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New reference sections for the Semilla Sandstone Member of the Mancos Shale and their genetic implications

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Abstract

Newly recognized exposures of the Upper Cretaceous Semilla Sandstone Member of the Mancos Shale in the Hagan Basin, Galisteo Lowlands, and southern San Juan Basin expand the known depositional limits of the member. These new exposures of the Semilla Sandstone exhibit an upward succession of transitional, sandy bioturbated, interbedded, and crossbedded shelf facies. The contact with the underlying Mancos Shale is gradational in all areas examined. The uppermost crossbedded facies of the Semilla is everywhere in sharp contact with the overlying Mancos Shale. Proposed reference sections for the Semilla in the Hagan Basin and Galisteo Lowlands are virtually identical to the type section of the member on the east side of the San Juan Basin. All of these widely spaced sandbodies were deposited at approximately the same stratigraphic position relative to the overlying Juana Lopez Member marker horizon. Faunal evidence confirms biostratigraphic correlation between the Semilla sandbodies in the type section and the new sections. Local cross sections demonstrate a lenticular sandbody geometry. The facies architecture of these sandbodies is interpreted to represent shelf sand ridge deposits. The ridges formed over a much larger geographic area than has been documented previously.

Introduction

The Upper Cretaceous Semilla Sandstone Member of the Mancos Shale was defined initially by Dane et al. (1968) as a formal stratigraphic unit. The type area is on the eastern side of the San Juan Basin at the Holy Ghost Spring recreation area, approximately 7.5 mi south of La Ventana, New Mexico (Fig. 1). Additional exposures of the Semilla other than those at the type area are known but have not been studied in detail. The stratigraphic relationship of these outcrops to those at the type area and their implications for genesis of the Semilla are therefore poorly understood. This paper describes outcrops mentioned but not explicitly described in Dane et al. (1968) and LaFon (1981). These include exposures of the Semilla in the Hagan Basin, Galisteo Lowlands, and the southern San Juan Basin (Fig. 1). The primary objectives are to establish reference sections of the member in the Hagan and Galisteo areas. The relationship of these new sections to the type section and their implications for Semilla sandbody genesis will be discussed briefly.

Previous work

At the type area the Semilla Sandstone is bounded above and below by marine units of the Mancos Shale. Faunal collections by Dane et al. (1968) and by the author indicate that the Semilla lies within the *Prionocyclus hyatti* Biozone of latest middle Turonian age (Fig. 2). A few meters of marine shale separate the top of the Semilla from the overlying upper Turonian, calcarenitic Juana Lopez Member of the Mancos Shale. Approximately 60 m of marine shale separate the base of the Semilla from the underlying lower Turonian Bridge Creek Limestone Member of the Mancos Shale (Fig. 2). ☞

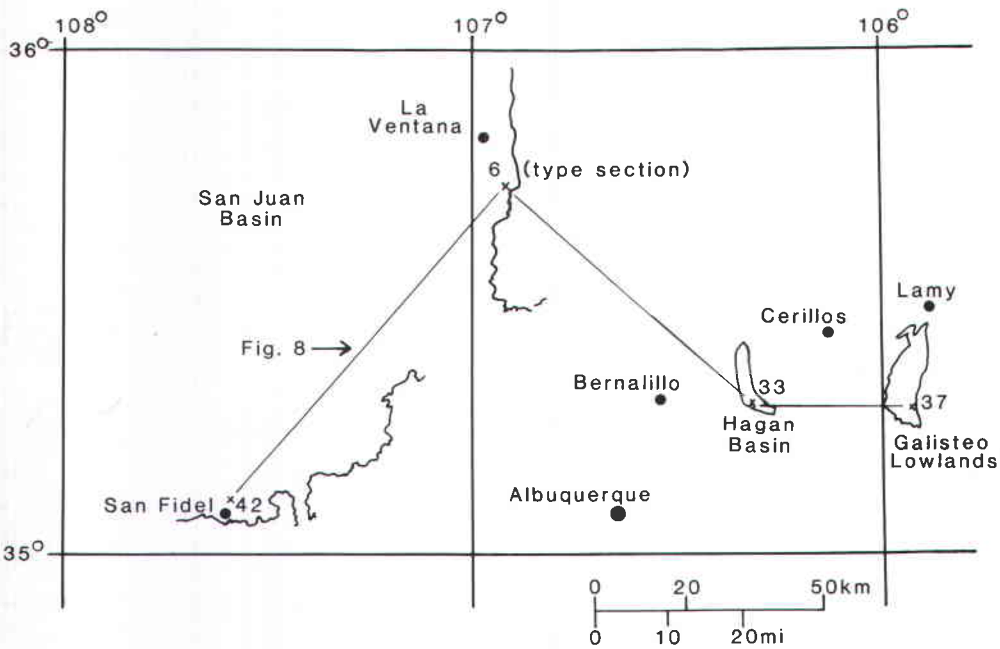

FIGURE 1—Location map of study areas. Basin outlines show Cretaceous–Jurassic contact; numbered sections indicate control points used in Fig. 8.

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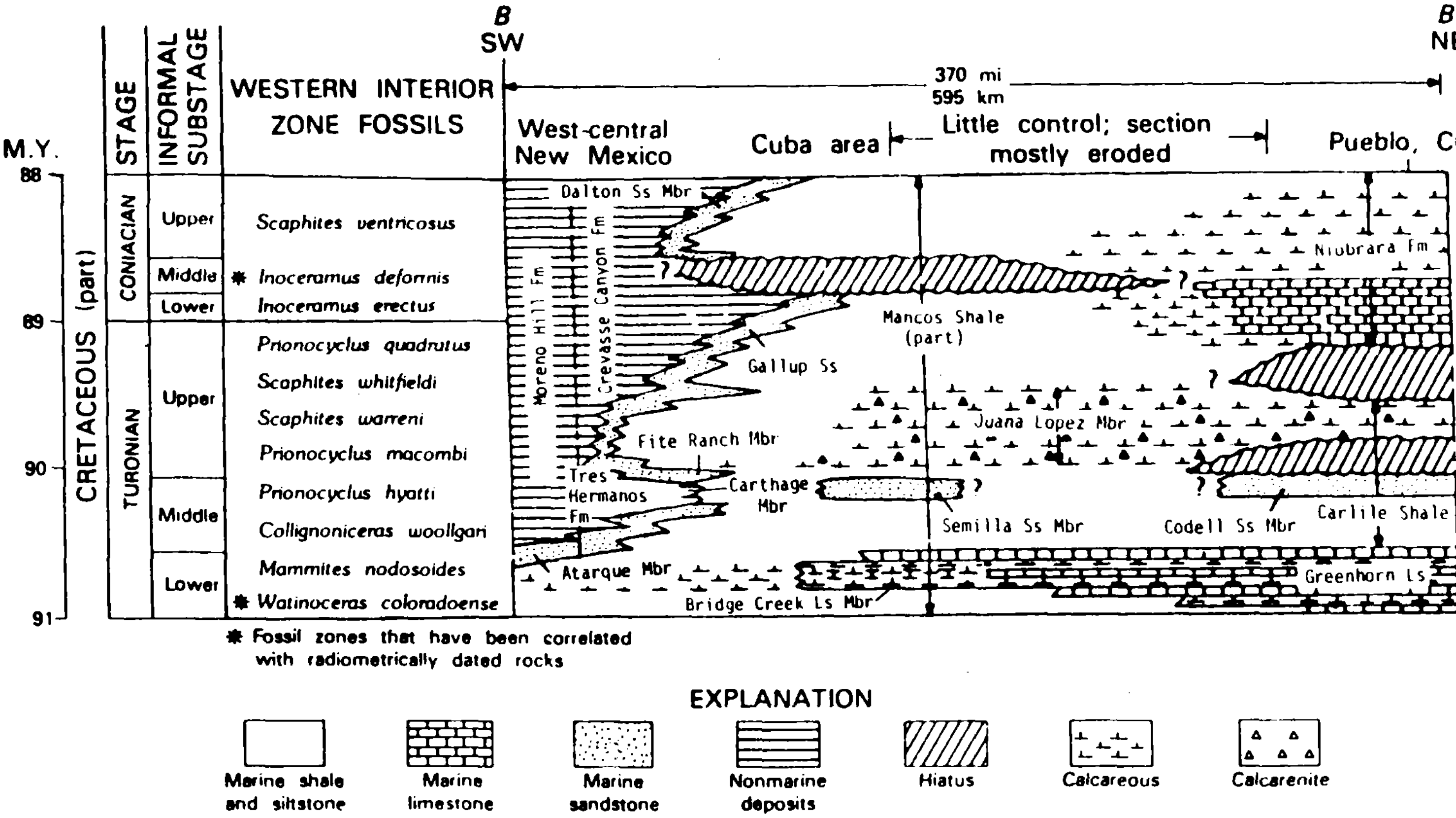

FIGURE 2—Chronostratigraphic cross section of Turonian and Coniacian units of west-central New Mexico and Pueblo, Colorado. (Modified from Merewether et al., 1983, reprinted by permission of Society of Economic Paleontologists and Mineralogists, Rocky Mountain Section) Note queried limits of the Semilla Sandstone Member.

The known outcrop belt of the Semilla Sandstone in the eastern San Juan Basin extends discontinuously north and south of the type section a total distance of approximately 22 mi. LaFon (1981) proposed a depositional model for the Semilla based on examination of a portion of this area. He concluded that "the Semilla formed as two discrete offshore sand bars", naming them the Holy Ghost and Bernalillito Arroyo bars, respectively (Fig. 3). The bars gradationally coarsen upward from the underlying Mancos Shale and are capped by crossbedded medium-grained sand. They are separated laterally by muddier interbar areas. LaFon (1981) attributed genesis of the Semilla to storm-driven transport of sand from the prograding Turonian paleoshoreline (Atarque Sandstone Member of the Tres Hermanos Formation, Fig. 2) into offshore areas of deposition. Following Campbell (1973), LaFon proposed that sand accumulation was primarily controlled by a slight steepening of the shelf floor resulting in a loss of current transport capacity and deposition. In this way the Semilla offshore bars gradually aggraded during the overall regressive episode of shoreline progradation. However, no supporting evidence was presented for the location or existence of the shelf slope break. Additional exposures of the Semilla Sandstone described in this paper provide a more complete understanding of the distribution of Semilla offshore sandbodies and may help refine Semilla genetic models.

Hagan Basin reference section

Stearns (1953) first mentioned the occurrence of "moderately bedded brown sandstone" below the Juana Lopez Member south of Hagan, New Mexico. Black (1979) briefly noted the marine-bar origin of this sandstone and believed it to be time equivalent to the Semilla Sandstone Member of the San Juan Basin. LaFon (1981) also mentioned the Semilla in this area.

The sandstone in the Hagan Basin occurs approximately 28 m below the top of the Juana Lopez Member and attains a maximum exposed thickness of approximately 12.0 m. It forms a low west–northwest-trending hogback offset by several small faults in the vicinity of the old Diamond Tail Ranch house south of the ghost town of Hagan (Fig. 4). The outcrops can be traced southeast of the ranch house for 1.7 mi, beyond which Cretaceous rocks are covered by Quaternary colluvium. To the west the sandstone thins rapidly, passing into a muddy sandstone containing a septarian concretionary horizon approximately 1 m thick. The Semilla index fossil *Prionocyclus hyatti* (Stanton) was collected from the concretions and from the main outcrop belt. This sandstone is biostratigraphically and lithologically equivalent to the Semilla Sandstone Member at the type area and should therefore be considered part of the member.

The most complete exposure of the Semilla Sandstone in the Hagan Basin occurs just southwest of the old Diamond Tail Ranch

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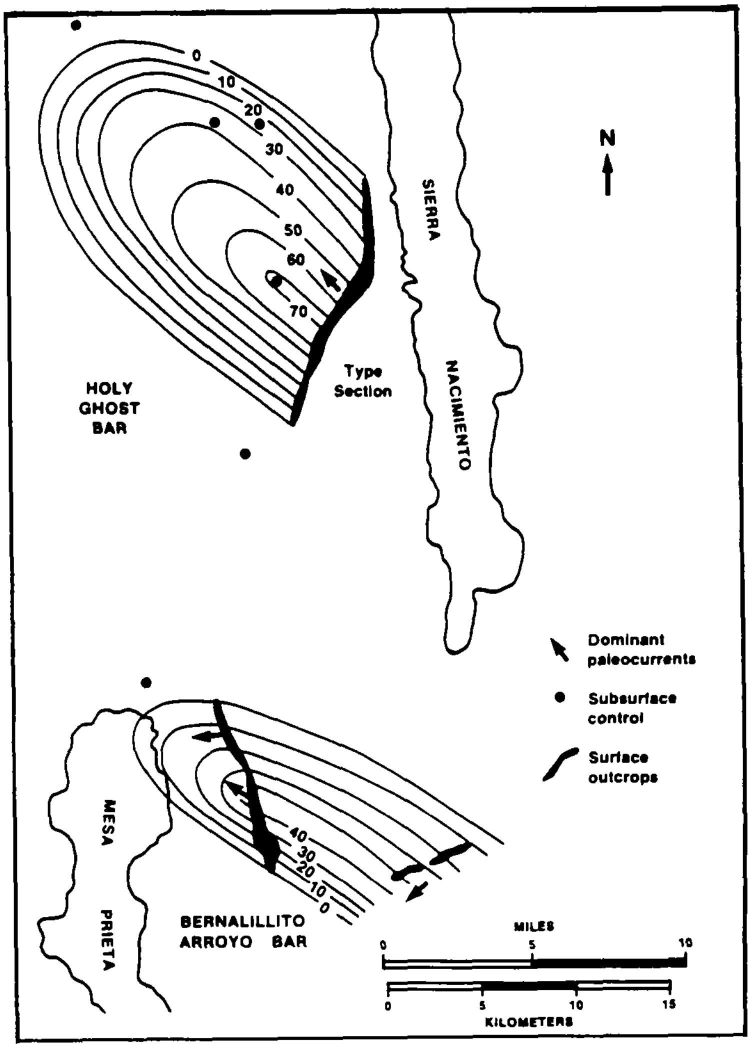

FIGURE 3—Isopach of the Semilla Sandstone on the eastern side of the San Juan Basin. Contour interval is 10 feet. (Modified from LaFon, 1981, reprinted by permission of American Association of Petroleum Geologists)

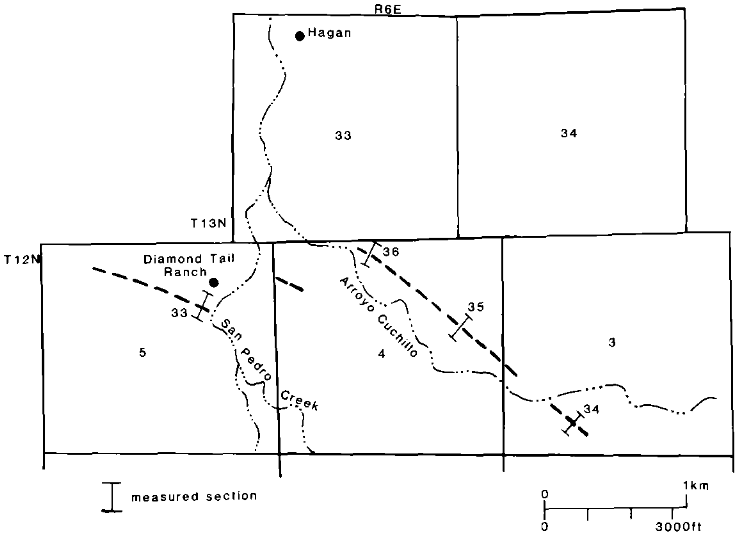

FIGURE 4—Detail map of Semilla Sandstone outcrops (dashed line) in the Hagan Basin. Numbered sections indicate control points used in Fig. 5.

TABLE 1—Characteristics of Semilla Sandstone lithofacies. Symbols are used in Figs. 5, 7, and 8.

Facies	Lithology	Sedimentary structures	Biogenic structures	Symbol
Crossbedded	300–350 μm, well-sorted, quartzose sand; thin (1–3 cm) lenses of silty bioturbated sandstone separates some units; typically poorly preserved.	Tabular tangential and trough cross sets, 15–40 cm thick; mostly sharp, planar contacts between units, some with irregular scoured contacts; wave- or interference-rippled upper surfaces common.	Occasional subhorizontal burrows on bedding surfaces.	(C_B)
Interbedded	200–300 μm quartzose, moderately sorted, stratified sand interbedded with poorly sorted, finer grained bioturbated units. Shale clasts common along bedding planes. Includes distinctive phosphate pebble–shark teeth lag near base; resistant ledge former.	Beds range from 5 to 30 cm thick, and thicken upward; sharp irregular lower contacts, bioturbated upper contacts. Stratified units consist of horizontally laminated and rare trough crossbeds.	Extreme lateral variability in degree of bioturbation; vertical and subhorizontal *Ophiomorpha, Thalassinoides, Zoophycos,* and *Cylindrichnus* recognized, horizontal *Rhizocorallium, Thalassinoides* on bedding surfaces.	(I_B)
Sandy bioturbated	100 μm poorly sorted sand coarsening upward to 250 μm; ~10–15% matrix; sorting improves upward, occasional shell fragments, up to six zones of calcareous septarian concretions; slope-forming to basal cliff-forming unit.	Primary structures destroyed by bioturbation; rare, well-sorted, thin (~2 cm) lenses of undisturbed, horizontally laminated sand; shale partings and clasts common.	Predominantly 100% bioturbated; rare, distinct *Ophiomorpha* and *Thalassinoides* burrows present.	(S_B)
Transitional	100 μm muddy sand and shale, calcareous septarian concretions; typically recessed slope-forming unit.	Thin-bedded, horizontally laminated.	Absent to rare.	(Tr)

house along a small tributary drainage to San Pedro Creek (section 33, Figs. 4 and 5). Here the Semilla consists of an upward-coarsening sequence of three distinct lithofacies summarized in Table 1. The lower contact of the Semilla with the Mancos Shale is nowhere exposed in the Hagan Basin. In other areas where it is exposed, it grades from a black, fissile shale upward into muddy sandstone of the transitional facies (Table 1). The contact is placed where the percentage of sandstone exceeds that of shale. The transitional facies consists of thinly bedded (1–3 cm), horizontally laminated, very fine grained, muddy sandstones and shale. It grades upward into the sandy bioturbated facies (Table 1). This facies is poorly sorted, containing particles as coarse as medium-grained sand dispersed throughout a bioturbated matrix with approximately 10 to 20% disseminated shale. Throughout most of the facies all traces of primary sedimentary structures have been destroyed by bioturbation. Rare, well-sorted, horizontally laminated lenses of fine- to medium-grained sandstone are also present. Capping the sandy bioturbated facies is a distinct, massive to weakly laminated, 50–60-cm bed consisting of well-sorted, medium-grained sandstone. Phosphate pebbles as large as 4 mm in diameter, shark teeth, shale clasts, and shell debris are concentrated in the upper 3–10 cm of the bed. Some shell fragments are as large as 4.5 cm in diameter. The unit is approximately 25% burrowed with subhorizontal *Ophiomorpha* and *Thalassinoides* traces being most common. This bed marks the base of what is herein termed the interbedded facies. This facies consists of horizontally stratified units alternating with thinner, densely burrowed units (Fig. 5 and Table 1). Individual beds thicken upward and are separated by sharp, irregular contacts. These beds compose the uppermost Semilla Sandstone Member within the Hagan Basin and are sharply overlain by black, fissile Mancos Shale. The vertical facies assemblage described above for section 33 is substantially representative of the Semilla as it occurs in the Hagan Basin. It is herein proposed as a reference section for the member in this area.

Galisteo Lowlands reference section

A thin, but persistent, hogback-forming sandstone below the Juana Lopez in the Galisteo Lowlands was first noted briefly by Stearns (1953). He described it as "generally only 1 or 2 feet thick, but at one locality in the southeast part of the Galisteo Lowlands, soft massive sandstone below the principal bed increases the thickness to 30 feet." Working from Stearns' description the author located the principal outcrops of this sandstone approximately 12 mi south of Lamy, New Mexico, and east of NM–41 on the San Cristoval Ranch (Fig. 6).

The sandstone in the Galisteo Lowlands occurs approximately 33 m below the top of the Juana Lopez Member. It forms a low north–south-trending hogback that is well exposed over approximately 2.3 mi by cuts of Arroyo Gaviso (Fig. 6). It continues a short distance north of Arroyo Gaviso where it becomes covered by Quaternary alluvium. To the south it thins rapidly to a point where it has been eroded by small tributaries of the Arroyo Gaviso. The Semilla index fossil *Prionocyclus hyatti* (Stanton) was collected from this sandstone. It is biostratigraphically and lithologically equivalent to the Semilla Sandstone Member at the type section and should therefore be considered part of the member.

An exceptionally well exposed, complete section of the Semilla in the Galisteo Lowlands is present along a small meander-bend cut of Arroyo Gaviso (section 37, Figs. 6 and 7). All facies recognized in the Hagan Basin and described in Table 1 are present in this section. The lower contact is gradational from dark, fissile Mancos Shale below into muddy sandstone of the transitional facies above. The transitional facies again grades upward into the sandy bioturbated facies. Septarian concretions found only along the northwestern extreme of the outcrop belt at Hagan are present randomly distributed throughout the transitional facies. Within the sandy bioturbated facies the concretions are laterally continuous enough to be traced along most of the main outcrop belt. Commonly the concretions are well-cemented lithologic equivalents of the surrounding material in which they are found. More rarely they are

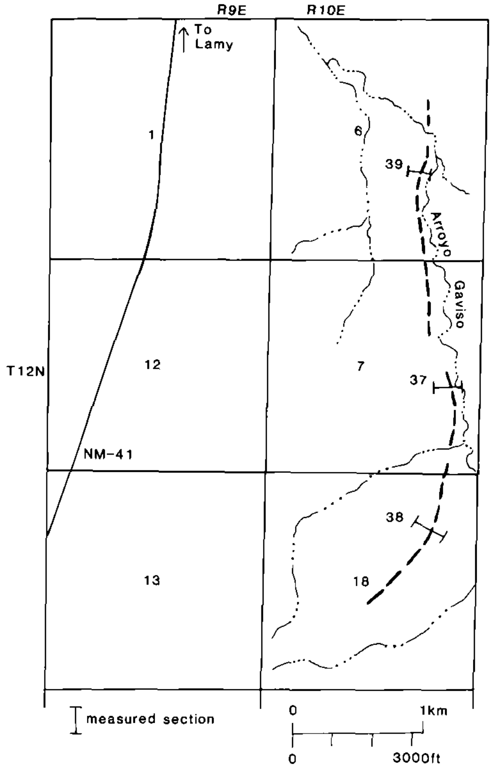

FIGURE 6—Detail map of Semilla Sandstone outcrops (dashed line) in the Galisteo Lowlands. Numbered sections indicate control points used in Fig. 7.

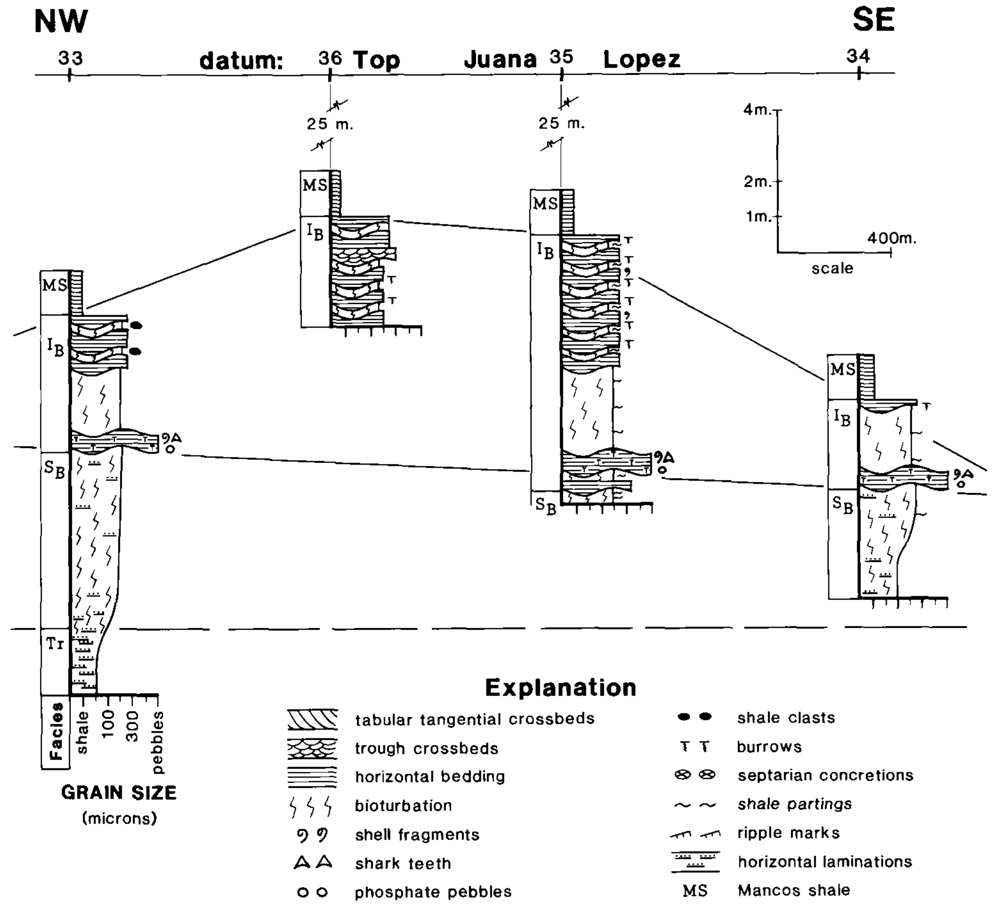

FIGURE 5—Cross section showing facies relationships of Diamond Tail ridge in the Hagan Basin. See Table 1 for explanations of facies designations and Fig. 4 for line of section.

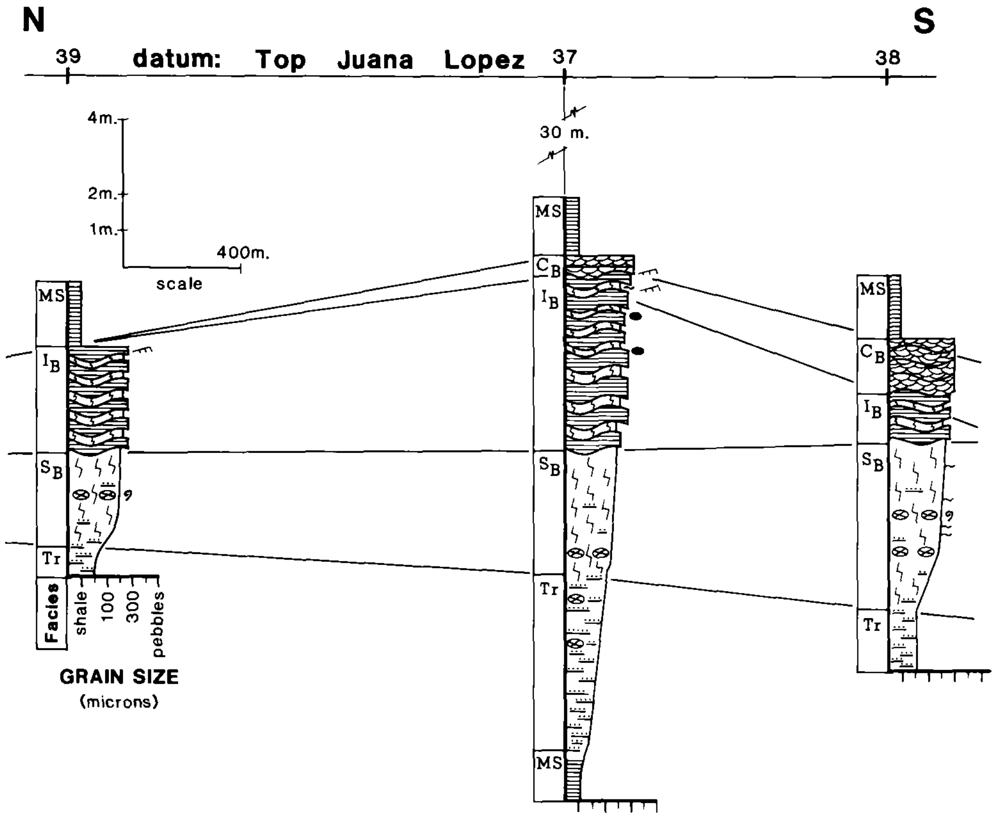

FIGURE 7—Cross section showing facies relationships of San Cristoval ridge in the Galisteo Lowlands. See Table 1 for explanations of facies designations and Fig. 6 for line of section.

richly fossiliferous, containing a fauna representative of the *Prionocyclus hyatti* Biozone.

As in the Hagan Basin, the interbedded facies caps the sandy bioturbated facies. The distinctive pebble–shell bed present in the Hagan Basin was not observed in the Galisteo Lowlands. Instead, units typical of the upper interbedded facies at Hagan cap the sandy bioturbated facies. At Hagan however, both the horizontally stratified and intervening bioturbated units increase in thickness upward within the facies. At Galisteo the horizontally stratified units thicken to a maximum of 30 cm whereas the intervening bioturbated units progressively thin upward to a minimum of 4 to 8 cm. Near the top of the facies interference-ripple marks are common on the bedding planes of the stratified units.

Capping the interbedded facies is the crossbedded facies (Table 1). This facies is not present in the Hagan Basin. Poorly lithified and friable, it is usually very poorly preserved in outcrop. In this area it consists of trough cross sets in beds 15 to 30 cm thick. Limited paleocurrent measurements suggest a predominant southwesterly flow. These units compose the uppermost Semilla Sandstone Member in the Galisteo Lowlands and are sharply overlain by black, fissile Mancos Shale. The vertical facies assemblage described above for section 37 is substantially representative of the Semilla as it occurs in the Galisteo Lowlands. It is herein proposed as a reference section for the member in this area.

Facies geometry and environmental implications

The overall geometry of the Semilla Sandstone in the Hagan Basin and Galisteo Lowlands is shown in Figs. 5 and 7, respectively. The top of the Juana Lopez Member is utilized as a datum in the cross sections. Regional studies indicate that, at least in these localized areas, this horizon is essentially synchronous (Dane et al., 1966; Hook and Cobban, 1980). Where possible, all outcrop sections of this study are tied to the Juana Lopez as a datum. The Semilla is present approximately 28 to 33 m below this marker horizon.

The facies associations of the Semilla Sandstone in the Hagan Basin and Galisteo Lowlands form lenticular "pods" that appear to thin and pinch out laterally from the reference areas. The geometry of the individual facies is difficult to determine because of restricted exposures in these areas. At the Hagan Basin reference area the transitional facies was observed only at section 33. Approximately 2 mi west–northwest of this section however, only septarian concretions in muddy sandstone are present 30 m below the Juana Lopez, indicating lateral continuity of the transitional facies and thinning of all other facies. Thickness trends within the interbedded facies also support thinning of the Semilla away from the reference area. The interbedded facies is approximately 8.0 m thick southeast of section 33. It thins gradually in both directions away from this area (Fig. 5) and pinches out into the concretionary muddy sandstone horizon to the northwest.

Within the Galisteo Lowlands reference area the sandy bioturbated facies thickens gradually to the south. The overlying interbedded facies thins to the north where it composes the topmost units of the Semilla Sandstone. It also thins to the south where a thick (~1.5 m) crossbedded interval is present. The geometry of these units within this small area, along with Stearns' (1953) description of the Semilla as "generally only 1 or 2 feet thick" elsewhere in the Galisteo Lowlands, supports thinning of the Semilla away from the reference area.

Subsurface data indicate that this lenticular geometry also characterizes the Semilla in areas surrounding its maximum outcrop development. LaFon (1981) inferred a similar geometry for Semilla sandbodies at the type area on the east side of the San Juan Basin (Fig. 3). Facies present at the type area are similar to those at the reference areas described above. The overall lenticular geometry of the Semilla suggests that it may have formed as shelf sand ridges analogous to those on the modern mid-Atlantic U.S. shelf (Swift, 1976; Swift and Field, 1981). Similarities between facies recognized in the Semilla Sandstone and other Western Interior Cretaceous units interpreted as shelf sand ridge deposits lend further support to a shelf sand ridge interpretation (see Tillman and Martinsen, 1984; Kofron, 1987; Wolter, 1987). The Semilla sandbodies in the Hagan Basin and Galisteo Lowlands are herein named the Diamond Tail Ridge and the San Cristoval Ridge respectively, after the ranches on which they occur.

Southern San Juan Basin section

"On the west side of San Jose Canyon, massive to weakly bedded sandstone below the basal part of the Juana Lopez" was interpreted by Dane et al. (1968) to be part of the Semilla Sandstone. The author has measured a 25-m section at San Jose Canyon, approximately 2 mi north of San Fidel, New Mexico (Fig. 1). It consists of two sandstone bodies separated by a 7.5-m covered interval, inferred to be shale. This section (section 42, Fig. 8) represents the southernmost known exposure of the Semilla Sandstone Member. It occurs approximately 9 mi north of the currently known, seaward pinchout of the correlative Tres Hermanos paleoshoreline. The sandstone is exposed for only a short distance in San Jose Canyon because of slumping within the overlying Gallup Sandstone and Mt. Taylor volcanic flows. It could not be followed east or west away from the San Jose Canyon area.

Lithologically the sandstones consist of a vertical succession of facies similar to those described at the reference areas in the Hagan Basin and Galisteo Lowlands. The uppermost crossbedded facies is sharply overlain and separated from the Juana Lopez by approximately 8 m of Mancos Shale. The Juana ☞

Lopez is very thin and poorly exposed here. Two molds of *Inoceramus costellatus* (Woods) were collected from the sandstone units. *Inoceramus costellatus* is indicative of the *Prionocyclus hyatti* Biozone (Kauffman, 1977), suggesting correlation with Semilla sandbodies at the type area. It appears that in this area two Semilla sand ridges developed, superimposed one on the other. An alternative interpretation may be that the lowermost sandstone at San Jose Canyon represents a heretofore unrecognized exposure of the Fite Ranch Member of the Tres Hermanos Formation. Similarities between the vertical lithologic succession measured by Molenaar (1983) at Putney Mesa on Acoma tribal land (his section 61B) and the section at San Jose Canyon (8.7 mi northeast of Putney Mesa) support this interpretation. If correct, San Jose Canyon represents the oldest known exposure of the Fite Ranch Member. Hook, Molenaar, and Cobban (1983) report that the Fite Ranch is diachronous, being older to the north. The interpretation presented here is consistent with this trend. Unfortunately, problems obtaining access to Acoma tribal lands prevented field checking of these inferred relationships between Putney Mesa and San Jose Canyon.

Stratigraphic relationship to type section

The Semilla type section (section 6, Fig. 8) consists of a vertical facies sequence that is similar to those previously described. The lower contact is gradational, passing upward from Mancos Shale into the transitional and then the sandy bioturbated facies. Six septarian concretionary horizons are present within the sandy bioturbated facies. Many of these are richly fossiliferous, containing faunal elements of the *Prionocyclus hyatti* Biozone. The pebble–shell bed recognized in the Hagan Basin is present capping the sandy bioturbated facies. Above this bed the interbedded facies is relatively thin. The overlying crossbedded facies is well developed and sharply overlain by Mancos Shale. The uppermost facies thicken and thin away from the type section, suggesting a lenticular geometry similar to that seen in the Hagan and Galisteo areas. LaFon (1981) has interpreted a similar Semilla sandbody geometry at the type section.

The stratigraphic relationship of the new measured sections to the type section of the Semilla on the eastern side of the San Juan Basin is depicted in Fig. 8. The occurrence of the *Prionocyclus macombi* Biozone within the Juana Lopez Member is used as a datum in this cross section. Regional studies indicate that this zone occurs at the top of the member in the southern San Juan Basin. It occurs at the base of the member at the Juana Lopez type section near Cerrillos, New Mexico (Fig. 1), and on the eastern side of the San Juan Basin near the type section of the Semilla (Hook and Cobban, 1980). Therefore, the top of the Semilla is shown relative to the top of the Juana Lopez in section 42, and relative to the base in sections 6, 33, and 37 (Fig. 8). This should provide a more accurate

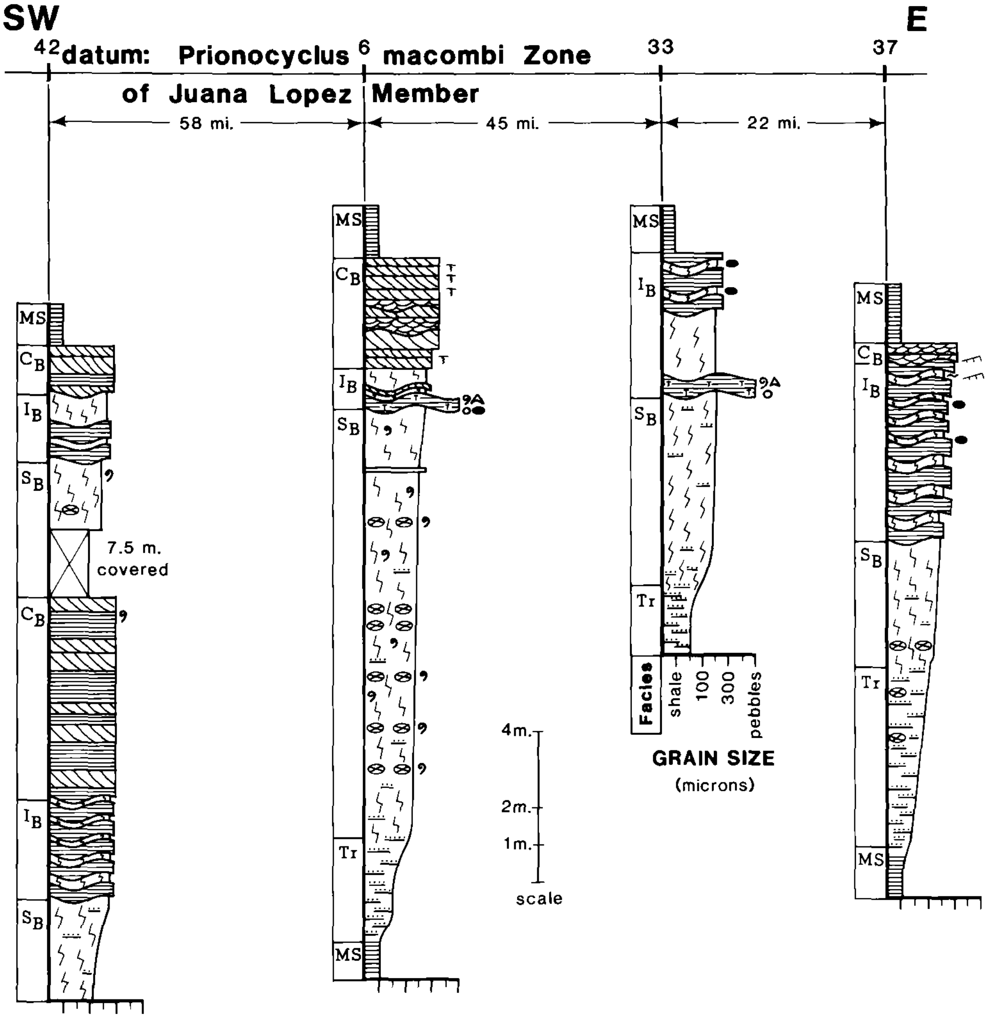

FIGURE 8—Regional cross section showing relation of proposed Hagan Basin (33) and Galisteo Lowlands (37) reference sections, and southern San Juan Basin (42) section to the Semilla type section (6) on the east side of the San Juan Basin. See Table 1 for explanations of facies designations and Fig. 1 for line of section.

datum event with which to compare these Semilla sections.

The cross section shows that the various sandbodies described in this paper were deposited at approximately the same stratigraphic position relative to the overlying Juana Lopez marker horizon. Lithologic and biostratigraphic correlation between these widely spaced areas clearly supports the formal inclusion of these sandbodies within the Semilla Sandstone Member as it is defined at the type section. However, the cross section should not be interpreted as indicating continuous deposition of these sandbodies in all areas between the sections displayed. Rather, it appears that the uppermost sandy bioturbated, interbedded, and crossbedded facies were deposited as lenticular, discontinuous shelf sand ridges that are only partially exposed in the areas shown in Fig. 8. In contrast, the lowermost transitional facies was deposited in areas of maximum ridge development as well as in intervening areas between ridges. Preliminary results of subsurface analysis indicate that these trends extend over a much larger geographic extent than has previously been thought.

Conclusions

Additional exposures of the Semilla Sandstone Member described in this paper are lithologically similar to the type section of the member on the east side of the San Juan Basin. Faunal evidence documents a clear biostratigraphic correlation of the widely spaced exposures. Vertical and lateral facies successions strongly support a shelf sand ridge interpretation for the Semilla. The ridges formed over a much larger geographic extent than has been documented previously. Therefore, processes affecting ridge generation at the type area must have been active in the areas described in this paper as well. Any model for Semilla shelf sand ridge genesis must account for all of these ridges present at the surface as well as those that may be present in the subsurface.

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Vincent C. Kelley

(1904–1988)

Vincent C. Kelley, eminent New Mexican geologist, made outstanding contributions to our geologic literature, taught hundreds of geologists at the University of New Mexico, and was a major worker in our professional organizations. Excellent field geologic work done by his students reflects on his example; most of his research was in the field dealing with local and regional geology.

Interestingly, his first job was for the U.S. Geological Survey on Utah's alunite deposits under the direction of Eugene Callaghan, who later was NMBMMR's director (1949–1957). Vin's major reports include: for the U.S. Geological Survey, those on the San Juan Mountains mineral deposits and stratigraphic–structural studies for the USGS Fuels Branch on Sierra Lucero, New Mexico, Pagosa Springs, Colorado, and the Big Horn Basin, Wyoming; for the University of New Mexico Publications in Geology, iron ore in New Mexico, geology of the Caballo Mountains (with Caswell Silver), regional structure and tectonic history of the Colorado Plateau; and for NMBMMR, geology of the Pecos country, geology of the Ft. Sumner quadrangle, Scenic Trip to the Geologic Past for the Albuquerque area, geology of the Albuquerque Basin, geology of the Sandia Mountains and vicinity (with Stuart A. Northrop), geology of the Española Basin, and geology and technology of the Grants uranium region (compiler).

Vin was one of the organizers and the first president of the New Mexico Geological Society in 1947, honorary member in 1955, chairman and editor of the first field conference guidebook in 1950, and leader of many of those field trips as well as contributor of numerous articles to the NMGS guidebooks. He was a charter member of the New Mexico Mining Association in 1940, served on its Board of Directors for many years, and was vice-president during 1947–1950.

Dr. Kelley was active in numerous national professional organizations, including Geological Society of America (Fellow in 1942, Councilor in 1960–1962), Society of Economic Geologists, Society of Mining Engineers of AIME, and American Association of Petroleum Geologists.

Vin was born in Seattle, Washington; he received his AB from UCLA in 1931, MS from Cal Tech in 1932, and PhD also from Cal Tech in 1937. He began teaching at the University of New Mexico in 1937 and took over as chairman of the Geology Department in 1962, serving in this capacity until he retired in 1970. His teaching influence can be seen by the more than 60 theses and dissertations for which he served as chairman. His geologic investigations were mainly of structure and stratigraphy with emphasis on economic geology as indicated by the numerous reports on New Mexico base- and precious-metal deposits, ground-water resources, highway routing, and deposits of turquoise, gravel, limestone, barite, talc, fluorite, coal, pumice, perlite, kyanite, manganese, and oil and gas. Dr. Kelley's bibliography fills several pages of small type.

Forceful lecturer, keen observer, and meticulous writer, Vin's chief joy was field geology in which he excelled and whose methods he enthusiastically communicated to students and coworkers. With his long legs, he was difficult to keep up with in the field. Albert Schweitzer noted, "For us the great men are not those who solve the problems, but those who discover them." Vincent C. Kelley discovered and solved many of New Mexico's geologic puzzles. His bibliography and the eminence of his students attest to his stature.

Vin's personal warmth and helpfulness have been enjoyed by me in the field from the Cerrillos in 1951 through many parts of the state including the upper Pecos, Black Range, Zuni Mountains, Pedernal Mountains, Rhodes Canyon in the San Andres Mountains, and just a few years ago, the east side of the Sacramento Mountains several miles north of Cloudcroft. When we climb over the outcrops, we can look up ahead—he'll be there.

—Frank E. Kottlowski