**Flemingostrea elegans**, n. sp.: guide fossil to marine, lower Coniacian (Upper Cretaceous) strata of central New Mexico

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**Abstract**

The marine oyster *Flemingostrea elegans*, n. sp., appears suddenly in lower Coniacian (Upper Cretaceous) strata of central New Mexico. It has no immediate ancestor in the Western Interior of the United States and has not been found anywhere outside central New Mexico. *Flemingostrea elegans* occurs in nearshore sandstones in the Mulatto Tongue of the Mancos Shale in Socorro County and the Gallup Sandstone of Lincoln County. This medium-sized oyster, with its distinctive teretraloid fold, is an excellent guide fossil to the lower Coniacian, and is a great aid in distinguishing the Mulatto Tongue from other tongues of the Mancos Shale in Socorro County and in differentiating Coniacian from Turonian sandstones in Lincoln County. It occurs in great numbers, often as articulated shells, and is easily distinguished from all other Turonian through Coniacian oyster species by the fold in its lower valve. Its presence above coal beds in the lower part of the Crevasse Canyon Formation provides definitive evidence for a third cycle of transgression/regression of the western shoreline of the Late Cretaceous Seaway as far south in New Mexico as central Socorro County.

The Santonian dwarf species, *Flemingostrea nanus* (Johnson 1903), known only from Santa Fe County, New Mexico, is redescribed and illustrated. *Flemingostrea nanus*, *F. elegans*, n. sp., and the upper Cenomanian *F. prudentia* (White 1877), are the only species of *Flemingostrea* known from the Western Interior.

*Ostrea eleganta* Newberry 1876, which has been confused in the literature with *F. elegans*, n. sp., should be considered formally as a nomen dubium (a forgotten name) and not used again. *Ostrea eleganta* was named but not described or illustrated by J. S. Newberry in his geological report of Captain J. N. Macomb’s 1859 San Juan exploring expedition. F. B. Meek, who wrote the paleontological report on the Cretaceous fossils collected on that expedition, did not describe, illustrate, or mention it. Newberry’s type specimens were illustrated in 1883 by C. A. White, again without description. Attempts to recover Newberry’s type locality along the Canadian River, Colfax County, New Mexico, were unsuccessful.

**Introduction**

The shells of the distinctive lower Coniacian marine oyster *Flemingostrea elegans*, n. sp., occur in great numbers in thin, resistant, nearshore sandstones in central New Mexico (Fig. 1).

*Flemingostrea elegans* can be differentiated from all Turonian or Coniacian oyster species in the Western Interior by a conspicuous, symmetrical, low-amplitude, teretraloid fold that marks the adult part of the left (or lower) valve (Fig. 2). The right (or upper) valve of an adult shell has a prominent break in slope where it changes from flat to inclined downward. This downward inflection produces a tongue-like extension that makes the upper valve convex-up when viewed in living position and allows it to fit tightly into the fold on the lower valve (Fig. 3). Maximum convexity of the upper valve is at this change in inclination, which corresponds to the position of the adductor muscle pad or scar (Fig. 3). The articulated shells of *F. elegans* resemble brachiopods because of the teretraloid fold.

*Flemingostrea elegans* is a medium-sized oyster, generally less than 50 mm high, and relatively slender. Articulated specimens are plano-convex in section, oval in outline with a height to length ratio of about 1.2, and slender with a height to thickness (of both valves) ratio of about 2.6. The thickness of an individual valve varies, with thicker valves occurring in coarser sandstones deposited in higher-energy environments. Ornamentation of both valves consists primarily of concentric growth lamellae, but about four out of every 10 lower valves have weak to moderate radial sculpture. The adductor muscle scar is large, subcentral, and kidney shaped.

Sedimentation rates in some of these nearshore environments were apparently high enough intermittently that the oysters were buried completely, often in life position, before the shell-closing adductor muscle deteriorated and relaxed, allowing the spring-like ligament to open the two valves. Completely articulated specimens are more common in friable sandstones, often with little or no attached matrix, than in coquinas. The more resistant coquinas form the tops of ridges in open countryside and may be the only exposed sandstone in the arroyos. The key to identifying *F. elegans* in the coquinas, where they usually occur as disarticulated valves, is the change in slope of the adult part of the upper valve (Fig. 4). The stratigraphic occurrences of *F. elegans* chart a complex history for the movement of the western shoreline of the Late Cretaceous Seaway across central New Mexico during the early Coniacian (Fig. 5). These oysters occur in the Mulatto Tongue of the Mancos Shale in Socorro County, New Mexico, but are in the stratigraphically lower, but partially equivalent, Gallup Sandstone in Lincoln County. The Mulatto Tongue is the uppermost of the three major tongues of...
Mancos Shale in Socorro County; it occurs approximately 100–150 ft (30–45 m) above the top of the Gallup Sandstone. The assumptions inherent in Figure 5 are that: (1) deposition of the Dilco Coal Member in Socorro County lasted the entire time represented by the Cremnoceramus deformis Zone; (2) deposition of the Gallup Sandstone in Lincoln County lasted until the end of the time represented by the C. crassus Zone; and (3) the western shoreline retreated penecontemporaneously from both Socorro and Lincoln Counties at the end of the C. crassus time. The age of the upper part of the Crevasse Canyon Formation in both counties is unconstrained by the collections discussed in this paper.

The implication of these biostratigraphic occurrences is that during the early Coniacian, Socorro County was emergent, then covered by the sea, then emergent again; whereas, Lincoln County was covered by seawater, then emergent. This means that during the early Coniacian the western shoreline of the Late Cretaceous Seaway was to the west and south of Lincoln County, but retreated from, then advanced across Socorro County. The seaway retreated from both counties penecontemporaneously probably during the early part of the middle Coniacian. In Socorro County the shells of F. elegans occur in sandy strata deposited during the third major transgression (T3 of Molenaar 1983) of the Late Cretaceous Seaway across New Mexico; those from Lincoln County in the Gallup Sandstone occur in strata deposited during the second major regression (R2 of Molenaar 1983) of the seaway.

The resistant shell beds are so conspicuous in the field in Socorro County that they are reliable indicators that can distinguish the marine beds in the Dalton Sandstone Member of the Crevasse Canyon (?) or the Mulatto Tongue of the Mancos Shale from the underlying, nonmarine beds of the Dilco Coal Member of the Crevasse Canyon Formation. In Socorro County, F. elegans occurs in the Mulatto Tongue approximately 100 ft (30 m) above the first and only occurrence of the lower Coniacian inoceramid bivalve Cremnoceramus erectus (Meek) in the Gallup Sandstone. In Lincoln County, New Mexico, where the rocks are more fossiliferous, there is better biostratigraphic control: F. elegans occurs in the Gallup Sandstone with C. erectus near the base of its range and C. crassus (Petrascheck) near the top of its range. See Figure 5.

In published records, this new oyster species has been misidentified as Ostrea anomioodes Meek (e.g., Cobban 1986, p. 88, fig. 6H–I), as O. elegantula Newberry (e.g., Darton 1928, pp. 75–76), as Flemingostrea aff. prudentia (Arkell 1986, p. 75), and as F. elegans (Hook and Cobban 2007, fig. 3). This repeated misidentification is primarily the result of the morphological similarity of upper valves of immature individuals of elegans to anomioides, elegantula, and prudentia. (Compare Fig. 3C with Figs. 14B, C, and G.) Stephenson (1936, pp. 2 and 7) discussed the close morphological relationship between O. elegantula and O. anomioides but thought there was a significant age difference. Dyman et al. (2000, fig. 4) have shown conclusively that O. anomioides is confined to upper Albian rocks in western Montana; lower valves of adults of both O. anomioides and O. elegantula lack the characteristic low-amplitude fold of F. elegans.

The upper valve of F. elegans is so similar morphologically to the only illustrated upper valve of Ostrea elegantula (White 1883, pl. XXXVI, fig. 5; reproduced as Fig. 14C) that I referred this new species to F. elegantula in the initial drafts of this paper. In addition, this new species has been identified as F. elegantula on a columnar section for northern Socorro County.
low-amplitude fold present in *F. elegans*. Although there has been confusion about which specific name to use for this oyster, there has been no confusion about its biostratigraphic importance: It is an excellent guide fossil to the lower Coniacian.

In the sections of this paper that follow, *Flemingostrea elegans*, n. sp., is described and illustrated with specimens from Socorro and Lincoln Counties, New Mexico. Its geologic range is restricted to the lower Coniacian. Its geographic range is (at present) restricted New Mexico. Type and reference localities will be described and illustrated. Working out the stratigraphy of *F. elegans* has increased the number of major cycles of transgression and regression of the Late Cretaceous Seaway that have affected central New Mexico from two to three. As this new information is incorporated into geologic quadrangle maps in Socorro County, it will add considerable stratigraphic and structural detail to areas formerly mapped as undifferentiated Crevasse Canyon Formation.

![FIGURE 4—Photograph of a coquina, whitened, paratype (USNM 542215), of *Flemingostrea elegans*, n. sp., from the Jackson well section of Lincoln County, New Mexico, Gallup Sandstone, USGS locality D6770. a—upper valve, b—lower valve, and c—internal mold of the marine bivalve *Cypriomenia* sp. Reduced 0.5 ×.](image)

**Stratigraphy**

The purpose of this portion of the paper is to establish a reasonable stratigraphic framework for the marine beds containing *F. elegans* and associated fauna in Socorro and Lincoln Counties. It is neither to define the exact boundaries between stratigraphic units, nor to impose a paleontologically defined stratigraphic nomenclature on central New Mexico. However, the presence of *F. elegans* in shaly strata above coal beds in Socorro County implies that the depositional environment changed from nonmarine to marine and necessitates a change in stratigraphic nomenclature of either formation or member rank.

In central Socorro County the base of the upper part of this intertongued marine sequence rests on a paludal shale that contains a thin coal bed. In the stratigraphic sections that follow, the boundaries between the intertongued units have been drawn on the basis of lithology, not environment of deposition. Existing stratigraphic names have been used, rather than defining new stratigraphic units. For example, in Figures 6 and 7 the contact between the Dilco Coal Member and the Mulatto Tongue is drawn between a nonmarine sandstone below and a nonmarine shale above because the nonmarine/marine contact, which is higher in the section, is a shale on shale contact.

An interesting analogy to this depositional situation between the Dilco Coal Member and the Mulatto Tongue exists in Socorro County within the Tres Hermanos Formation, which was deposited during an earlier cycle of transgression and regression of the western shoreline. The Carthage Member is the medial, marginal marine and nonmarine shaly part of the Tres Hermanos Formation that separates the lower Atarque Sandstone Member from the upper Fite Ranch Sandstone Member (Hook et al. 1983, p. 20). Both sandstone members are of marine origin. Initially in Socorro County, the Carthage Member is thought to be completely of nonmarine origin, and the Fite Ranch Sandstone, a coastal barrier sandstone, was thought to mark the beginning of the second transgression of the western shoreline into the county (see Hook et al. 1983, sheet 1B, section 59). Recent work on Sevilleta National Wildlife Refuge, 15 mi (24 km) to the north of Carthage, has shown that the upper 30 ft (10 m) of the Carthage Member is marine and that the contact between marine and nonmarine beds is a shale on shale contact (Hook and Cobban 2007, fig. 3). Subsequent collecting from the Carthage Member in the Carthage coal field (D14546) has confirmed that the upper 30 ft (10 m) of the Carthage Member is a gray marine shale that rests on approximately 35 ft (12 m) of red and purple paludal shales.

Structural complications in almost every area of Upper Cretaceous outcrop in the two counties mean that the boundaries will have to be established by detailed mapping at a scale of 1:24,000 or larger, which is beyond the scope of this work. The stratigraphic framework will have to be worked out with detailed correlations to better understood areas either within or outside Socorro and Lincoln Counties. Fortunately, preliminary geologic mapping at a scale of 1:24,000 is either in progress or completed on at least two quadrangles in Lincoln County (Bull Gap and Oscura), on two quadrangles in Socorro County (Mesa del Yeso and Caton Agua Buena), and on one quadrangle in Otero County (Golondrina Draw) on which *F. elegans* has been found. The mapping of these quadrangles is supported by the federal StateMap Program, which is managed by the U.S. Geological Survey and the New Mexico Bureau of Geology and Mineral Resources.
Background

For many years, the geological evidence in Socorro County supported only the two earliest of the five major transgression/regression cycles of the western shoreline of the Late Cretaceous Seaway in New Mexico (e.g., Hook 1983 and Molenaar 1983). The earliest cycle, the Greenhorn Cycle, began in middle Cenomanian time and lasted until middle Turonian time; the second cycle, the Carlile Cycle, began in middle Turonian time and ended in early Coniacian time. Each of these two cycles encompasses several hundred feet of strata. The third cycle, if present, would encompass only a few tens to hundreds of feet of section because Socorro County would lie at or near the maximum southwestward position of the western shoreline of the seaway.

This third cycle, called here, informally, the Mulatto cycle, would have begun later in early Coniacian time and lasted until perhaps latest early Coniacian time if it were present in Socorro County. Initially, there was no modern evidence for the Mulatto cycle in Socorro County. However, it was difficult to discount the reports of marine fossils, including Ostrea elegantula, above the Mesaverde [Dilco] coal beds in Socorro County by such a renowned field geologist as N. H. Darton (1928, pp. 75–76), and by Gardner (1910, p. 455). If these marine faunas were stratigraphically above the coals and not older, ecologically similar bivalve faunas faulted into juxtaposition, then it would mean that there had been a third cycle of transgression/regression of the Late Cretaceous Seaway in Socorro County.

In 1978 F. elegans, identified in field records as Ostrea anomioides, was collected from a coquina (D10605) containing nothing but oysters at Carthage in the Crevasse Canyon Formation, an estimated 100 ft (30 m) above the Gallup Sandstone. At that time it was not known if F. elegans could have lived in brackish water or whether it was a purely marine oyster. With nothing but F. elegans in the rocks, this collection was assumed to represent a brackish water accumulation, indicating that the western shoreline had at least gotten close to Carthage. However, F. elegans (identified as O. anomioides) had been collected in 1968 in association with the Coniacian inoceramid Cremnoceramus crassus south of Carrizo (D6770).

After returning to New Mexico in 2003, I collected what I thought was a brackish water fauna from a 1-ft-thick sandstone in the Crevasse Canyon Formation, approximately 130 ft (40 m) above the Gallup Sandstone on the Sevilleta National Wildlife Refuge in northern Socorro County. Subsequently, this collection (D14479) was found to contain abundant F. elegans in association with the marine bivalves Pheloptheria sp. and Pleuriocardium curtum (Meek and Hayden). This find, at one of Darton’s (1928, p. 75) localities, constituted the first “modern” evidence for this third transgression into Socorro County and indicated, once again, that the early geologists working in New Mexico made astute and accurate observations.

In addition, in 2004 a marine fauna (D14482) with F. elegans was collected from a 7-ft (2-m)-thick sandstone in the Crevasse Canyon Formation, approximately 60 ft (18 m) of what looked like marine shale and sandstone just south of Sevilleta National Wildlife Refuge on the Mesa del Yeso quadrangle. This locality is probably the same one reported by Darton (1928, p. 76) from 1 mi southeast of Mesa del Yeso containing Ostrea sp. This shaly section emerges out of the valley alluvium, so there is no stratigraphic context for the sandstone from below and there is an erosion surface approximately 30 ft (10 m) above D14482 (Fig. 8E). In 2007, another marine fauna

![Carthage measured section](image-url)
again with *F. elegans* was found above the coal at Carthage (D14559). Several older fossil collections that have direct bearing on the question of the position of the shoreline in Lincoln County have been found in the USGS Mesozoic Invertebrate Collections at the Federal Center in Denver, Colorado. These collections will be discussed in the section of the paper on Lincoln County.

All specimens of *F. elegans* collected in Socorro County, New Mexico, have come from marine rocks above the lowest (= major) coal seam in the Dilco Coal Member of the Crevasse Canyon Formation. These rocks include the undifferentiated Crevasse Canyon Formation, the Dalton Sandstone Member of the Mesaverde Formation (?), and the Mulatto Tongue of the Mancos Shale. Specimens from southwest Lincoln County have come entirely from the Gallup Sandstone.

All of these formally named rock units have their type localities in the southern San Juan Basin, far to the northwest of Socorro and Lincoln Counties. The Gallup Sandstone (member of the Mesaverde Formation) was named by Sears (1925, p. 17) for 250–400 ft (76–122 m) of shale lying between the Dilco Coal and Dalton Sandstone Members of the Mesaverde Formation.

The Mulatto Tongue of the Mancos Shale was named by Hunt (1936) for three massive sandstones and interbedded shale and coal, 180–250 ft (55–76 m) thick, at the top of the Mancos Shale at the town of Gallup, McKinley County, New Mexico. The member was named for the village of Dilco (now Mentmore), approximately 5 mi (8 km) west of Gallup, McKinley County, New Mexico, where four coal beds were worked. The name Dilco is an abbreviation for the Direct Line Coal Company. The Dalton Sandstone Member (of the Mesaverde Formation) was named by Sears (1934, p. 17) for excellent exposures of approximately 100 ft (30 m) of (marine) sandstone at Dalton Pass, McKinley County, New Mexico. Allen and Balk (1954, pp. 91–92) raised the Gallup Sandstone to formal rank and reasigned the Dilco Coal and Dalton Sandstone Members to the Crevasse Canyon Formation. The Mulatto Tongue of the Mancos Shale was named for Canyon Mulatto, 9 mi (14.5 km) northwest of San Mateo, Cibola County, New Mexico.

**Socorro County**

All the collections containing *F. elegans* from Socorro County have come from marine rocks that are stratigraphically above coal beds in the basal part of the Dilco Coal Member of the Crevasse Canyon Formation. At present these marine strata are either mapped as or included in the undifferentiated Crevasse Canyon Formation on Sevilleta National Wildlife Refuge (Baker 1981) and in the Carthage coal field (Anderson and Osburn 1983 [reproduced in Hoffman and Hereford 2009] and Cather 2007). In the Jornada del Muerto coal field they are included in the undifferentiated Mesaverde Group (Tabet 1979). Just north of the townsite of Carthage and just southeast of the southern boundary of the Sevilleta National Wildlife Refuge, these marine shales have been mapped as the D-Cross Tongue of the Mancos Shale (Anderson and Osburn 1983 and Cather et al. 2005). Stratigraphic names that now appear appropriate for these marine rocks are the Mulatto Tongue of the Mancos Shale in all areas and questionably the Dalton Sandstone Member of the Mesaverde Formation on Sevilleta National Wildlife Refuge.

**Carthage coal field area**

In the Carthage area there are two measured sections approximately 2 mi (3 km) apart that support substantial collections of *F. elegans*.
Carthage measured section 2 (Fig. 7), which is just north of the Carthage townsite, is not as well constrained stratigraphically because of structural complications. It begins somewhere above the main coal seam of the Dilco Member, but contains two tongues of marine rocks separated by nonmarine rocks, including a thin coal bed. At present, both of the shaly units have been assigned to the Mulatto Tongue and the nonmarine sandstone units to the Dilco. Thicknesses of units are approximate because of large increases in dip magnitude, usually on the updip side of a covered interval.

The lower Mulatto Tongue could be as much as 33 ft (10 m) thick, but occurs in a structurally complex area that is mostly concealed. However, a well-exposed 4-ft (1.2-m)-thick sandstone ledge near the middle of the interval contains a marine bivalve and gastropod fauna near its base (USGS locality D14857) that includes F. elegans; a more brackish water fauna containing abundant fragments of the oyster Crasnostrea soleniscus (Meek) occurs at the top of this sandstone unit.

This fossiliferous bed, unit 12, is the only hard evidence for the initial incursion of the Mulatto shoreline into the Carthage area. The beds on either side of it, which are mostly to partly covered, may be nonmarine. Unit 11, the gray, noncalcareous shale below, appears marine, but does not contain fossils. If the underlying and overlying units are nonmarine, then unit 12 represents the extent of this incursion of the seawater. The lower fossil collection (USGS locality D14857) from unit 12 contains the most diverse marine fauna from the Mulatto Tongue and is the only Mulatto collection from Socorro County to contain “Lopha” sannionis (White) and F. elegans. “Lopha” sannionis is represented by a single specimen of the late form. The upper collection (USGS locality D14858) contains abundant broken and disarticulated specimens of C. soleniscus, but they do not occur in reef-like masses.

Cocquina to reef-like beds of C. soleniscus seem to occur only in regressive sandstones in central New Mexico. A good example is in the regressive middle Turonian Atarque Sandstone Member of the Tres Hermanos Formation exposed on Sevilleta National Wildlife Refuge. On the refuge the top of the regressive Atarque Sandstone is a 6-ft (2-m)-thick, reef-like accumulation of C. soleniscus (see Hook and Cobban 2007, fig. 3).1 It also appears to be the case for the top of the lower Coniacian Mulatto Tongue on the refuge (Hook and Cobban 2007, fig. 3), where an erosion surface rests on top of the C. soleniscus bed. A possible exception to this regressive “rule of thumb” was reported by Brown (1988) from the transgressive Borrego Pass Lenti of the Crevassa Canyon Formation (Coniacian) farther north in the southern San Juan Basin.

The presence of this thin marine unit in what was thought to be nothing but nonmarine Dilco, apparently above the Carthage coal seam, but below both a minor coal bed and the main body of the Mulatto Tongue indicates that there was a minor oscillation of the Mulatto shoreline in the Carthage area before the main transgression/ regression. The thin marine Dilco sandstone suggests that Carthage may have been very close to the turnaround point for the seaway at this time. This bed may have been covered or not fossiliferous at Carthage 1 (Fig. 6).

The upper Mulatto Tongue (Figs. 8A–C) is at least 73 ft (22 m) thick and composed primarily of gray, noncalcareous shale, with a thin coal bed near the base. The most conspicuous feature of the upper Mulatto, though, is not the resistant oyster bed (USGS locality D14480), but rather the many large calcareous concretions that the shale contains. These unusually large concretions (Figs. 8B, C) are elliptical, as much as 3 ft (1 m) high and 6 ft (2 m) long, and composed of bedded, fine-grained sandstone at the base, followed by bedded limestone and capped by a single cone-in-cone limestone layer as much as 6 (15 cm) thick. Weathered prisms from the cone-in-cone layer litter the ground around the concretions (Fig. 8C).

The usual source of fossils is a thin ironstone layer that develops at the top of the sandstone layer in many large cone-in-cone concretions and often continues beyond the margins of the concretions as a distinct bed. These purplish-weathering ironstones are very fossiliferous near the base of the upper Mulatto at the D14480 level, where they yield an abundant and diverse fauna dominated by F. elegans (although no ammonites and no inoceramids). Higher in the section, the faunas are sparse and usually consist of one to a few small bivalves, for example at the D14862 level.

The basal calcareous shale, the higher cone-in-cone concretions, and the faunas of the upper Mulatto Tongue at Carthage 2 correlate very nicely with the Mulatto Tongue at Carthage 1 (compare Fig. 6 with Fig. 7).

In 2010, Gardner’s (1910, p. 455, pl. XXI) Montana Group fossil locality was relocated in the SW4 sec. 15 T5S R2E, approximately 50 ft (15 m) stratigraphically above the entrance to the Government coal mine, which is 1 mi (1.5 km) south of the townsite of Carthage. Gardner (1910, p. 455) listed four species of bivalves and two species of gastropods in his collection. The fossils from USGS locality D14917 consists almost entirely of the internal molds and impressions of oysters that occur in a 3-in-thick, fine-grained sandstone approximately 1 ft above a zone of very large, orange-weathering concretions in a shaly sequence. The calcareous shells of the oysters have been leached from the enclosing sandstone leaving a space around the internal mold, giving the rock a “worm-eater” appearance. For the present, these oysters are

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1Crasnostrea soleniscus does not occur in the upper part of the Atarque Sandstone Member in the Carthage coal field area as reported by Cather (2007, description of maps units).
FIGURE 9—Cibola Canyon measured section showing the positions of the collections of *Flemingostrea elegans* from the Mulatto Tongue of the Mancos Shale and the Dalton Sandstone Member (?) of the Crevasse Canyon Formation. This section was measured on the slope below the hill with the spot elevation of 5,192 ft, located in the east-central portion of the La Joya 7.5-min quadrangle, Socorro County, New Mexico. [] indicates a collection from another locality. See Figure 1 for location.

Both the Mulatto and the D-Cross Tongues of the Mancos Shale in the Carthage coal field consist of gray, noncalcareous shale that contains abundant, large, yellowish-orange-weathering, cone-in-cone concretions. These concretions are superficially similar, making the two tongues difficult to distinguish from each other in structurally complex areas. However, the cone-in-cone concretions in the Mulatto Tongue (Fig. 8C) tend to be larger and more elliptical than those in the D-Cross (Fig. 8D), and have bedded sandstone bases. The cone-in-cone structure is confined to the top of the Mulatto concretions (Fig. 8C), whereas it covers the entire D-Cross concretion (Fig. 8D). Weathered prisms from the Mulatto cone-in-cone layer commonly litter the ground (Fig. 8C).

Sevilleta National Wildlife Refuge area

In the northeast Socorro County, the best constrained section is the one from Cibola Canyon (Fig. 9) on the Sevilleta National Wildlife Refuge. This measured section begins at the top of the Gallup Sandstone and includes the Dilco coal bed mined at the Garcia y Goebel mine approximately 15 ft (5 m) above the base. Darton (1928, p. 75) made two collections of marine fossils from above the coal at this location. Stanton identified the abundant oyster from these two collections as *Ostrea elegantula*. Here, articulated valves of *F. elegans* (D14500) occur in a 5-ft (1.5-m)-thick bed of very friable sandstone (unit 5) that is 103 ft (31 m) above the top of the Gallup Sandstone. Additional collections of *F. elegans* come from a 1-ft (30-cm)-thick bed of sandstone (D14479, unit 9) that is 133 ft (41 m) above the top of the Gallup Sandstone. The Dilco Coal Member of the Crevasse Canyon is about 103 ft (31 m) thick, and the Mulatto Tongue of the Mancos Shale, whose upper contact is an erosion surface, is at least 28 ft (8.5 m) thick. The 5-ft (1.5-m)-thick, fossiliferous sandstone (unit 5) is questionably referred to the Dalton Sandstone Member of the Crevasse Canyon. The presence of a *Crassostrea soleniscus* coquina (D14503) directly on top of the *F. elegans* sandstone (D14479) suggests that this 2-ft (61-cm)-thick, highly resistant sandstone (unit 10) is at or very near the top of the marine section.

The Gallup Sandstone on Sevilleta National Wildlife Refuge near the principal reference section for the Dakota Sandstone (Hook and Cobban 2007) contains large, dark-brown-weathering, highly fossiliferous concretions that yielded many specimens of lower Coniacian index fossil *Cremnoceramus*.
FIGURE 10—Mesa del Yeso measured section showing the positions of the collections of *Flemingostrea elegans* from the Mulatto Tongue of the Mancos Shale. This section was measured in the NW¼ sec. 32 T1S R5E, Mesa del Yeso 7.5-min quadrangle, Socorro County, New Mexico. See Figure 1 for location and Figures 8E and F for outcrop images.

Farther to the southeast, the 123-ft (38-m)-thick section of sandy shale (Fig. 10) that emerges out of the alluvium (Fig. 8E) about a quarter of a mile southeast of Mesa del Yeso and the refuge’s southern boundary in NW¼ sec. 32 T1S R5E, was initially one of the most puzzling Cretaceous sections in Socorro County. A 10-ft (3-m)-thick resistant bench of fine-grained, ripple-marked (Fig. 8F) and crossbedded sandstone, 80 ft (24 m) above the base of the section, stands in stark relief to the surrounding gray shales. The ripple marks have wavelengths of approximately 70 mm and amplitudes of approximately 10 mm. This bench is capped by a 2-ft (61-cm)-thick, even more resistant, purplish-weathering, sandstone concretion zone that is extremely fossiliferous. Fossils from this level (D14482) consist almost entirely of shells of *Flemingostrea elegans* and *Pleuriocardia subcurtum*. Initially, this shaly outcrop was thought to be the D-Cross Member of the Mancos Shale because of the similarity of this fossiliferous sandstone to the marker sandstone of Baker (1981) in the D-Cross Tongue on Sevilleta National Wildlife Refuge.

In 2004, when the D14482 collection was made, the D-Cross Tongue was the uppermost marine shale known from Socorro County. So, assignment to the D-Cross seemed to be the only viable choice. However, the faunas from the two sandstones are quite different; D11205 from the D-Cross marker sandstone is dominated by the early form of the oyster *“Lopha” sannionis* (see Hook and Cobban 2007, fig. 3), whereas the Mesa del Yeso fauna is dominated by *F. elegans*. The section at Cibola Canyon (Fig. 9) established that there were marine strata above the Gallup dominated by *F. elegans*. Consequently, all 123 ft (37 m) of this measured section have been assigned to the Mulatto Tongue. The lower 80 ft (24 m) of the outcrop consists of interbedded sandstones and silty shales, part of which may be nonmarine, but contain no fossils. Cone-in-cone concretions similar to those from the Mulatto Tongue at Carthage (Fig. 8C) have recently been observed at the east end of the outcrop belt approximately 20 ft (6 m) above the D14482 level. This Mesa del Yeso outcrop of Mulatto Tongue is mapped as the D-Cross Tongue on the preliminary geologic map of the Mesa del Yeso 7.5-min quadrangle (Cather et al. 2005). This outcrop was also visited by Darton (1928, p. 76), where he collected *Ostrea sp.* (= *F. elegans*) and *Cardium curtum* (= *P. subcurtum*).

**Other areas**

**Jornada del Muerto coal field**—Near the north end of the Jornada de Muerto coal field (Fig. 1), abundant *F. elegans* have been collected from an 8-in (20-cm)-thick, fine-grained sandstone (D14561) that is 116 ft (35 m) above the Gallup Sandstone and 60 ft
The Gallup Sandstone is extremely thick in Lincoln County compared to Socorro County. The most complete stratigraphic section is exposed along Jackson Draw. In 1968, E. R. Landis and W. A. Cobban (USGS) measured almost 400 ft (122 m) of sandstone and siltstone that they assigned to the Gallup Sandstone. The total thickness of the Jackson well section (Fig. 11) includes several mostly to partly covered intervals that may include some inter-tongued marine shale, but nothing thick enough to map as a separate unit. They placed the contact between the Gallup Sandstone and the Dico Coal Member of the Crevasse Canyon at the top of a 15-ft (4.5-m)-thick pale-yellowish-brown, laminated sandstone (Fig. 11, unit 25). Above that is a 60-ft (18-m)-thick covered interval that contains a spoil pile from a Dico coal prospect near the top. Although the top of the D-Cross Shale is not exposed along Jackson Draw, the lowermost resistant beds exposed are consistent with being at or near the base of the Gallup.

The lower 300 ft (91 m) of the Jackson well section is fossiliferous and lies entirely within the lower Coniacian. *Cremnoceramus erectus* appears first in the section approximately 120 ft (37 m) above the base (unit 10, D6767); it ranges through approximately 30 ft (10 m) of section to unit 14 (D6768). At both levels it is associated with the late form of *Lopha* sannionis and *Pleuroceridium curtum*. *Cremnoceramus crassus* appears in unit 37, approximately 214 ft (65 m) above the base of the Gallup and ranges through unit 23 (D6771), 300 ft (91 m) above the base, where it occurs in a coquina composed of *F. elegans*. *Flemingostrea elegans* has been observed but not collected in the section at approximately the D6765 level (unit 3), 12 ft (4 m) above the base, where it occurs with the late form of *Lopha* sannionis. *Flemingostrea elegans* ranges through almost 300 ft (91 m) of section, about three-quarters of the Gallup Sandstone exposed at Jackson Draw. Approximately 50 ft (15 m) above the coal prospect, Landis and Cobban observed, but did not collect, poorly preserved, brackish-water bivalves (*Corbicula?* sp.) in a limy concretion interval. This observation suggests that the western shoreline may have advanced across southwestern Lincoln County after formation of the Dico coal swamps. Ongoing mapping in the region may reveal the presence of the higher marine tongue (*Mulatto Tongue?) in this area and the Capitan area where *C. elegans* has been reported from above the coal.

Cobban (1986) illustrated the following species from the Gallup Sandstone at this Jackson well section: *Cremnoceramus crassus* (identified as *Inoceramus erectus*, D6770, fig. 4A); *Legumen* sp. (D6765, fig. 4C); the late form of *Lopha* sannionis (D6768, fig. 6C, E); *Pisoma?* sp., D6770 (fig. 8A); *Flemingostrea elegans* (as *Ostrea anomioides*, D6770, fig. 8I-b); *Pleuroceridium crassum* (D6770, fig. 8I-c); and *Lio pistha* sp., D6775 (fig. 9M).

**Jackson well section**

**Bull Gap/Rim Rock Canyon section**

The Bull Gap/Rim Rock Canyon section (Fig. 12) is one of the more important sections in Lincoln County because it is the only one in the county in which the upper part of the D-Cross Tongue of the Mancos Shale contains fossils that allow it to be dated definitively as early Coniacian. *Cremnoceramus erectus*, index fossil to the basal lower Coniacian, and *Scaphites frontenianus*, an ammonite formerly thought to be confined to the higher *C. deiformis* Zone (Kennedy and Cobban 1991, p. 86), have been collected from large, orange-weathering limestone concretions in the D-Cross Shale, approximately 60 ft (18 m) below the base of the Gallup Sandstone (D12655).

In addition the type-lot specimens of *Flemingostrea elegans* (D14910), which exhibit beautiful preservation of completely articulated shells (Fig. 13), were collected here, approximately 118 ft (36 m) above the base of the Gallup (Fig. 8G). The lower 160 ft (49 m) of the Gallup Sandstone are well exposed, very fossiliferous (Fig. 8H), and laid out classically as two ridges separated by a valley (Fig. 8G). The section also contains the remnants of a 5-ft (1.5-m)-thick *Crassostrea soleniscus* oyster reef (D14907); broken fragments of the extremely thick shells of *C. soleniscus* litter the ground.

The dip slope of the first ridge is an extremely resistant, 4-in (10-cm)-thick coquina of *F. elegans* (D14908) that rests on top of the reef and is 41 ft (12.5 m) above the base of the Gallup. A poorly preserved cremnoceramid (*C. erectus?) was observed on top of this bed.

*Cremnoceramus crassus* (D14875), index fossil to the upper lower Coniacian (Fig. 5), occurs in a limy, relatively coarse sandstone just below the top of the second ridge, approximately 134 ft (41 m) above the base of the Gallup. *Cremnoceramus crassus*, a relatively small species, occurs with abundant, well-preserved, late forms of *C. erectus* (Fig. 8H). Surprisingly, the middle lower Coniacian guide fossil, *C. deiformis*, does not occur in this section or any other section in Lincoln County.

Normal marine faunas dominated by inoeramids and *F. elegans* alternate with brackish-water faunas dominated by *C. soleniscus* in this section, suggesting that the western shoreline advanced then retreated in this area a few times. However, there is no sedimentary evidence that the area was ever subaerially exposed during deposition of the initial 150 ft (50 m) of the Gallup Sandstone. Neither the top of the Gallup nor base of the Crevasse Canyon is exposed where this section was measured, just west of US-54.

Cobban (1986) illustrated the following species from the D-Cross Tongue of the Mancos Shale and the Gallup Sandstone at the Bull Gap/Rim Rock Canyon section: *Forresteria* sp. (D12655, fig. 4I-j); and *Cremnoceramus erectus* (D12660, fig. 5H and D12655, fig. 6B).

**Lincoln and Otero Counties**

Specimens of *F. elegans*, including the type lot, from Lincoln County, New Mexico, have come entirely from the Gallup Sandstone.

The best constrained collections of *F. elegans* are from the Gallup Sandstone southwest of Carrizozo. There, the basal lower Coniacian index inoeramid *Cremnoceramus erectus* occurs below *F. elegans* near the top of the D-Cross Tongue, and the uppermost lower Coniacian index inoeramid *Cremnoceramus crassus* occurs with *F. elegans* in the upper third of the Gallup Sandstone. Details of these occurrences are given below for the Jackson well and Bull Gap/Rim Rock measured sections.

Three older collections made between 1911 and 1925 contain *F. elegans*. These older collections have labels indicating they came from (1) above a Dico coal bed in the Capitan area (USGS locality 13495), from (2) an unassigned Sandstone in the White Oaks area (8071), and from (3) an unassigned sandstone, probably the Gallup, south of Carrizo (7449). Otero County has yielded four collections of *F. elegans*, three from the Mancos Shale on the Mescalero Apache Indian Reservation and one from south of Three Rivers from the Gallup Sandstone.
FIGURE 11—Jackson well measured section showing the positions of the collections of *Flemingostrea elegans* from the Gallup Sandstone. This section was measured in the SW¼ sec. 13 T10S R8E, Oscura 7.5-min quadrangle, Lincoln County, New Mexico. See Figure 1 for location.

Other areas

Three older collections from Lincoln County, New Mexico, that contain *F. elegans* have been found in the USGS Mesozoic Invertebrate fossil collections stored at the Federal Center in Denver, Colorado. These collections were made between 1911 and 1925 and have Washington, D.C., locality numbers, which are not preceded by the Denver letter “D.” These collections were made in the Capitan, White Oaks, and Carrizozo areas.

**Capitan**—Washington collection 13495 contains several oysters identified originally as "*Ostrea elegantula*, Newb." The label indicates they were collected 1.5 mi (2.4 km) northwest of Capitan, New Mexico, from lower Colorado beds, on the west side of a fault, south 600 ft (183 m) from locality H-29. They are from a sandy clay at the top of a 25 ft (7.6 m) sandstone above a coal bed. They were collected by a geologist by the name of Hansen on May 26, 1925. The collection consists of six black specimens of *F. elegans*, including one articulated specimen 2.51 cm long by 3.13 cm high by 1.12 cm thick with a well-developed terebratuloid fold. One upper valve is 1.19 cm thick. This collection, which appears to be from a unit above a Dilco coal, indicates that the Capitan area experienced the Mulatto transgression of the seaway following the Gallup regression.

Bodine (1956) in a study of the Capitan coal field reports several fossiliferous beds in what he called the Mesaverde group. All his fossils are from either his lower sandstone member or the lower part of his middle shale unit; all the coals occur in the upper part of his middle shale unit. *Flemingostrea elegans* (D 10471) was collected from unit 14 of his lower sandstone unit, a 4-ft (1.2-m)-thick, very fossiliferous, quartzose sandstone that is 55 ft (17 m) below the middle shale (Bodine 1956, p. 20, table 1). Bodine (1956, p. 7) reports *Cardium pauperculum* from the base of the middle shale. Both of these localities are from below the major coal seams in the Crevasse Canyon Formation; they would probably be placed in an intertongued sequence of Gallup Sandstone and Mancos Shale using the more refined stratigraphic nomenclature available at this time.

**White Oaks**—Washington collection 8071 is a small lot containing *F. elegans* and the marine snail *Turritella* sp. This collection was made 2 mi (3.2 km) east of White Oaks. It came from 16 ft (4.9 m) above the top of the sandstone mentioned at locality 212, from beds of Benton age. Carroll H. Wegemann collected these fossils on October 18, 1912, as part of the White Oaks project (Wegemann 1914). There is no record of locality 212. One beautiful specimen of *F. elegans* is 4.44 cm high by 3.19 cm long by 2.79 cm thick. According to Wegemann (1914, p. 340) collection 8071 came from 65 ft (20 m) above the base of his formation 2, a 400-ft (122-m)-thick mixed
Bull Gap / Rim Rock Canyon

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**Genus Flemingostrea Vredenburg, 1916**

**Type species**—*Ostrea Flemingi* D’Archiac and Haime, 1853, from the lower Eocene of Pakistan (Stenzel 1947, p. 174).

**Diagnosis**—medium- to large-sized oyster with subequal, ovate to triangular valves and a prominent, broad (terebratuloid) fold opposite to the hinge that appears gradually in later growth, creating a hump in the profile of the left (lower) valve and a tongue-like extension in the right (upper) valve. Right valve during early growth is flat. Many species have regularly spaced concentric growth rings that are generally evenly spaced. Attachment scars are small to absent. The adductor muscle imprint is relatively large and kidney shaped. The shell wall can be exceptionally thick in the umbonal area.

**Occurrence**—*Flemingostrea* occurs in Cenomanian (Upper Cretaceous) through the Miocene (Tertiary) rocks in North and South America, Africa, Asia, and Russia.

**Discussion**—Stenzel (1959, p. 32) states that “A peculiarly folded shell, showing in a terebratuloid fold at the margin opposite the hinge, is characteristic of the genus...” He (p. 32) documents the following evolutionary trends within *Flemingostrea*:

1. Progressive development of radial sculpture from feeble frills of the foliaceous lamellae to spinose processes,
2. Progressive change in shell outline from ovate to orbicular to triangularly distorted.
3. All of these trends except development of spines are evident to some degree within the populations of *F. elegans* recorded within the lower Coniacian of New Mexico. Stenzel (1959, p. 32) notes further that these evolutionary changes occurred slowly and feebly, “…so that the species do not differ materially from each other.”

**Distribution**—There are only three species of the genus *Flemingostrea* known from the Western Interior. The oldest species, *F. prudentia* (White) (see p. 49, Figs. 14F–G), occurs in the upper Cenomanian *Metococeras mosbyense* Zone. Cobban and Hook (1984, fig. 4) show the known distribution of *F. prudentia* in an arcuate belt of brackish-water rocks that is parallel to the western shoreline of the Late Cretaceous Seaway during *M. mosbyense* time in the Black Mesa–Kaiparowits Plateau area of Arizona and Utah. The middle species, *F. elegans*, n. sp., occurs in the lower Coniacian of central New Mexico. The youngest species, *F. nanus* (Johnson), redescribed below, is from the Santonian of New Mexico.

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**Flemingostrea elegans**, n. sp.

**Figures 2, 3, 4, 13**

*Ostrea elegans*; Darton (1928, pp. 75–76).

*Ostrea anomioides*; Osburn and Arkell (1986, p. 40).

*Flemingostrea aff. prudentia*; Arkell (1986, pp. 75–76).

*Ostrea anomioides* Meek; Cobban (1986, p. 88, fig. 6H–I).

*Ostrea elegans* White; Cather et al. (2005, description of map units).

*Flemingostrea elegans*; Hook and Cobban (2007, p. 79, fig. 3).

**Types**—Holotype, specimen no. 51, Appendix, p. 56, (USNM 542207), USGS locality D14910, Fig. 13A;
Paratypes, specimen nos. 52–56, Appendix, (USNM 542208–542212), USGS locality D14910, Fig. 13B–F; Paratypes (USNM 542213), USGS locality D14559, Fig. 2; Paratype (USNM 542214), USGS locality D14500, Fig. 3; and Paratype (USNM 542215), USGS locality D6770, Fig. 4.

Description—Flemingostrea elegans conforms to most of the features of the genus but is quite variable in size, shape, and valve thickness. The species is of medium size with subequal valves. Specimens from the type lot (see Appendix, p. 56), collected at the Bull Gap Canyon, Lincoln County, New Mexico. A—Upper valve of the holotype, specimen no. 51 (USNM 542207). B—Lower valve with crinkles and a small attachment scar, paratype, specimen no. 52 (USNM 542208). C—Lower valve with a small attachment scar, paratype, specimen no. 56 (USNM 542212). D—Lower valve, paratype, specimen no. 54 (USNM 542210). E—Upper valve of a paratype, specimen no. 55 (USNM 542211). F—Lower valve with crinkles, paratype, specimen no. 53 (USNM 542209). The largest specimen, B, has a height of 41.4 mm and a length of 36.7 mm. Reduced 0.9 x.

The articulated paratype USNM 542213 from Carthage (Fig. 2) has faint radial “gashes” out to a length of 16 mm. These gashes radiate outward from the beak, forming angles of approximately 45° with respect to the hinge line and giving the shell a crenulated appearance. This specimen, which is not complete, has a minimum height of 50.4 mm, a length of 40.9 mm, and a thickness of 18.3 mm. The upper valve changes slope and becomes mature at a height of 37.1 mm. The valves of this specimen are open approximately 8 mm at the ventral margin, and the shell is filled with matrix. Its ventral view, therefore, shows the tebratuloid fold that is characteristic of the genus Flemingostrea (Fig. 2).

Attachment scars are absent on all but a few of specimens. Only three specimens in the type lot have attachment scars (see Appendix, p. 56); all are small, less than 2 mm across; two of these specimens are illustrated (Figs. 13B and C). No individual in any of the collections grew on another. The calcite valves of F. elegans are generally preserved as original shell material. Internal molds are probably the result of breakage of the shells after they were weather free from the matrix.

Etymology—The specific name elegans (handsome) is in homage to Dr. John Strong Newberry’s early contributions to the geology of New Mexico and a way to retain the flavor of his species elegantula (quite handsome). For a variety of reasons detailed in a later section of the paper (see p. 51), Newberry’s species name is unacceptable and should be treated as a nomen oblitum, a forgotten name.

Occurrence—Collections come from 35 localities in central New Mexico, primarily in Lincoln and Socorro Counties but also from Valencia, Bernalillo, and Otero Counties. The best-dated occurrences are in Lincoln County, where the lowest occurrence of F. elegans is with or above Cremnoceramus erectus (Meek) and the highest occurrence is with or above C. crassus (Petrascheck). These two species of Cremnoceramus date occurrences of F. elegans as early Coniacian. At the Bull Gap/Rim Rock Canyon section (Fig. 12), F. elegans occurs in beds above the last occurrence of C. crassus, suggesting that it may range higher in the section.

Type lot—the holotype and five paratypes all come from USGS locality D14910, NE¼ SW¼ SW¼ sec. 17 T9S R8E, Bull Gap 7.5-min quadrangle, Lincoln County, New Mexico (Fig. 8G). The types and 61 other well-preserved specimens are from a 5-ft (1.5-m)-thick, soft, slope-forming sandstone interval that is 118 ft (36 m) above the base of the Gallup Sandstone. This unit seems to be the source of completely articulated, loose specimens that roll down the scarp slope of the second Gallup ridge. The specimens from the type locality do not represent a random sample; they were collected

Footnote: The height was reconstructed by multiplying its length of 39.9 mm by the average H/L aspect ratio of 1.2 from the Appendix (p. 56).
was able to tolerate a relatively wide range of salinities from normal marine to brackish, but always on the seaward side of the shoreline.

The lack of attachment scars on all but a few of the more than 200 specimens in the collections indicates that *F. elegans* was a free-living oyster as an adult, probably with the lower valve partially buried in the sediment on the sea floor. One unillustrated specimen has a smooth subcircular scar approximately 7.9 mm in diameter.

**Discussion**—*Flemingostrea elegans* occurs in great numbers and always in sandstones, indicating a preference for high-energy environments. The closer the environment was to the shoreline, the thicker the shell and the less likely the valves are to be articulated or in life position. For example, at the Cibola Canyon section (Fig. 9) the thickest right valve from the low-energy environment at the D14500 level is 4.8 mm; a typical right valve from the high-energy environment at the D14479 level is 7.9 mm.

Articulated shells, for example those from the type lot (D14910), are indicative of an environment of deposition with a relatively high, intermittent sedimentation rate. In living oysters the ligament acts like a spring to hold the valves open; the adductor muscle keeps the valves closed. Thus, when the oyster dies and the muscle deteriorates and relaxes, the shell opens and the valves are at the mercy of waves and currents. Thus, the beautiful preservation of articulated valves at USGS locality D14910 indicates this population of oysters was buried very rapidly to a depth where the weight of the overlying sediment was greater than the force exerted by the ligament.

**Occurrences of Flemingostrea elegans** are more often associated with abundant *Plu ricoarcadia curtum* (Meek and Hayden) or *P. sub curtum* (Meek) than with the lower Cretaceous inoceramid zonal index species of *Cremnoceramus*.4 Molenaar et al. (1996, fig. 2) show that *C. cactus* and *P. curtum* share a common range. This situation is advantageous for field recognition because the small heart-shaped “cardiums” with radial ribs that often weather white are easier to find and identify than the incoherent.5

*Flemingostrea elegans* has been misidentified as *Ostrea elegans*, *Flemingostrea prudentia*, and *Ostrea anomioides* for more than 100 yrs (see Fig. 14). For more detail the reader is referred to the discussion on the history and usage of *Ostrea elegans* beginning on p. 51. The upper valves of all three species, especially in the immature stage, resemble each other. *Flemingostrea elegans* differs from both *O. elegans* and *O. anomioides* in possessing a terebratuloid fold in the mature shell, which places it in the genus *Flemingostrea*. *Flemingostrea prudentia* has a curved axis and is more rounded in outline (Figs. 14F and G). The superficial resemblance between *F. elegans* and *O. elegans* falls apart in the details. First, *elegans* has a fold in the adult shell; *elegans* does not. Second, *elegans* has a reniform adductor muscle scar; *elegans* has an oval one (White 1883, pl. XXXVI, fig. 6; reproduced as Fig. 14E). Third, *elegans* lacks chomata, while *elegans* has (see White 1883, pl. XXXVI, fig. 6; reproduced as Fig. 14E).

This description of *F. elegans* emphasizes attributes that a field geologist can recognize because this oyster species should be a useful field tool. Tree cover in the higher elevations in Lincoln County can make it very difficult to differentiate the Coniacian strata from similar-appearing Turonian strata, for example, sandstones in the Tres Hermosas Formation. Mapping occurrences of *Flemingostrea elegans* can help with this task.

Stephenson (1936) recorded *Ostrea elegans* from the Santonian of the Gulf Coast. His Santonian specimens are probably a different species, more related to *O. bella* (Conrad) as illustrated by White (1883, pl. XXXIX, fig. 6). Akers and Akers (2002, p. 196) regard *O. bella* as a Campanian species in Texas. Both *O. bella* and Stephenson’s *O. elegans* are characterized by radial shell architecture and lack the terebratuloid fold characteristic of *Flemingostrea*. Also, Stephenson’s species has chomata (numerous small denticles near the hinge), which *elegans* lacks and a much smaller adductor muscle scar than *elegans* has. See, for example, Stephenson (1936, pl. 1, fig. 9). The lack of the terebratuloid fold in both *bella* and Stephenson’s *elegans* indicates that they are not species of *Flemingostrea*.

Valves of juvenile *Flemingostrea elegans* bear a strong resemblance to *O. anomioides* Meek (Figs. 14 A and B) and have been misidentified as *O. anomioides*. However, *Ostrea anomioides* is a smaller, older species. Upper valves of the two are quite similar, but mature lower valves of *O. anomioides* lack the terebratuloid fold that places *elegans* in the genus *Flemingostrea*. *Ostrea anomioides* is now known to be an upper Albian species with a known distribution confined to western Montana (Dyman et al. 2000).

Stenzel (1959, pp. 32–33) assigns 11 species of oyster to the genus *Flemingostrea*, of which only the brackish-water form, *F. prudentia* (White 1877; Figs. 14F and G) occurs in the Western Interior. Eight of these eleven species occur in Cretaceous rocks, but only one of those eight, *F. oleana* (Stephenson 1945), is assigned to the lower

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3 See Cobban (1986, figs. 4A, 4B) for illustrations of *C. cactus* (identified as *I. deformis*) and *P. curtum*, respectively.

4 Stenzel (1959, pp. 32–33) did not include the dwarf species *Ostrea anomioides var. nanus* as part of the Tribe *Flemingostreini*. *Flemingostrea nanus* reaches maturity at a height of approximately 1 cm. See description of *F. nanus*.

5 See Cobban (1986, fig. 8I) for typical examples; here, several specimens of “cardium” (labeled “c”) are on a slab of sandstone associated with an upper valve of *F. elegans* (identified as *O. anomioides* Meek and labeled “d”) and an unlabeled lower valve of *F. elegans* in the lower left of the photograph.
Coniacian. Stephenson (1945) described Ostrea oleana from Jasper and Wayne Counties, Mississippi, where it is known only from core samples from deep petroleum wells. Flemingostrea oleana occurs in glauconitic sandstones just below beds with Pycnodonte acella (Roemer), a species that is not known from New Mexico. It does, however, occur nearby in eastern Colorado (D14050) and in western Kansas, both in the basal part of the Fort Hays Limestone Member of the Niobrara Formation along with Cremnoceramus deformis (Hattin 1977, fig. 14). Stephenson’s species, oleana, like most members of the genus, bears a strong resemblance to F. elegans. This is especially true in the aspect ratio of height to length in which an adult specimen of oleana has exactly the same aspect ratio of 1.2 as the type lot of F. elegans (Appendix, p. 57). Flemingostrea oleana differs from F. elegans in the following three key characteristics. First, the terebratuloid fold in F. oleana is off center, located on the anterior side of the oyster; that is, the axis of the fold is on the right side of the left valve and the left side of the right valve in exterior views (see Stephenson 1945, figs. 1, 3, respectively). Second, F. oleana is a more inflated (plumper) species, with an adult height to thickness ratio of 1.9 versus 2.6 for F. elegans, and a juvenile of oleana has a ratio of 1.8. Most of the inflation occurs in the upper valve of F. oleana, which is more convex initially than the flat portion of the upper valve of F. elegans. This gives the juvenile portion shell a convexo-convex profile, rather than the plano-convex profile of elegans. Third, F. oleana lacks crinkles, the radial elements that characterize a little more than a third of the type sample of F. elegans. Stephenson (1945, p. 74), in distinguishing F. oleana from F. battenesis (described originally as Ostrea johnsoni Stephenson 1936) qualifies the lack of radial elements in oleana by saying that if they are present, then they are "...obscure and delicate." None are shown in his line-drawing illustrations (Stephenson 1945, figs. 1–7). Flemingostrea battenesis, which is probably a slightly younger species than F. oleana, has a more convex right valve and a sinusoidal commissure, the line of closure between the two valves.

Geographic distribution—Flemingostrea nanus is known only from lower Coniacian rocks in New Mexico with documented occurrences in Socorro, Lincoln, Santa Fe, Bernalillo, Otero, and Valencia Counties.

Flemingostrea nanus (Johnson 1903)

Description—Flemingostrea nanus is a small oyster species that appears to be a scaled-down version of F. elegans. The shell is small, thin, plano-convex, ovate or circular in outline, and lacks an attachment scar. The lower valve is shallow with a small beak that projects just beyond a straight hinge line. The adductor muscle scar is subcentral, impressed, and subcircular. The upper valve is nearly flat and bears an indistinct muscle scar. The surfaces of both valves are ornamented with concentric growth lines, which are more prominent on the upper valve. Fine radiating striae can be seen near the anterior margin on the lower valve of a few specimens. The average specimen collected by Johnson (1903) has a height of 13 mm, a breadth of 10–13 mm, and a convexity of 3 mm. The average height of the six specimens in Figure 15 is 17.4 mm; the average height of 13 mm, a breadth of 10–13 mm, and a convexity of 3 mm. The average height of the six specimens in Figure 15 is 17.4 mm; the average length is 13.6 mm. Height at maturity for the specimens shown in Figure 15 is between 10.2 mm and 12.3 mm.

Etymology—Johnson (1903, pp. 113–114) used the varietal name nanus (“dwarf”)
FIGURE 15—Exterior views of figured specimens of *F. nanus* (Johnson), all from USGS locality 22861 at the Tongue Arroyo section, Santa Fe County, New Mexico. A—Upper valve of USNM 542216 showing a well-developed change in slope. B—Lower valve of USNM 542217 showing minor radial elements. C—Upper valve of USNM 542218. D—Upper valve of USNM 542219. E—Lower valve of USNM 542220 showing well-developed crinkles. F—Lower valve of USNM 542221 showing well-developed crinkles. Specimen A has a height of 18.7 mm, a length of 10.3 mm, and reaches maturity at a height of 10.2 mm. Enlarged 2.3×.

The illustrated specimens of *F. nanus* (Fig. 15) were collected at the Tongue Arroyo section, approximately 10 mi (16 km) south-west of Grand Central Mountain, from the Mesaverde Group, just beneath the first massive sandstone that underlies the coal zone, approximately 200 ft (61 m) above the soft Mancos shale tongue. There are more than 100 individual valves in the collection; the largest specimen (Fig. 15F) has a height of 18.9 mm and a length of 14.3 mm; it has well-developed crinkles. The collection was made by J. B. Reeside, Jr., and others on October 4, 1944. The collection has the Washington, D.C., collection number 22861.

**Paleoecology**—*Flemingostrea nanus* appears to have been a normal marine epifaunal suspension feeder. The lack of attachment scars on all specimens in the Washington collection (22861) indicates that *F. nanus* was probably a free-lying oyster as an adult, with the lower valve partially buried in the sediment on the sea floor. The valves are disarticulated, but not fragmented; a few have some attached fine-grained sandstone matrix. The small volumetric capacity of the shell combined with free-lying adults suggests that the optimum sedimentation rate was less than that for the larger *F. elegans*. These features indicate that *F. nanus* lived on an agitated bottom, but probably farther out to sea than did *F. elegans*.

**Discussion**—The description of *Flemingostrea nanus* was adapted from Johnson (1903, pp. 113–114). It reads much like the description of *F. elegans* above, with the notable exception of (1) size of the species, (2) the terebratuloid fold in the lower valve and the concomitant change in slope on the upper valve, and (3) crinkles. A typical adult valve of *Flemingostrea elegans* has about four times the area of a typical *F. nanus* and reaches maturity at a length of approximately 2 cm versus approximately 1 cm. Johnson may simply have overlooked the terebratuloid fold in his specimens, possibly because the shells are small and most are not articulated. Not every upper valve in the Washington collection shows the change in slope as well as the figured specimen shown as Fig. 14A. 

The number of individuals in Johnson’s collection is unknown. Radical ornamentation—crinkles occur on about one-third of the lower valves of *nanus* in the Washington collection; Johnson described crinkles as fine radiating striae. Two lower valves with well-developed crinkles are shown as Figures 15E and F.

Stephenson (1936, p. 6) placed *Ostrea anomaloides* var. *nanus* in synonymy with *Ostrea elegantula*, which he regarded as a guide fossil to the lower Santonian (Stephenson et al. 1942) possibly because: (1) The two species as published resemble each other morphologically; (2) They are both relatively small species (*nanus* is about half the size of Stephenson’s *elegantula*); and (3) They both have “elegant lamellae” or “crinkles,” although only a small percentage of specimens in the 22861 collection has crinkles.

Johnson’s variety *nanus* is treated as a valid species and not placed in synonymy with *elegans* primarily for two reasons: First, there is a profound age difference between the two species (early Coniacian for *elegans*; Santonian or Campanian for *nanus*.) Second, there is a profound size difference; adults of *elegans* are at least four times as large areally as adults of *nanus*.

Stenzel (1959, pp. 32–33) did not include *nanus* in a list of species he included in genus *Flemingostrea* most probably because Johnson’s (1903, pl. 1, figs. 10a–10d) illustrations do not show the terebratuloid fold. Without access to collection 22861 that shows this feature unequivocally (see Fig. 15), *nanus* would have been kept in the genus *Ostrea*.

**Geographic distribution**—*Flemingostrea nanus* is confined to Santa Fe County, New Mexico, where it has been collected from three localities.

because he realized his collection contained specimens of small adult individuals, not juveniles.

**Occurrence**—Johnson (1903, p. 114) collected this delicate shell from one horizon, where it occurs in great abundance, at two localities. The first is given as 1 mi west of Madrid in sandstones of Fort Pierre zone, where it occurs in great abundance, at two localities. The other is in Aachavica Arroyo, 1 mi (1.6 km) northwest of Grand Central Mountain. Johnson does not state the localities of his figured specimens. I visited both localities and was unable to find his prolific bed. However, 1.3 mi (2 km) N 77° W of Grand Central Mountain, I collected *Inoceramus balticus* from limestone concretions in the basal Mesaverde Group (D14504). This inocreramid indicates that strata in the vicinity of the type area for *Flemingostrea nanus* are of Santonian to Campanian age, making them much younger than the Cenomanian age strata containing *F. elegans*. The occurrence of *Ostrea anomaloides* var. *nanus* Johnson reported by Shimer and Blodgett (1908, p. 61) “…in the northwest corner of the Albuquerque sheet, fifteen miles southeast of Cabezon” may be a misidentification. It was collected (p. 58) from a 40-ft-thick fossiliferous section along with the Cenomanian oyster *Pycnodonte newberryi*, the Turonian oyster *Cameleolopha lugubris*, and the Turonian ammonites *Collignoniceras woollgari* and *Prionocyclus hyatti*.

The name Grand Central Mountain no longer appears on modern topographic maps. It does, however, appear on older maps, for example, on the geologic map of the Cerrillos area (Disbrow and Stoll 1957, pl. 1). Grand Central Mountain is the highest point in the Cerrillos Hills, shown with a circle but with the spot elevation of 6,976 ft in the NE¼ of sec. 6 T14N R8E, on the Madrid 7.5-min quadrangle, provisional edition of 1990, Santa Fe County, New Mexico.
The history and confusion surrounding the use of *Ostrea eleganta* is an integral part of this paper. This is especially true because I confused this new species with *O. eleganta* through the initial drafts of this paper. The key to discovering the misidentification was well-preserved upper valves from several localities that showed conclusively that the adductor muscle imprint is oval. From that point it became obvious that Newberry’s species lacked the terebratuloid fold in mature shells and had chomata. The fold is a generic character; the chomata, a specific characteristic.

Stenzel (1971, p. N964), in his exceptional treatise on fossil oysters, made the following comment on the importance of the adductor muscle scars. “The outlines and positions of the adductor muscle imprints are indicative of the interior anatomical topography of oysters. For this reason they are of utmost importance in the classification of fossil oysters.”

**Named, but not described or illustrated**

*Ostrea eleganta*, the “…remarkably neat little *Ostrea*…” of Newberry (1876, p. 33), has been a source of biostratigraphic confusion since Newberry mentioned that his new species occurred in rocks exposed along the Santa Fe Trail near present-day Springer, New Mexico. The rocks to which Newberry referred are now known to be the upper Turonian Juana Lopez Member of the Mancos Shale (Hook and Cobban 1980).

Newberry (1876, p. 33) did not describe his new species, but managed to confuse it in the text of his measured section along the Canadian River with both *Ostrea* [now *Camelolopha*] *lugubris* and *Ostrea congesta*. By introducing the new species name without a description, Newberry rendered *Ostrea eleganta* a nomen nudum, a “naked name.”

Some time later, Newberry sent the type specimens of *Ostrea eleganta*, which he had collected, presumably, in 1859, to C. A. White, an oyster specialist at the USGS in Washington, D.C. White illustrated two of them (Figs. 14C–E) as *Ostrea eleganta* Newberry in his review of the fossil Ostreidae of North America (White 1883, pl. XXXVI, figs. 5–7). White (p. 295) ascribed the authorship of the species to Newberry, who had neither a manuscript nor a published paper to support formal authorship as required today. White (1883, p. 295) did not describe the species, but indicated that it might be identical to *Ostrea bella* Conrad 1857, which he also illustrated (pl. XXXIX, fig. 6).7

Boyle (1893) in his catalog of North American Mesozoic invertebrates listed in chronological order every reference to North American Mesozoic invertebrate species published to that date. He showed Newberry as the author of the species, *Ostrea eleganta*, but gave the date of publication to White (1883). Boyle (1893, p. 209) did not have a separate entry for the date *O. eleganta* entered the literature as a new species, as he did for almost every other species in the catalog. The first mention of *O. eleganta* as a new species was, of course, Newberry (1876).

T. W. Stanton, in faunal lists for other geologists, either ascribed authorship to Newberry (Dumble 1895, p. 386; Vaughan 1900, p. 81; Lee 1917, pp. 177, 193, 202) or identified the species without the author’s name (Darton 1928, pp. 75–76). Stephenson (1936, p. 6), however, felt that White was the species’ author as did Shimer and Shrock (1944, p. 391). The first published identification of a fossil oyster as *O. eleganta* was made in Dumble (1895), soon after White (1883) illustrated Newberry’s type specimens. So, regardless of the nomenclatural problems associated with *O. eleganta* that are recognized today, field geologists were using Newberry’s species at the end of the nineteenth century.

Newberry (1876, p. 33) collected his “…remarkably neat little *Ostrea*” along the banks of the Red [Canadian] River in northeast New Mexico from “…ferruginous, laminated, sandy limestone…” These limestone beds are now known to be in the Juana Lopez Member of the Mancos Shale, which is of late Turonian age. Both T. W. Stanton and J. B. Reeside (as recorded in Stephenson 1936, p. 7) believed that Newberry’s original age assignment was in error, because all later collections, as identified by T. W. Stanton, had come from younger beds in New Mexico and Texas. All of these later collections, with the exception of Stephenson’s (1936) Alabama collections and his one specimen from the Hagan Basin, New Mexico, appear in the literature in faunal lists without illustrations or descriptions. None of those later collections was made in the presumed type area. Stanton (as quoted in Stephenson 1936, p. 7) doubted whether the cotype specimens came from the Canadian River area. He thought they may have come from younger beds of Montana age in the Hagan coal field near Uña del Gato, New Mexico.

Hook and Cobban (1980) located what they believed to be the site of Newberry’s (1876, p. 33) measured section along the banks of the Canadian River in Colfax County, New Mexico. They were, however, unable to duplicate his collection of *O. eleganta*. They suspected (1) that the type specimens of *O. eleganta* (two of which were illustrated by White, 1883) were collected elsewhere and (2) that Newberry confused his new species with the oyster *Camelolopha lugubris* (Conrad), a small species that is extremely abundant in Juana Lopez calcarenites along the banks of the Canadian River. Newberry’s (1876, p. 33) description of the rocks in his measured section supports this second conclusion. The section includes a “Ferruginous, laminated, sandy limestone [the Juana Lopez Member of the Mancos Shale]…a great storehouse of fossils, of which, perhaps the most abundant is a remarkably neat little *Ostrea*, hitherto undescribed, which I have called *Ostrea eleganta*; one of the most common and widely distributed Middle Cretaceous fossils of New Mexico.” The oyster that is extremely abundant in the Juana Lopez calcarenites is *C. lugubris*, which is one of the most widely distributed Cretaceous fossils in New Mexico.

Newberry completed the geologic field work along the Canadian River in 1859 and submitted his final report for the San Juan exploring expedition in 1860. Publication was delayed by the Civil War until 1876. In 1860 F. B. Meek prepared the paleontologic report on the Cretaceous fossils collected by Newberry; publication was also delayed by the Civil War until 1876. Both reports were published in a single volume (Macomb 1876). Included in Meek’s (1876a, pp. 123–124; pl. 1, figs. 1a–d) report were a description and illustrations of *Ostrea lugubris* Conrad, but there was no mention of *O. eleganta*. Meek (1876a, p. 123) noted that *O. lugubris* “…seems to be a common and characteristic species in the lower portions of the Middle Cretaceous of New Mexico.”

Lee (1917, pp. 177, 193, 202, and 213) collected specimens attributed to *Ostrea eleganta* Newberry in northeast New Mexico and Darton (1928, pp. 75–76) in west-central New Mexico. Darton’s collections are from the Mulatto Tongue of the Mancos Shale exposed on or just outside the present-day Sevilleta National Wildlife Refuge, Socorro County, New Mexico, where many of my specimens were collected. Both Lee’s (1917) and Darton’s (1928) New Mexico collections are from Coniacian or younger rocks. Dumble’s (1895, p. 386) collections from Presidio County, Texas, and Vaughan’s (1900, p. 81) collections near El Paso, Texas, are from rocks containing *Mantehites* (Delaurealla) delawarenensis (listed as Schloenbachia delawarenensis) of early Campanian age (Cobban et al. 2008, p. 88).

Stephenson (1936, pl. 1, figs. 5–9) illustrated two well-preserved specimens from the Santonian of Alabama and one specimen from USGS locality 6778 from the Hagan Basin, New Mexico (his pl. 1, fig. 10) as *O. eleganta*. However, the left valves of his...
illustrated specimens are “...ornamented with a series of delicate, slightly upraised, elegantly crinkled concentric lamellae, spaced 1 to 2 millimeters apart” (Stephenson 1896, p. 7). The cotypes of O. elegantula illustrated by White (1883, pl. XXXVI, figs 5-7; reproduced as Figs. 14C–E) lack these crinkled lamellae, suggesting that Stephenson’s specimens were misassigned based on the concept of the species used at that time. Ostrea bella, however, which White regarded as a possible synonym of O. elegantula, has these “elegant” lamellae.

White (1883, p. 295) in his discussion of Ostrea elegantula stated that “This form is probably identical with Ostrea bella Conrad, but as I am not quite certain of this, I give both names a place in this list. Professor Newberry’s reference to his form was written before the publication of Conrad’s description, but his report was not published until long afterward, in 1876.”

In his discussion of Ostrea bella, White (p. 292) states that O. bella “…is probably too closely like the form which is named Ostrea elegantula to be regarded as a distinct species.” This apparent synonymy by White may have led Stephenson to misapply the name O. elegantula to his Santonian fossils. Stephenson (1893, p. 6), however, did not put O. bella in synonymy with O. elegantula. Stephenson (in Stephenson et al. 1942) regarded O. elegantula as a key index fossil to the lower Santonian and showed its range on the Geological Society of America’s Chart No. 9—Correlation of the outcropping Cretaceous formations of the Atlantic and Gulf Coastal Plain and Trans-Pecos Texas.

Thirty-eight years later, Hook and Cobban (1980) added to the confusion surrounding O. elegantula in their study of the Juana Lopez beds in northeastern New Mexico, in the presumed type area of O. elegantula. They (Hook and Cobban 1980, fig. 2) were able to find an outcrop that matched Newberry’s (1876, p. 33) description, but were unable to duplicate his oyster fauna. They concluded (p. 42) that Newberry had confused Canuleolopha lugubris with his “...remarkably flat little Ostrea...” and that the type of O. elegantula were identical to the types of the later named and more widely recognized O. beloiti Logan 1899. Even though O. elegantula had date priority over O. beloiti, it had not been used in the literature for almost 40 yrs; whereas, O. beloiti had been used widely during that time. They, therefore, suggested that O. elegantula be regarded as a nomen oblitum, a forgotten name. In a later paper on the occurrence of O. beloiti in Trans-Pecos Texas, Cobban and Hook (1980, p. 170) reiterated their suggestion that O. elegantula be considered a nomen oblitum, as did Kennedy et al. (1989, p. 112). The confusion has continued in print into the new millennium with the publication of Texas Cretaceous Bivalves 2 by the Houston Gem and Mineral Society (Akers and Akers 2002). Their figure 167 (p. 196) contains a description of O. beloiti Logan 1899 in tabular format that is based on Stephenson’s (1936) description of O. elegantula. Their figure 168 (p. 197) contains line drawings of four oyster shells in the center of the page labeled Ostrea beloiti Logan 1893. These drawings are four of the five figures that Stephenson (1936, plate 1, figs. 6–9) used to illustrate Ostrea elegantula White.

The new collections of oysters from lower Coniacian rocks in Socorro and Lincoln Counties that are similar to the figured types of Ostrea elegantula (in White 1883 and as Figs. 14C–E), indicated that Cobban and Hook (1980) were greatly in error. The types of O. elegantula are distinct morphologically from those of O. beloiti. Therefore, there is no need to treat O. elegantula as a nomen oblitum because of its (supposed) synonymy with O. beloiti.

Summary

The historical review has shown that O. elegantula Newberry is a species that (1) was named (and later illustrated), but never defined (a nomen nudum), (2) cannot be found at its type locality, (3) has been used in the literature over the last 130 yrs for at least three morphologically distinct oyster species that range in age from late Albian to Santonian, and (4) has been a source of confusion since it was named.

Despite all this confusion, I preferred to use O. elegantula Newberry as illustrated by White (1883, pl. XXXVI, figs 5-7; reproduced as Figs. 14C–E) for this new oyster species that is a key guide fossil to the lower Coniacian in west-central New Mexico. However, the obstacles to use of Newberry’s name proved too difficult to overcome, even before I realized that the species elegantula could not be assigned to the genus Flemingostrea.

First, there would have been no type locality for O. elegantula. Most specimens of F. elegans come from nearshore sandstones. These sandstones represent high-energy, paleoenvironments that do not exist in lower Coniacian rocks exposed along the banks of the present-day Canadian River in northeast New Mexico where Newberry (1876, p. 33) indicated he collected the type specimens. Second, there is no record that Newberry was ever in Socorro or Lincoln Counties, the area in which F. elegans is most abundant.

Third, there is the “legality” of using the name elegantula. Although the International Code of Zoological Nomenclature (International Commission on Zoological Nomenclature 1999) makes a special provision for species names proposed before its adoption in 1931, it is doubtful whether elegantula meets all the criteria for an indication.

Newberry’s (1876) geological report, in Macomb’s “Report of the exploring expedition from Santa Fe, New Mexico, to the junction of the Grand and Green Rivers of the great Colorado of the west in 1859” satisfies the publication and naming requirements of Article 11. Article 12 on names published before 1931 states that each name must be accompanied by a description or a definition or by an indication. An indication for a species name is satisfied by a description or illustration of the taxon that is being named. The discrepancy here is that the illustration of Ostrea elegantula appeared 7 yrs after the species name appeared in print.

This situation of having specific or generic names published in lists without formal descriptions and/or illustrations was apparently not uncommon in the paleontological literature of the United States in the later half of the nineteenth century. A similar case appears in Meek (1876b, p. 11), where he introduced the subgenus Gryphaeostrea Conrad 1865 with type species Gryphaea vomer Morton within the genus Ostrea. He noted (p. 11, footnote) that “…Mr. Conrad did not publish a diagnosis of this type, but merely gave the name in a list of fossils. At my request, however, he gave me in a manuscript the above diagnosis, and mentioned the above type.”

Closer to the heart of the biostratigraphy used in this paper is the inoceramid Cremno-ceramus deformis Meek. The date C. deformis was described is 1871, not 1877 as is often cited. “Although Meek only listed his new species in his paper of 1871, it is accompanied by a valid indication in the form of a reference to Hall’s figure (1845, pl. 4, fig. 2)” (Walaszczyk and Cobban 2000, p. 88).

An analogous situation is the oyster species Flemingostrea subradiata (Cragin 1893). Cragin (1893, p. 200, pl. XLV, fig. 11) described and illustrated the new species Ostrea carica from the Upper Cretaceous Lewisville Sandstone Member of the Woodbine Formation of Denton County, Texas. He merely mentioned (p. 200) in the draft—not in the published paper—that he considered some of the specimens with the “…anterior part of both valves ornamented with more or less pronounced and rather numerous, narrow, radial plications…” to be a distinct species. In his manuscript he gave these forms the name O. subradiata. At the time of

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9Newberry’s field work was completed in 1859, but the report’s publication was delayed until 1876 by the outbreak of the Civil War. Conrad’s description was published in 1857 in the Report of the U.S. and Mexican Boundary Survey, v. 1, pt. 2, p. 156, pl. 10, fig. 4a, b. Thus, if the two species were to be identical, then Conrad’s name would have date priority.

9Ostrea beloiti occurs in an oyster cockina at the base of Lincoln Limestone Member of the Greenhorn Formation along the banks of the Canadian River (Hook and Cobban 1980, fig. 4) and is listed as Gryphaea pitcheri in Newberry’s (1876, p. 33) section. They assumed, erroneously, that Newberry’s collections of O. elegantula had come from this section and, therefore, had to have come from this lower formation because the only other oyster in the section, Canuleolopha lugubris, occurred in the higher calcarenite.

52 New Mexico Geology May 2010, Volume 32, Number 2
publication he considered them as simply "...an individual phase of O. carica."

Stephenson (1952, pp. 75–76), however, in his work on Woodbine faunas of Texas, considered both O. carica and O. subradiata to be valid species. He (pp. 75–76) states that "Among 21 available shells that are believed to be cotypes of carica none show the characteristic radial costae [rib]s of O. subradiata. Costae are also wanting on the shells in the cluster illustrated by Cragin. Although the cotypes might conceivably be regarded as individual smooth variants, the absence of costae on so many examples, and the fact that many of them are elongated in outline, seem to justify treating the costate, subcircular to broadly subovate forms as a separate species. It seems desirable to preserve the name subradiata, which Cragin originally intended to apply to these costate shells, although the legality of ascribing authorship to him may be open to question." Stenzel (1959, p. 33) had no problem with the legality of Stephenson’s assignment and placed subradiata (Cragin 1893, p. 200) in the genus Flemingostrea.

A forgotten name
I, like Lloyd Stephenson, find it desirable to honor one of the West’s pioneer geologists by preserving a species name he proposed more than 100 yrs ago. However, there are too many problems associated with Ostrea elegantula to consider it a valid species. Accordingly, I feel that Ostrea elegantula Newberry should be considered formally as a nomen oblitum, a forgotten name, and that it should not be used for Upper Cretaceous oysters in New Mexico or elsewhere.

However, I, along with a long list of other geologists including T. W. Stanton, one of the giants of Western Interior paleontology, and N. H. Darton, arguably the greatest field geologist ever, have used Newberry’s species name incorrectly for the similar lower Coniacian oyster species Flemingostrea elegans. Although the outbreak of the Civil War delayed publication of Macomb’s report until 1876, Newberry did not revise the text he submitted in 1860. In a prefatory note dated June 1, 1876, Newberry (1876) stated that "[t]he observations made fifteen years ago, if accurately made, have equal value now as then; if inaccurate, it is only right that the credit of the correction of errors should belong to those who make such corrections. The geological narrative now given stands, therefore, just as written, and is a fair exponent of the state of our geographical and geological knowledge of the West at the date of its preparation. It is evident that to modify the report so as to conform to all the conclusions more recently reached, would be to falsify the record and greatly impair the independence and value of the statements it includes. The truth or error of these statements will soon be demonstrated by the extension of the explorations of other parties into this field. It is by just that credit or discredit of the trial to which the report is to be subjected should belong to the writer. Knowing that this work was done formerly and believing that it was in the main accurately done, he accepts the entire responsibility of it, whether for praise or blame."

Although I was initially confused about the specific name to use for this new species of oyster, I was never confused about its stratigraphic utility. Flemingostrea elegans is an ideal guide fossil: it occurs in great numbers, is easily identifiable, and is restricted geologically to lower Coniacian rocks and geographically to New Mexico. Dr. John Strong Newberry should be praised for his pioneering work on the geology of the Colorado Plateau and, specifically, in New Mexico. A brief biography of Newberry can be found in Chenoweth (1992).

I had hoped that Newberry’s species name, elegantula, could be preserved through a complete redefinition. Unfortunately, that did not prove to be possible. I am, however, paying homage to Dr. Newberry’s contributions to New Mexico’s geology by using the name elegans (handsome), which is a variation of elegantula (quite handsome), for this new species of Upper Cretaceous oyster.

Accordingly, Flemingostrea elegans is described and illustrated with specimens from Socorro and Lincoln Counties. This new species is restricted geologically to lower Coniacian strata and geographically (at present) to New Mexico. Reference stratigraphic sections at six localities in New Mexico are presented. Flemingostrea elegans is not conspecific with either the smaller and younger New Mexico oyster, F. nanus (Johnson 1903) or the penecontemporaneous Gulf Coast oyster, F. alana (Stephenson 1945).

Conclusions
Flemingostrea elegans, n. sp., is an excellent guide fossil to lower Coniacian strata in central New Mexico. It is a medium-sized oyster that occurs in great numbers in the Mulatto Tongue of the Mancos Shale in Socorro County, New Mexico, and the Gallup Sandstone of Lincoln County, New Mexico. Its unique feature among late Turonian and early Coniacian oysters is a low-amplitude fold in the lower valve that developed when the oyster reached maturity. The upper valve is flat in the juvenile stage, but flexes abruptly downward at an angle of 45° in the adult stage. It differs from contemporary oyster species like "Lophia" sammiosis by having concentric rather than radial ornamentation; it differs from Crassostrea soleniscus in being much smaller and having thinner valves.

Flemingostrea elegans, n. sp., appears suddenly in the lowermost lower Coniacian inoceramid zone of Cremnoceramus erectus (Meeke) and ranges through the uppermost lower Coniacian inoceramid zone of Cremnoceramus crassus (Petracheck). It has no immediate ancestor in the Western Interior; although it could be succeeded by the Santonian F. nanus (Johnson), also known only from New Mexico. The only other species of Flemingostrea in the Western Interior is F. pruinscis (White), an older species known only from upper Cenomanian, brackish-water strata from the Black Mesa–Kaiarpowits Plateau area of Arizona and Utah.

Acknowledgments
I thank the following organization and individuals for access to collecting localities: the Fish and Wildlife Service at Sevilleta National Wildlife Refuge (Cibola Canyon section); Dewy and Linda Brown, Fite Ranch (Carthage sections); and Robbie Hooten (Bull Gap and Rim Rock Canyon sections). Kevin C. McKinney and the late Robert Burkholder, both USGS, Denver, took the photographs of the oysters in Figures 14 and 4, respectively. Edwin R. Landis, USGS, retired, measured the Jackson well section. W. A. Cobban, USGS, Denver, and Neil H. Landman, American Museum of Natural History, provided thoughtful reviews that improved the manuscript.

Field support for this study was provided by Atarque Geologic Consulting, LLC. Fossil collections have been assigned USGS Mesozoic locality numbers; they begin with the prefix “D” for Denver and are housed at the Federal Center in Denver, Colorado. Type and illustrated specimens have been assigned USNM numbers and are reposited in the U.S. National Museum in Washington, D.C.

I thank W. A. Cobban and K. C. McKinney for sponsoring me as an adjunct at the USGS working on Upper Cretaceous stratigraphy and paleontology in New Mexico.

I owe a special debt of gratitude to W. A. Cobban, who shared his extensive knowledge of Upper Cretaceous faunas, especially the Coniacian inoceramids, with me. He and I talked extensively as the research on this paper progressed; he provided photocopies of key oyster papers that would have been very difficult for me to obtain. He allowed me to access the collections at the USGS Mesozoic Depository in Denver, Colorado. The paper benefited considerably from his insights.

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May 2010, Volume 32, Number 2
New Mexico Geology 53
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### Appendix

Measurements made on the type-lot specimen of *Flemingostrea elegans*, n. sp., and a comparison with *F. oleana*. “—” indicates measurement not possible, B = both valves, R = right valve, L = left valve, I = internal mold, Unk = unknown. *See Figure 3 for key to measurements.*

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<th>Valve(s)</th>
<th>Crinkles</th>
<th>Height* (mm)</th>
<th>Length* (mm)</th>
<th>Thickness* (mm)</th>
<th>Maturity* (mm)</th>
<th>H/L</th>
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<td>2.6</td>
<td></td>
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</tr>
<tr>
<td>F. oleana</td>
<td>60.0</td>
<td>50.0</td>
<td>32.0</td>
<td>1.2</td>
<td>1.9</td>
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</tr>
</tbody>
</table>

range from 20.5 mm 15.8 mm 5.8 mm 13.4 mm 0.99 1.92
to 41.5 mm 39.9 mm 23.3 mm 26.5 mm 1.34 3.76

25 with crinkles (40%)