As noted by Stearns (1943), there is a disconformable contact between the Eocene Galisteo Formation and the Upper Cretaceous Mesaverde Group. As summarized by Lucas (1982, p. 9):

> Mesaverde sandstones below the contact are fine to medium grained and thinly laminated. In contrast, Galisteo sandstones above the contact are coarse grained to conglomeratic and are more thickly laminated. Most Mesaverde mudstones are gray and black (organic rich). Most mudstones of the Galisteo Formation, however, are green andred. Although the Mesaverde-Galisteo contact locally appears to be conformable, regionally the contact is a major unconformity representing much of the Late Cretaceous and probably some of the early Tertiary (Stearns, 1943; Gorham, 1979; Beaumont, 1979).

These criteria of Stearns (1943) for selecting the Mesaverde-Galisteo contact are well accepted and have provided the basis for most subsequent mapping (e.g., Disbrow and Stoll, 1957; Bachman, 1975; Picha, 1982) and interpretation of the Laramide depositional and tectonic history of the Galisteo Basin (Baltz, 1978; Chapin and Cather, 1981; Gorham, 1979; Gorham and Ingersoll, 1979; Lucas and Ingersoll, 1981; Lucas, 1984; Smith et al., 1985; Cather, 1992; Lucas and Williamson, 1993; Abbott et al., 1995). In this paper, we demonstrate that the Galisteo Formation as currently construed consists of two tectonosequences, i.e., two lithologically distinctive, unconformity-bounded units deposited as responses to separate tectonic events. We eliminate the lower tectonosequence from the Galisteo Formation and identify it as a lithologically distinct, mappable unit—the Diamond Tail Formation. We also briefly discuss the tectonic implications of this revised stratigraphy.

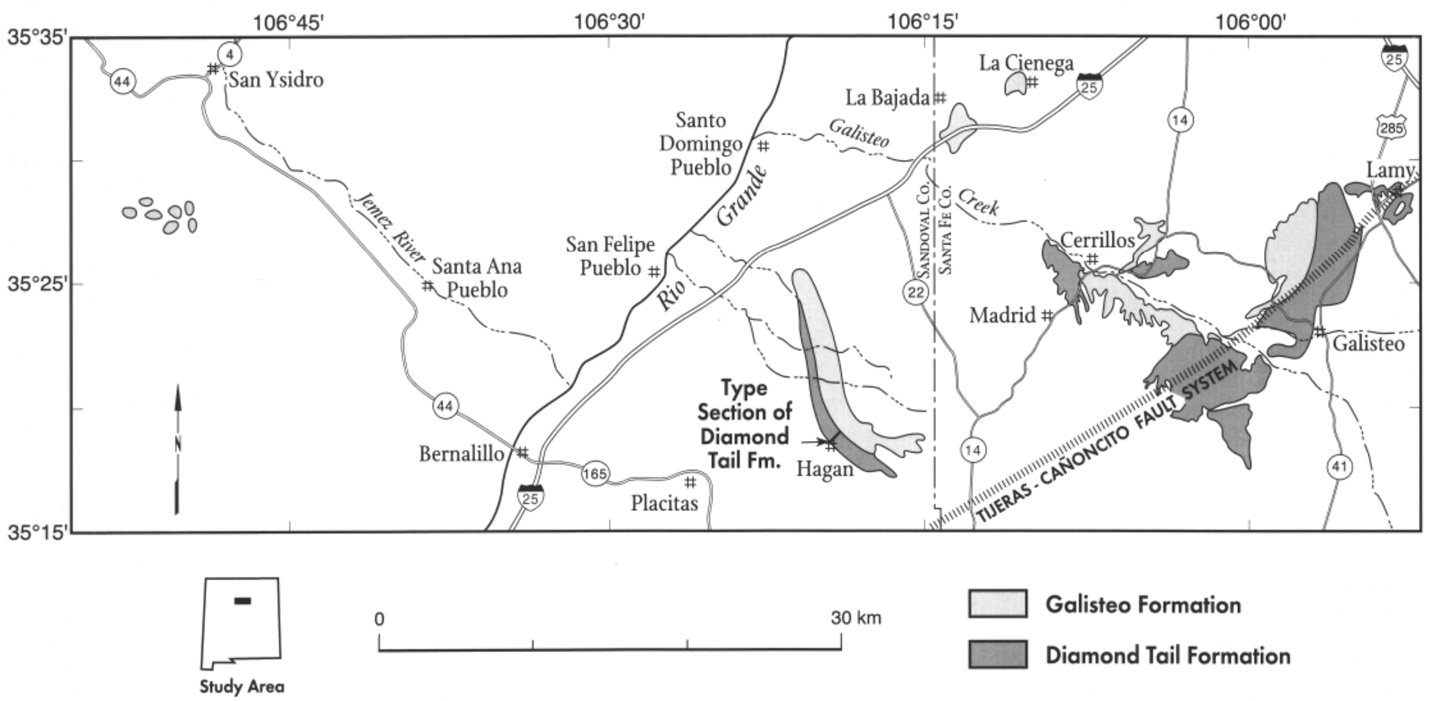

FIGURE 1—Approximate distribution of the Diamond Tail and Galisteo Formations in north-central New Mexico (modified from Abbott et al., 1995; Lucas, 1982; and Gorham, 1979).

Diamond Tail Formation

Name and type section

We recognize strata previously included in the lower part of the Galisteo as a separate stratigraphic unit, the Diamond Tail Formation (Fig. 1). The formation takes its name from the Diamond Tail Ranch in the Hagan Basin of Sandoval County. The type section of the Diamond Tail Formation and most of its Hagan Basin outcrops are on lands owned by the ranch.

The type section of the Diamond Tail Formation is 1.0 km north of the ghost town of Hagan in the NE¼NW¼SW¼ sec. 28 T13N R6E. This is essentially the same section as Gorham's (1979, appendix I, plate 5; Gorham and Ingersoll, 1979, fig. 2) Hagan section. Strata in this section that Gorham (1979) assigned to the lower part of the Galisteo Formation—his "lower buff-pebbly sandstone" through "lower buff-sandstone and mudstone" informal members—compose the type section of the Diamond Tail Formation. These strata also correspond to the informally designated "lower unit of the strata of the Galisteo basin" of Abbott et al. (1995).

At its type section (Fig. 2), the Diamond Tail Formation is 442 m thick. It disconformably overlies coal-bearing strata of the Menefee Formation (Picha, 1982) and is disconformably overlain by the Galisteo Formation. Here, three informal members of the Diamond Tail Formation can be recognized.

The lower member is 165 m thick and is mostly grayish-orange and yellowish-gray, medium- to coarse-grained, troughcrossbedded sandstone and conglomeratic sandstone. The sandstone is subarkosic to arkosic, and conglomerate clasts are dominantly quartzite and chert up to 0.5 cm in diameter, although a few larger (up to 4 cm diameter) clasts are present. Thin beds and lenses of olive-gray mudstone are a minor constituent. Ironstone cannonball concretions are common (Fig. 3B,C); logs and fragments of silicified wood are locally present. This lower member of the Diamond Tail Formation at its type section forms a prominent hogback between strike valleys formed by Menefee coals, lignites, carbonaceous shales and lenticular sandstones below and variegated mudstones of the middle member of the Diamond Tail Formation above. The basal contact is marked by a pronounced disconformity, with conglomeratic sandstone of the basal Diamond Tail overlying fine-grained sandstone and carbonaceous shale of the Mesaverde (Fig. 3A).

The middle member is 176 m thick and forms a northwest-striking valley at the type section. It consists of variegated light-olive to maroon mudstone and minor sandstone (Fig. 3D). Mudstones contain abundant sideritic concretions, many of which are cannonball shaped.

The upper member of the Diamond Tail Formation at the type section is 101 m of sandstone and mudstone similar in many features to the lower member. Sandstones are mostly subarkoses that are yellowish gray to grayish orange and trough cross-bedded. Some sandstone beds are pebbly, with numerous clasts of gray-to-white quartzite up to 0.5 cm in diameter. Mud-stone is a subordinate part of the unit and is greenish gray. The upper member forms a hogback together with overlying basal

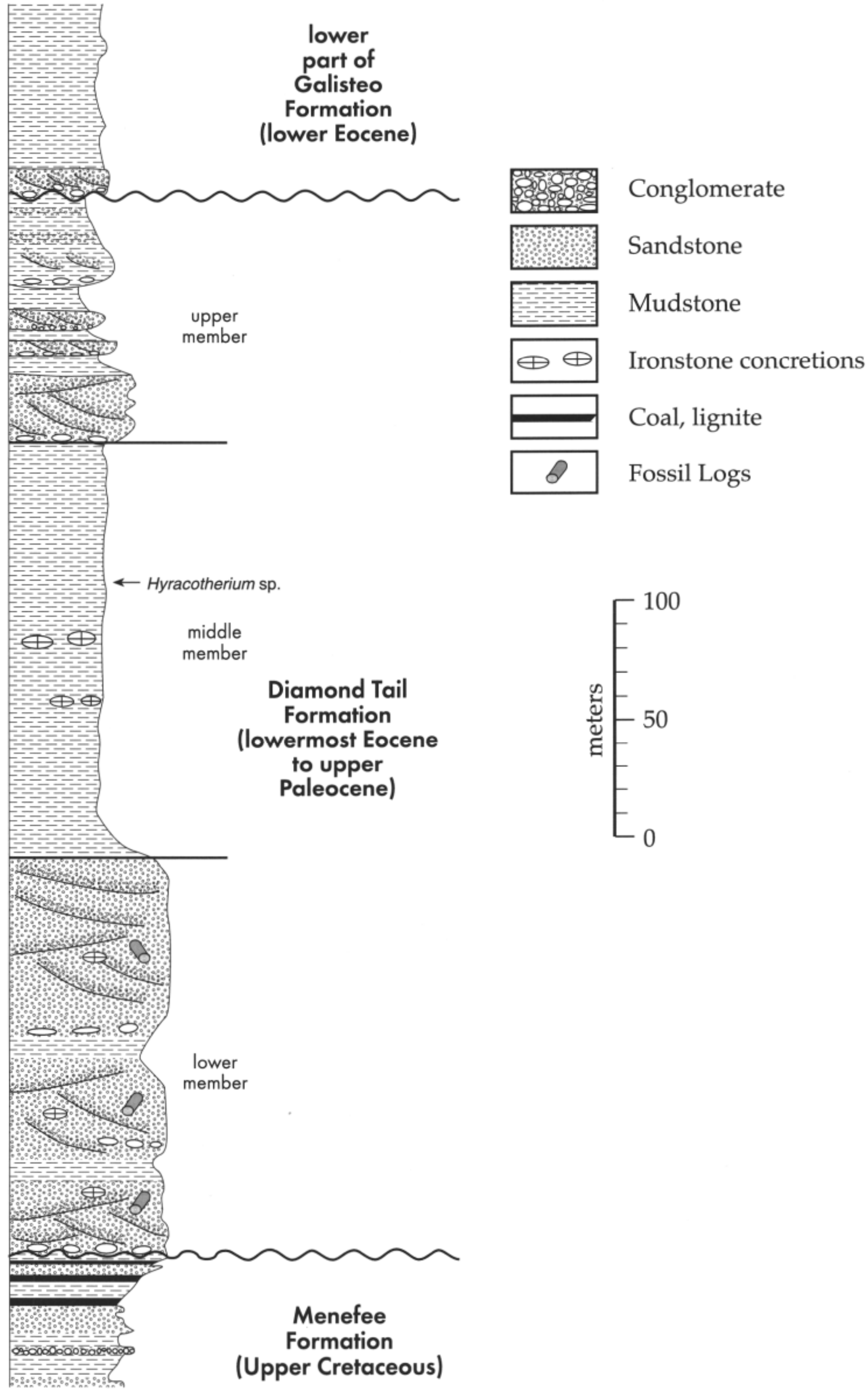

FIGURE 2—Type section of the Diamond Tail Formation near the ghost town of Hagan, SW¼ sec. 28 T13N R6E (modified from Gorham, 1979, plate 5).

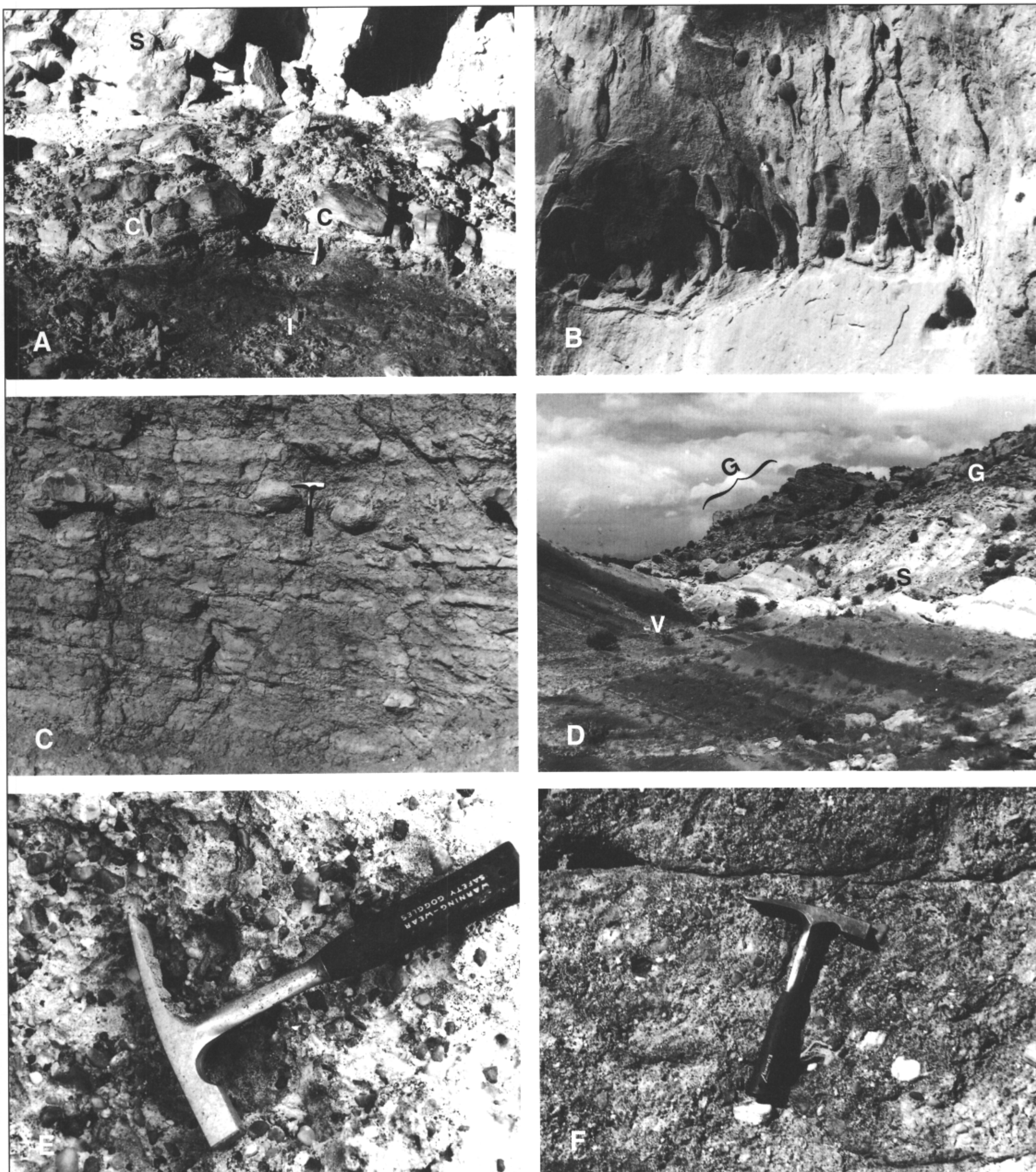

FIGURE 3—Selected outcrops of the Diamond Tail Formation. **A**, Basal sandstone (**s**) and conglomerate (**c**) overlying lignitic shale (**l**) of the Menefee Formation at the type section of the Diamond Tail Formation. **B**, Cannonball concretions in lower sandstones of Diamond Tail Formation at the type section. **C**, Cannonball concretions in interbedded sandstone and mudstone of Diamond Tail Formation north of Madrid. **D**, Overview of upper part of Diamond Tail Formation type section showing variegated mudstones (**v**) and upper sandstones (**s**) of Diamond Tail Formation overlain by basal sandstones and conglomerates (**G**) of Galisteo Formation. **E**, Basal conglomerate of Galisteo Formation at the Diamond Tail Formation type section. **F**, Basal conglomerate of Galisteo Formation at the Galisteo Formation type section.

conglomerate and sandstone of the Galisteo Formation (Fig. 3D). The base of the Galisteo Formation is readily selected above the upper member at the base of a laterally continuous conglomerate that has a coarse-grained, subarkosic, very pale orange to pale yellowish-brown matrix (Fig. 3E). Clasts are up to 4 cm in diameter and consist mostly of chert, quartzite, and Paleozoic limestone and sandstone. Paleozoic clasts become much more abundant higher in the section.

Modification of Galisteo Formation type section

Recognition of the Diamond Tail Formation restricts the Galisteo Formation and therefore alters the content of the Galisteo Formation type section. Lucas (1982, p. 9-10) described this type section east of Cerrillos in secs. 15, 16, 21, 22 T14N R8E. Units 10-21 of this section (120 m thick) are assigned by us to the Diamond Tail Formation. This limits the Galisteo Formation at its type section to units 22-83 of Lucas's (1982, fig. 4) section, for a total thickness of 979 m.

East of Cerrillos, the Diamond Tail Formation is exposed north of Galisteo Creek in secs. 16, 20, 21 T14N R8E. The basal bed of the formation is a locally conglomeratic brown sandstone; clasts are gray and white quartzite and chert as much as 0.5 cm in diameter. This conglomeratic sandstone rests with prominent scour on fine- to medium-grained quartzose sandstone of the Mesaverde Group. Overlying Diamond Tail Formation mud-stones are brown and gray, as are sandstones, which make up most of the Diamond Tail section. The sandstones are mostly medium- to coarse-grained, conglomeratic, trough-crossbedded subarkoses. Ironstone concretions are abundant. The base of the overlying Galisteo Formation is a polymodal conglomerate of Precambrian quartzite and granite with subordinate Paleozoic limestone, sandstone, and chert clasts similar to beds in the lower part of the Galisteo Formation at the type section of the Diamond Tail Formation (Fig. 3F). Red and green mudstone immediately overlie the basal Galisteo conglomerate near Cerrillos.

Contacts, distribution, mappability

The upper and lower contacts of the Diamond Tail Formation are regional unconformities. Coarse-grained sandstones and conglomerates at the base of the Diamond Tail Formation are scoured into finer-grained sandstones and coal-bearing shales of the Upper Cretaceous Mesaverde Group (generally Menefee Formation). Conglomerate at the base of the Galisteo Formation disconformably overlies locally pebbly sandstone of the Diamond Tail Formation.

The Diamond Tail Formation has a distribution similar to that of the overlying Galisteo Formation. Major outcrop belts of the Diamond Tail Formation (Fig. 1) are: (1) the Hagan Basin, where it crops out in a north–south belt encompassing the type section in T13-14N R6E [Stearns (1953), Kelley and Northrop (1975), Gorham (1979), and Picha (1982) are among the numerous workers who mapped as Galisteo Formation strata in the Hagan Basin that we assign to the Diamond Tail Formation]; (2) southwest of Cerrillos in T14N R7-8E and at the Galisteo Formation type section east of Cerrillos in secs. 16, 20, 21 T14N R8E where strata mapped as the lower part of the Galisteo Formation by Disbrow and Stoll (1957), Bachman (1975), and Lucas (1982), among others, belong to the Diamond Tail Formation; (3) farther east, outcrops south of Galisteo Creek along and around Arroyo Choro (T13N R8-9E) and to the northeast in the vicinity of (mostly west of) Galisteo in T13-14N R9-10E, include strata mapped as the lower part of the Galisteo Formation by Bachman (1975) and Johnson (1975) that we assign to the Diamond Tail Formation.

It is important to note that the Diamond Tail Formation is not present at the Windmill Hill area south of San Ysidro (T14N R1E; Fig. 1) where the basal Galisteo Formation rests directly on the Menefee Formation (Galusha, 1966; Slack, 1973; Lucas, 1982). The Diamond Tail Formation is not exposed in the St. Peter's Dome area near Los Alamos (Cather, 1992) or in the La Bajada or La Cienega areas southwest of Santa Fe (Sun and Baldwin, 1958), although it is possible the Diamond Tail exists in the subsurface in these areas.

Outcrops of Galisteo Formation have been mapped near Placitas by Stearns (1953), Kelley (1977), Kelley and Northrop (1975), and Menne (1989). These rocks are sandstone, drab mudstone, and rare, slightly pebbly sandstone that have been variably oxidized beneath the basal unconformity of the Santa Fe Group. We regard these beds as probably belonging to the Mesaverde Group. It is possible, however, that these strata belong to the Diamond Tail Formation, although no unconformity is apparent between them and the carbonaceous Cretaceous rocks beneath.

Conglomeratic sandstone and drab mudstone exposed near the towns of Galisteo and Lamy (Fig. 1) appear to be Diamond Tail Formation. The geographic distribution and the nature of the upper and lower contacts of the Diamond Tail in these areas, however, are in need of further study.

Mappability of the Diamond Tail Formation can readily be demonstrated at various scales. In most areas it can be easily mapped at a scale of 1:24,000, and it can be separated from the Galisteo Formation on broader regional-scale maps such as our Fig. 1.

Thickness and lithology

The maximum thickness of the Diamond Tail Formation is 442 m at its type section. In the Cerrillos area, a more typical thickness is 100-150 m. Dramatic changes in thickness of the Diamond Tail Formation take place laterally over short distances. For example, in the Hagan Basin, the Diamond Tail Formation is 442 m thick at its type section, but in Arroyo del Tuerto, 6.5 km to the north, it is only 210 m thick. A further 5 km to the north, it is less than 20 m thick.

The thickness distribution of the Diamond Tail is similar to that of the overlying Galisteo Formation in the Hagan Basin (see Gorham, 1979). Both units thin to the northwest and exhibit their maximum thicknesses near the ghost town of Hagan. The basal unconformity of the Galisteo Formation, which we select at the base of Gorham's (1979) "lower white conglomeratic sandstone" near Hagan, appears to climb northwestward in paleoelevation. This is shown by the northwesterly onlap of progressively younger units within the Galisteo against the basal unconformity (see Gorham, 1979, plate 5). The northwestward thinning of the Diamond Tail Formation appears to be the result of both greater pre-Galisteo erosion to the northwest and syndepositional thickening of the Diamond Tail to the southeast near Hagan.

Most of the Diamond Tail Formation is yellow, orange and gray, medium- to coarse-grained arkose and subarkose (see Gorham, 1979, for petrographic descriptions). Trough-crossbedding is the dominant bedform of these sandstones, and locally they contain abundant petrified wood and ironstone cannonball concretions.

Conglomeratic sandstone (and, more rarely, conglomerate) also is a common rock-type in the Diamond Tail Formation. These conglomeratic units contain mostly small (<0.5 cm diameter), well-sorted clasts dominantly of white and gray quartzite and chert. Diamond Tail Formation conglomeratic sandstones and conglomerates are thus easily distinguished from Galisteo Formation conglomerates, which are commonly coarser-grained (>2 cm diameter) and contain a greater variety of clast lithologies (quartzite, chert, limestone, granite, sandstone). Clast compositions suggest that coarse detritus in the Diamond Tail was recycled primarily from texturally and mineralogically mature clasts derived largely from Mesozoic strata. In contrast, clasts in the Galisteo Formation in the Hagan area undergo an abrupt upsection evolution from a Diamond Tail-like suite in the basal conglomerate to a more litho-logically diverse, texturally and mineralogically less mature suite above. In other areas, such as near Cerrillos, the basal Diamond Tail-like suite is missing, and the polymodal suite comprises the basal conglomerate. These relationships indicate that sediments above the basal Galisteo unconformity were largely supplied by rising basement uplifts that exposed Paleozoic and Precambrian rocks except in local areas, such as near Hagan, where scouring and resedimentation of Diamond Tail deposits was initially dominant. The detrital record of apparent unroofing shown by the Diamond Tail /Galisteo sequence is broadly similar to the unroofing of late Laramide uplifts described elsewhere in New Mexico (Seager and Mack, 1986; Gather, 1991, 1992).

Except in the vicinity of the type section, Diamond Tail mudstones are green or gray; no red-bed mudstones are present. Mudstone in the upper part of the Diamond Tail Formation in the area of its type section, however, is maroon (dark reddish brown and grayish red) and contains numerous sideritic nodules. In contrast, red mudstones of the Galisteo Formation are brick red (moderate reddish brown) and lack sideritic nodules.

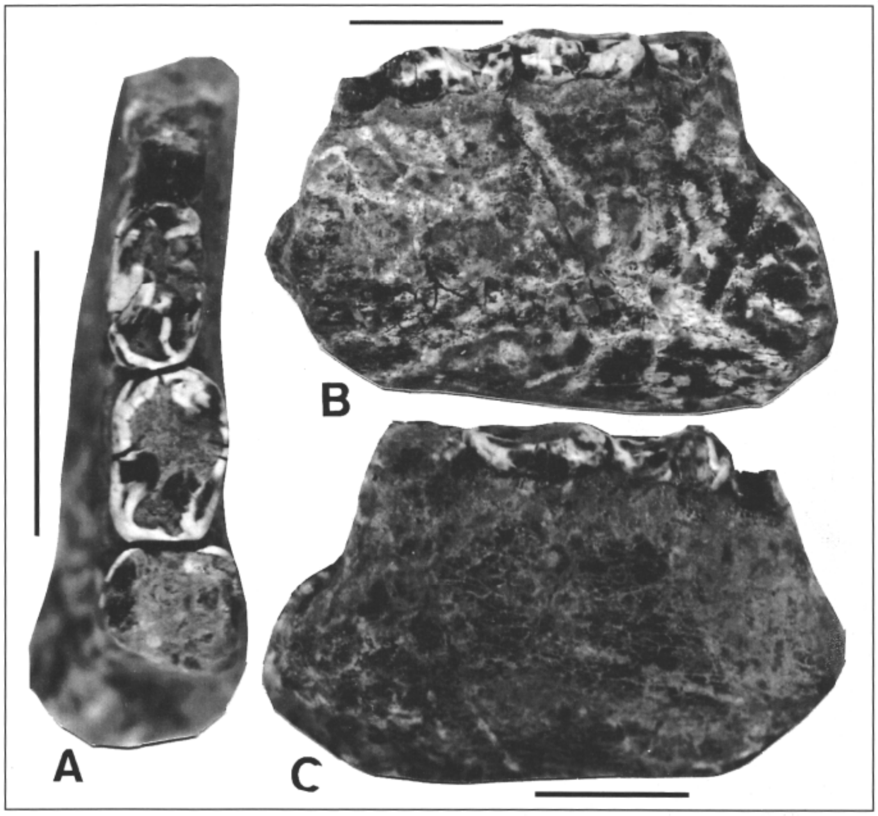

FIGURE 4—NMMNH P-25046, left dentary fragment with P_{3-4} and partial P_2 and M_1 of *Hyracotherium* sp., occlusal (**A**), labial (**B**), and lingual (**C**) views. Bar scales are 1 cm long.

Age and correlation

Until this study, no fossils other than petrified wood were known from the Diamond Tail Formation, so no direct evidence ,of its age was available. All previously reported fossils from the strata of the Galisteo Basin were found in the restricted Galisteo Formation, above the Diamond Tail.

NMMNH (New Mexico Museum of Natural History and Science) P-25046 from NMMNH locality 3043 in the Diamond Tail Formation is a left dentary fragment with a partial P_2 P_{3-4}, and partial M_1 (Fig. 4). The dentition is highly worn, indicating a relatively mature individual. The specimen is referred to *Hyracotherium* sp. based on its size and premolar morphology. The P_2 is narrow (width = 2.5 mm) but possesses a small talonid. The posterior premolars (P_{3-4}) are molariform and possess prominent metaconids in a lingual position and large hypoconids in a labial position. Both lack distinct paraconids but have weak paracristids at the anterior of the tooth. The labial faces of both teeth are marked by a discontinuous basal cingulid.

The tooth size (P_3 length = 6.5 mm, width = 3.5 mm; P_4 length = 6.7 mm, width = 4.4 mm; M, anterior width = 5.3 mm) falls within the range of *H. angustidens* and *H. vasacciense* (Kitts, 1956). Unfortunately, the characters used to distinguish these species (e.g., presence/absence of diastema between P_1 and P_2, P_3 morphology: Kitts, 1956) are not present in this specimen. The Wasatchian land-mammal "age" (lma) is typified by the occurrence of *Hyracotherium*. *Hyracotherium* is not known before the Wasatchian lma (late Paleocene–early Eocene) but ranges into the Bridgerian Ima (Krishtalka et al., 1987).

The above specimen was recovered from the upper part of the middle member of the Diamond Tail, 1.1 km northeast of Hagan (NE¼SE¼ sec. 28 T13N R6E). The youngest dated Cretaceous unit it overlies, the Menefee Formation, is of early Campanian age. The oldest age-diagnostic fossils from the overlying Galisteo Formation are middle Wasatchian (earliest Eocene) mammals found 248-303 m above the Diamond Tail–Galisteo contact near Cerrillos (Lucas, 1982; Lucas and Williamson, 1993). The *Hyracotherium* fossil from the Diamond Tail Formation must be older than the Lysitean mammals from the lower part of the overlying Galisteo Formation, but is not older than earliest Wasatchian (Graybullian). The data provided by adjacent stratigraphic units are consistent with a late Paleocene–early Eocene age for the upper part of the Diamond Tail Formation.

We tentatively correlate the Galisteo-Diamond Tail unconformity with the base of the upper persistent sandstone of the Llaves Member of the San Jose Formation in the San Juan Basin. The underlying Regina Member (and correlative Ditch Canyon and lower Llaves Members, see Smith, 1988) is dominantly drab, variegated mudstones and subarkosic sandstones(Baltz, 1967; Smith, 1988; Williamson and Lucas, 1992). Lithologic similarities between the Diamond Tail and Cuba Mesa–Regina Members include basal sandstone-dominated sequences, subarkosic sandstones with numerous cannonball concretions and silicified wood, generally drab mudstones with numerous sideritic concretions, and conglomerate dominated by well-rounded clasts of quartzite and chert. These similarities, as well as comparable stratigraphic position and age, allow a tentative correlation of the Diamond Tail Formation with the Cuba Mesa and Regina Members of the San Jose Formation in the San Juan Basin (Fig. 5). Correlation with the Paleocene Nacimiento Formation (see Baltz, 1967, p. 57) can probably be ruled out because of the generally fine grained nature of the Nacimiento and the fact that it has not yielded any fossils as young as Wasatchian (Williamson and Lucas, 1992; Williamson, 1996). A more complete understanding of the temporal correlation between strata of the San Juan and Galisteo Basins must await better constraints on the age of the lower part of the Diamond Tail Formation and of the upper Nacimiento and lower San Jose (Cuba Mesa Member) Formations.

Tectonic significance

The Galisteo Basin is one of several wrench-related basins of late Laramide

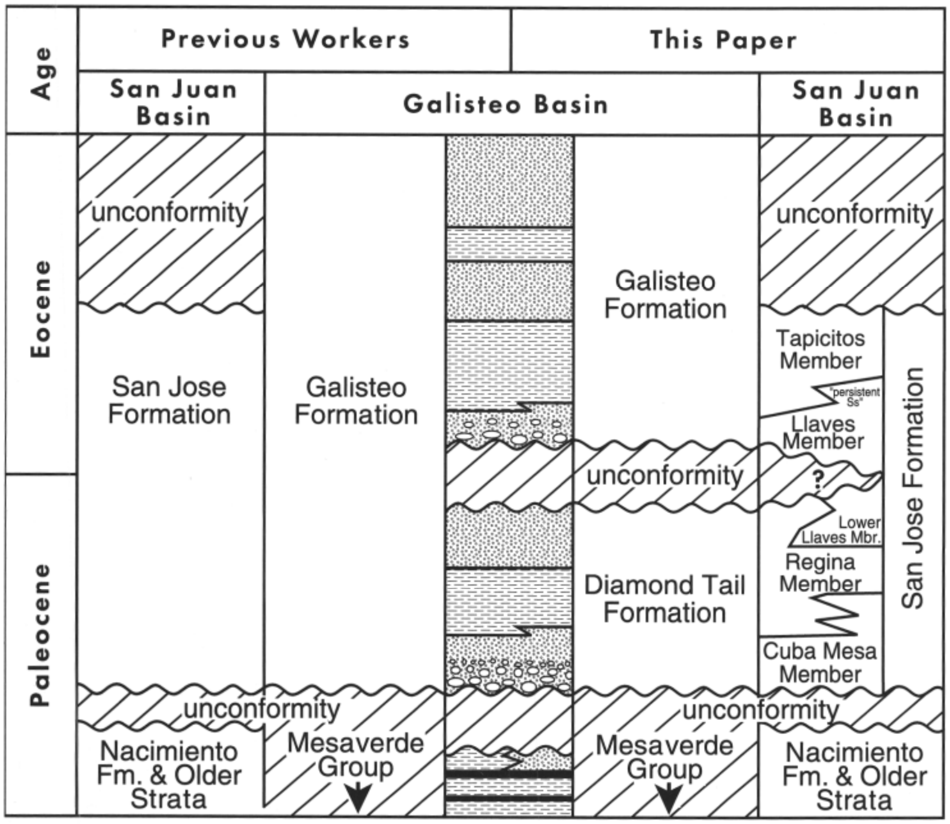

FIGURE 5—Previous correlation of Galisteo Formation to San Juan Basin strata compared to that advocated in this paper.

age (Echo Park-type basins of Chapin and Cather, 1981) in New Mexico. The Galisteo differs from these other basins in at least three major ways: (1) the Galisteo Basin has a transtensional, rather than a transpressional, origin (Cather, 1992; Abbott et al., 1995); (2) the late Laramide strata of the Galisteo Basin contain two distinct tectonosequences, whereas other Echo Park-type basins in New Mexico appear to contain only one; and (3) the Galisteo Basin contains a thick sequence of late Laramide clastic deposits that were derived in large part from an extensive catchment in the San Juan Basin area of the eastern Colorado Plateau (Cather, 1992, fig. 7). In contrast, sediments in wrench-related basins to the north and south (El Rito, Carthage—La Joya, and Cutter Sag—Love Ranch basins; see Chapin and Cather, 1981) appear to have been locally derived from smaller catchments on transpressional uplifts along the eastern boundary of the Colorado Plateau.

The three attributes of the Galisteo Basin described above may be interrelated and share a common origin. The extensional aspect of the Galisteo Basin appears to have been related to transtensional deformation along the Tijeras—Cañoncito fault zone, which acted as a releasing bend in the right-lateral wrench system of the Laramide southern Rocky Mountains (Cather, 1992). This extensional aspect of deformation would tend to produce alocal gap of low topographic relief in the otherwise high-standing transpressional welt that formed along the eastern margin of the Colorado Plateau during late Laramide time. Low relief in the Galisteo Basin area would have facilitated the integration of paleodrainage across the Plateau margin and may explain the external paleodrainage of the San Juan Basin (Smith, 1988, 1992a). In contrast, other late Laramide basins on the eastern part of the Colorado Plateau [Baca Basin (Cather and Johnson, 1986); Piceance Creek Basin (Johnson, 1988)] were bounded on the east by transpressional uplifts and show evidence for paleohydrographic closure.

In the Hagan area, the Diamond Tail and Galisteo Formations both display their maximum thicknesses to the southeast, adjacent to the Tijeras—Cañoncito fault zone. Both units thin markedly to the northwest, and the basal beds of the Galisteo appear to lap northwestward across the eroded top of the Diamond Tail. The Tijeras—Cañoncito fault zone was an active intrabasin structure in the Galisteo Basin during the Eocene, as shown by preservation of Upper Cretaceous rocks and beds of the Diamond Tail Formation on the up-thrown, southeast block (Abbott et al., 1995). These relationships suggest that the Diamond Tail and Galisteo Formations represent two distinct tectonosequences in part of a basin that was subsiding and tilting southeastward along the Tijeras-Cañoncito fault zone. The Tijeras—Cañoncito fault zone was right-oblique normal during the Laramide (Abbott, 1995), which lends support to the half-graben model for the Galisteo Basin proposed by Cather (1992).

We cannot demonstrate that the unconformity that intervenes between the Diamond Tail and Galisteo Formations is tectonic in origin. It is possible, for example, that this unconformity was the result of sedimentary offlap and subsequent onlap driven by climatically influenced rates of sediment supply in a uniformly subsiding half graben. We feel, however, that the abrupt influx of locally derived Precambrian and Paleozoic clasts at or slightly above this unconformity argues for a tectonic origin.

The upper Galisteo Formation tectonosequence of early to late Eocene age in the Galisteo Basin is lithologically similar to the fill of other Echo Park-type basins in New Mexico, which consist of variegated red-bed sequences that contain polymodal conglomerates dominated by locally derived Paleozoic and Precambrian lithologies. Although not well constrained everywhere, the age of the fill in these other basins is middle to late Eocene (see summary in Lucas and Williamson, 1993), coeval with the upper part of the Galisteo Formation. In contrast, the upper Paleocene—lower Eocene tectonosequence in the Galisteo Basin (i.e., Diamond Tail Formation) has no lithologic or temporal equivalent in the Echo Park-type basins of New Mexico. The Cuba Mesa—Regina section in the San Juan Basin, however, is lithologically similar to the Diamond Tail Formation, being dominated by a drab sequence of mudrock, sandstone, and minor conglomerate characterized by well-rounded clasts of quartzite and chert (Smith, 1988; Williamson and Lucas, 1992). Although the Cuba Mesa Member is undated pale-ontologically, its upper part intertongues with the Regina Member, which has yielded Wasatchian fossils. The Regina Member (and laterally equivalent lower Llaves and Ditch Canyon Members) is overlain by the upper persistent sandstone of the Llaves Member and the red beds of the Tapicitos Member of middle Wasatchian (Lysite) age. We have shown a possible unconformity at the base of the upper persistent sandstone of the Llaves Member in Fig. 5, although this is speculative. Smith (1988, 1992b) argued that an increased contribution of coarse, basement-derived detritus to mudrocks of the Tapicitos Member may have allowed greater oxidation and reddening during Eocene pedogenesis than in the finer grained, more poorly drained paleosols of the drab Regina Member. A similar explanation may apply to deposits of the Galisteo Basin, where an increase in basement-derived detritus at or near the base of the Galisteo Formation (as shown by clast lithology) coincides approximately with the change from drab to red coloration. The probable tectonic origin of the unconformity beneath the Galisteo Formation suggests that an episode of middle Wasatchian (-53 Ma) tectonism caused widespread unroofing of basement terranes in the Laramide Brazos-Sangre de Cristo uplift, which contributed detritus to both the Galisteo Formation and the Tapicitos Member of the San Jose Formation.

The lower (Diamond Tail) tectonosequence of the Galisteo Basin is unique among the Echo Park-type basins of New Mexico, both lithologically and chronologically. Although we can only speculate about the origin of this early tectonosequence, it is possible that the unique transtensional nature of the Galisteo Basin caused sediments to be trapped sooner than in basins along the high-standing, transpressional regions to the north and south. Additionally, the extensive San Juan Basin catchment that apparently exited through the Galisteo Basin (Cather, 1992) would have supplied voluminous sediments to provide a stratigraphic record of any subsidence events within the basin.

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