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STRATIGRAPHY AND PALEOENVIRONMENTS OF THE HAGAN BASIN, NORTH-CENTRAL NEW MEXICO

RAYMOND V. INGERSOLL and VINCENT C. KELLEY
Department of Geology
University of New Mexico
Albuquerque, New Mexico 87131

INTRODUCTION

The purpose of this paper is to summarize present knowledge of the stratigraphy and paleoenvironments of the Phanerozoic section exposed in the Hagan basin, north-central New Mexico (fig. 1). Excellent exposures of Mississippian through Quaternary strata occur in this area in a homoclinal structure that tilts the section east and northeast at the northeast end of the Sandia uplift, a Neogene fault block formed concurrently with rifting. Structural and intrusive events within the Hagan basin complicate stratigraphic interpretations and correlations (Beaumont, this guidebook; Black, this guidebook; Kelley, 1977; Kelley and Northrop, 1975). Nonetheless, this is one of the most complete exposures of the Phanerozoic section in New Mexico.

Most of the information presented here is a condensation of Kelley and Northrop (1975, p. 28-76), with additions and modifications based on subsequent work.

MISSISSIPPIAN

Arroyo Periasco Group

Mississippian strata occur sparsely in the Sandia Mountains as structurally isolated thin beds of near-shore and/or tidal-flat marine deposits (see Armstrong and Mamet, this guidebook). Lithologies include sandstone, limestone, dolomite, dedolomite, chert and mudstone. The Arroyo Periasco Group is nonconformable on Precambrian rocks and is overlain disconformably by the Pennsylvanian Magdalena Group. Thickness in the Sandia Mountains ranges from 0 to 22 m, with present thickness primarily determined by pre-Pennsylvanian erosion. The Arroyo Pefiasco Group does not crop out in the Hagan basin.

PENNSYLVANIAN

Magdalena Group *Sandia Formation*

The Sandia Formation nonconformably overlies Precambrian rocks everywhere that Mississippian strata are absent, and is overlain gradationally by the Madera. The Precambrian rocks formed a peneplain with local relief of a few meters during the Pennsylvanian before Sandia deposition. The Sandia is transitional into the Madera, with the base of the Madera usually chosen as the base of the lowest massive limestone up section from the Precambrian. Variations in thicknesses of the Sandia and Madera are a function of local definition as well as depositional processes. Thickness of the Sandia ranges from 6 to 61 m. The Sandia occurs on the high western face of the Sandia Mountains, as well as in several inliers on the east slope and in the Placitas area.

The Sandia predominantly consists of the following lithologies, in order of decreasing average abundance: sandstone, mudstone, limestone and conglomerate. Considerable lateral and vertical variations in lithology occur, but conglomerate tends to be more common toward the base and limestone tends to be more common upward. Sandstone and conglomerate tend to be arkosic with evidence of local derivation from Precambrian crystalline terranes. There are many sandy limestones and limey sandstones, with lateral and vertical gradations common. Deposition probably occurred in shallow marine and coastline environments formed as the sea transgressed the peneplained Precambrian surface and as the ancestral Rocky Mountains began to emerge (see Casey and Scott, and Woodward and Ingersoll, this guidebook). Paleoenvironments were complex and migrated rapidly during much of the Pennsylvanian.

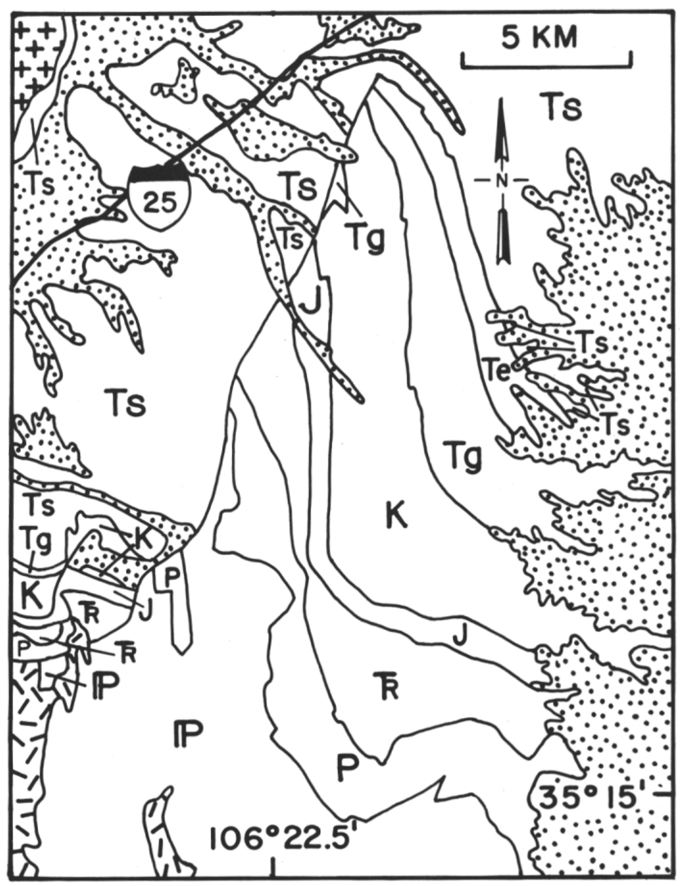

Figure 1. Generalized geologic map of the Hagan basin-Placitas area. No structures are indicated, although many of the contacts shown are faults. Jack-straw pattern: Precambrian; IP: Pennsylvanian; P: Permian; TR: Triassic; J: Jurassic; K: Cretaceous; Tg: Galisteo (Eocene); Te: Espinaso (Oligocene); Ts: Santa Fe (Neogene); cross pattern: basalt (Neogene); stippled pattern: Quaternary. After Kelley (1977).

Madera Formation

The base of the Madera Formation is gradational and conformable with the underlying Sandia, and the top of the Madera is gradational and locally unconformable with the overlying Abo. The top of the Madera has been termed Red Tanks, Agua Torres or Bursum in several central New Mexico areas. The Madera forms the eastern dip slope of the Sandia Mountains and also occurs along the south and west margins of the Hagan basin, particularly on Montezuma Mountain. The Madera dominantly consists of marine limestone with variable amounts of sandstone, conglomerate and black, gray, reddish-brown or purplish mudstone. The coarse-grained clastic units are similar to those of the Sandia (primarily arkosic and derived from Precambrian crystalline terranes). White, gray, brown and black chert is common in the limestone. Thickness of the Madera varies from 139 to 420 m, with some of this variation being due to rapid lateral and vertical facies changes.

Most Madera limestones, and other lithologies locally, are abundantly fossiliferous. Common fossils include Foraminifera, Brachiopoda, Anthozoa, Bryozoa, Bivalvia, Gastropoda, Cephalopoda, Trilobita, Ostracoda, Crinoidea and plants. Fossil evidence indicates variable depositional environments ranging from shallow marine to near-shore to swamp and lagoonal to nonmarine. Many locations show rhythmic alternations of marine and nonmarine environments, suggesting cyclothemic transgressions and regressions during the Pennsylvanian (see Perkins, 1959).

PERM IAN

Abo Formation

The base of the Abo Formation is mapped above the highest marine fossil-bearing beds in the Madera. The top of the Abo is conformable with the overlying Yeso, with a sharp contact. However, locally, the highest Abo and the lowest Yeso sandstones are similar in lithology. The Abo occurs along the lower east side of the Sandias (along the southwest side of the Hagan basin) and in the Placitas area. Thickness of the Abo ranges from 210 to 275 m.

The Abo predominantly consists of alternating reddish-brown sandstone and mudstone, with minor beds of conglomerate and limestone, especially in the lower part. Variegation of lavender, purple and gray occurs, especially in the lower part. Sandstone and conglomerate are arkosic, commonly crossbedded and lenticular, suggesting deposition in fluvial-alluvial channels surrounded by floodplains (mudstone deposits). Fossils are rare, although some wood-fragment, plant, amphibian and reptile fossils have been found.

Yeso Formation

The Yeso Formation is distinguished from the underlying Abo principally by its even bedding, more tan color, and finer-grained and more quartzose sandstone. The sharp upper contact with the San Andres is conformable to disconformable. Distribution of the Yeso is similar to that of the Abo, although the Yeso tends to form poorer outcrops, due to its greater friability. Thickness of the Yeso ranges from 100 to 170 m.

The Yeso typically consists of tan-brown sandstone, light reddish- or orange-brown siltstone, and limestone or dolomite. Gypsum is common in other areas, but is not found in the Hagan-Sandia area, possibly due to post-burial dissolution. The lower part is more massively bedded and is recognized as the Meseta Blanca Member. The upper part of the Yeso mostly consists of alternately fine- and medium-grained sandstone. Limestone beds 1 to 3 m thick are present, especially in the middle of the unit, and these commonly are folded intraformationally. No fossils have been found in the Yeso in the Sandia area. The Yeso probably formed in a continental setting, as well as in arid back-reef seaways or restricted lagoons between source areas to the north and deep marine conditions far to the south (Rascoe and Baars, 1972).

San Andres Formation

The San Andres Formation has had a complex nomenclatural history; as used here, it includes the Glorieta Sandstone, which is in sharp conformable or disconformable contact with the underlying Yeso. The Bernal Member forms a thin upper unit which is equivalent to some part of the Artesia Group (Kelley, 1972, p. 14-16). The Bernal is overlain disconformably by the Santa Rosa. Total San Andres thickness varies from 20 to 100 m, in part due to pre-Santa Rosa erosion.

Two distinct lithologies characterize the San Andres in the Sandia-Hagan area. The Glorieta Sandstone consists of white, quartzose, medium-grained sandstone with parallel laminations and crossbedding. The San Andres Bonney Canyon Member consists of gray to black, very fine- to fine-grained limestone with some interbedded sandstone similar to the Glorieta. Chert and dolomite also occur. The Bernal is similar to the Yeso; locally, limestone in the Bernal contains small Brachiopoda. Paleoenvironments of the San Andres varied from marine to lagoonal to nonmarine, in an overall setting similar to that of the Yeso.

TRIASSIC

Santa Rosa Formation

The base of the Santa Rosa Formation (Upper Triassic) is disconformable on the San Andres, with local and regional relief on the sub-Santa Rosa surface up to a hundred meters. The top of the Santa Rosa is gradational and intertongues with the Chinle. Thickness of the Santa Rosa varies from 30 to 120 m due to its gradational and intertonguing upper contact, and its irregular lower surface.

The Santa Rosa typically consists of white, light-gray, buff and reddish-brown sandstone that is thinly to thickly bedded. Lenticularity and crossbedding are common, and conglomerate lenses and beds occur, principally in the lower part. Clasts primarily consist of limestone, sandstone and chert. Mudstone interbeds are more prevalent higher in the formation, and locally are transitional into the mudstones of the Chinle. Some petrified wood, probably coniferous, is present locally. The Santa Rosa probably was deposited by fluvial systems.

Chinle Formation

The Chinle Formation is conformable and intertongues or is gradational with the underlying Santa Rosa. The Chinle is overlain disconformably by the Entrada. Because of its significant thickness (395 to 425 m) and its less-resistant lithology (predominantly mudstone), it tends to form broad valleys with poor outcrops.

The Chinle predominantly consists of reddish-brown mudstone with numerous local thin sandstone units. Variegated colors (lavender, blue, light gray and greenish gray) are common, especially in the lower part. Thin nodular limestone beds are present locally in the upper part of the formation. No fossils have been reported from the Chinle in the Hagan area, although petrified wood, other plant fossils, freshwater bivalves, amphibians and reptiles have been found in other locations. Continental paleoenvironments (especially floodplains) are indicated by sedimentary structures, fossil evidence and regional relations.

JURASSIC

Entrada Sandstone

The Entrada Sandstone disconformably overlies the Chinle with a locally irregular contact. It is overlain conformably (locally disconformably) by the Todilto. The Entrada is Upper Jurassic, based on fossils in the Todilto and correlated marine beds on the Colorado Plateau. It forms prominent cliffs of buff, tan, orange or white sandstone. The Entrada ranges from 18 to 37 m in thickness.

The Entrada consists of fine- to medium-grained, well sorted, subrounded quartz sandstone, commonly exhibiting large-scale, eolian-type crossbedding. Sedimentary structures, grain textures, red coloration, lack of fossils and regional setting suggest that the Entrada was deposited as eolian dune sands. The upper part of the Entrada commonly is bleached yellow or white with no relation to original bedding planes, probably due to ground-water reduction of iron-oxide minerals; reducing solutions likely had their origins in the overlying organic-rich Todilto limestones.

Todilto Formation

The Todilto Formation conformably overlies the Entrada in a transitional contact. The Todilto grades into the overlying Morrison, although locally, the contact is disconformable. The Todilto tends to form resistant ridges capping the Entrada. Thickness of the Todilto ranges from 17 to 58 m, although dissolution and flowage of gypsum makes original thickness determinations difficult.

The Todilto consists of a lower limestone member and an upper gypsum member. The limestone member usually consists of fissile, papery thin laminations of gray to dark-gray limestone interbedded with clastic and organic material that represent yearly deposition (varves) controlled by seasonal climatic change (Anderson and Kirkland, 1960). The gypsum member dominates the Todilto in terms of thickness, and indicates saline deposition. Tanner (1972) favors deposition in subaqueous bars and dunes. At nearly all margins of the original Todilto, the limestone unit extends beyond the gypsum mem ber.

Morrison Formation

The Morrison Formation conformably (locally disconformably) overlies the Todilto, and is overlain disconformably by the Dakota. Variable lithologies have resulted in complex nomenclature involving several local and widespread members throughout New Mexico and neighboring states. Members possibly present in the Hagan-Sandia area include, in ascending order: Recapture (predominantly mudstone), Westwater Canyon (predominantly sandstone), Brushy Basin (predominantly mudstone) and Jackpile (predominantly sandstone). Total Morrison thickness varies from 150 to 280 m due to facies changes and post-depositional (pre-Dakota) erosion.

The mudstone of the Morrison (the predominant lithology) consists of variegated greenish, reddish, lavender and light-gray mudstone, with thin interbedded white, buff and orange sandstone. Variable thin beds of limestone and conglomerate are found in the upper and middle parts along with thin dense chert beds. Broadly speaking, the sandstone and conglomerate beds were deposited as lenticular channel-fill deposits within fluvial systems, and the mudstones represent deposition in floodplain environments (e.g., Flesch, 1974). Some deposits have eolian as well as fluvial origins. The Morrison has been affected by extensive diagenetic alteration, including uranium mineralization (see Chenoweth, this guidebook). Fossil logs and dinosaur bone fragments are the most common fossils.

CRETACEOU S

Dakota Formation

The Dakota Formation (Upper Cretaceous) disconformably overlies Morrison, and is overlain conformably by and intertongues with the Mancos. The definition of the Dakota varies locally, and this factor, in combination with facies changes and irregular lower surface, causes variations in thickness from 2 to 15 m.

The Dakota consists of well cemented marine and fluvial coarse-grained sandstone with interbedded black marine mudstone that was deposited by a sea that transgressed westward during the Cretaceous. As a result, the basal contact is time-transgressive. Conglomeratic and crossbedded fluvial sandstone and coal occur locally, but most of the unit formed in near-shore environments (e.g., Bejnar and Lessard, 1976; Molenaar, 1977). The depositional basin consisted of a broad retroarc basin with sediment sources to the west and southwest (see Woodward and Ingersoll, this guidebook). Shallow marine fossils occur in the Dakota, most notably the trace fossil *Ophiomorpha.*

Mancos Formation

The Mancos Formation intertongues with both the underlying Dakota and the overlying Mesaverde. The predominantly mudstone lithology results in low topography, commonly with poor outcrops, between the more resistant Dakota and Mesaverde. The intertonguing nature causes variations in definition, and thickness of the Mancos varies from 425 to 550 m in the Hagan basin.

The Mancos predominantly consists of black marine mudstone, locally carbonaceous or siliceous, with thin sandstone and limestone beds. The formation has been divided into several members of wide areal extent (equivalents of the Graneros, Greenhorn, Carlile and other units) (Black, this guidebook; Stearns, 1953b). Marine fossils similar to those listed below for the Mesaverde indicate near-shore to offshore depositional environments. The lower part of the Mancos generally is transgressive and the upper part generally is regressive (Coates and Kauffman, 1973; Molenaar, 1977). Regional setting was similar to that of the Dakota.

Mesaverde Group

The Mesaverde Group includes a variety of marine and nonmarine formations and facies deposited during complex transgressions and regressions during the Late Cretaceous. The Mesaverde intertongues with the underlying Mancos and is overlain unconformably by the Galisteo in the Hagan-Placitas area (Harrison, 1949). Thicknesses up to 1000 m are known elsewhere, but faulting and pre-Galisteo erosion make estimates of original thickness in the Hagan-Placitas area difficult.

Depositional environments include marine, paralic and nonmarine settings, many of the latter being associated with deltaic sedimentation (Molenaar, 1977). Marine mudstones tend to be black and fossiliferous; sandstones tend to be buff to light-colored and bioturbated and/or crossbedded, depending on facies; and nonmarine mudstones tend to be brown and associated with coal beds or humate deposits (e.g., Siemers and WadeII, 1977). Common marine fossils in the Mesaverde include the following: Bivalvia, Gastropoda, Cephalopoda and *Ophiomorpha.* Nonmarine units include abundant plant fossils.

TERTIARY

Galisteo Formation

The Galisteo Formation (Eocene) unconformably overlies the Mesaverde in the Hagan-Placitas area, although in other locations it rests upon other Cretaceous units, locally with marked angular unconformity (Black, this guidebook; Black and Hiss, 1974; Gorham and Ingersoll, this guidebook). Regionally, the Galisteo is overlain disconformably by the Espinaso, although in the Hagan basin, the contact is conformable and gradational. Thickness in the Hagan basin varies from 260 to 1295 m.

The Galisteo consists of alternating beds of colorful mudstone, sandstone and conglomerate deposited in fluvial channels and floodplains formed within a rapidly subsiding basin associated with Laramide basement uplifts (Gorham and Ingersoll, this guidebook). Sources for the sediment were to the northwest, north and northeast. Petrified wood and vertebrates are the most common fossils (see Lucas and Kues, this guidebook).

Espinaso Formation

The Espinaso Formation (Oligocene) gradationally overlies the Galisteo in the Hagan basin, and forms a prominent ridge. The Espinaso is overlain conformably to disconformably by the Santa Fe. Average Espinaso thickness is near 440 m.

The Espinaso consists of bluish-gray volcaniclastic breccia, conglomerate, sandstone and mudstone, volcanic flows (primarily of intermediate composition), and water-laid and airfall tuffs (Stearns, 1953a). Sources for this material likely are to the east in the San Pedro-Ortiz-Cerrillos porphyry belt. Boulders up to 3 m in diameter within mudstone suggest debris flows as the depositing agents for some beds. Much of the material has the appearance of fanglomerates. Fossils are rare in the Espinaso.

Santa Fe Group

The Santa Fe Group (Neogene) conformably to disconformably overlies the Espinaso in the Hagan basin. It is overlain conformably to disconformably by Quaternary units. The Santa Fe has variable thickness, ranging in excess of 3000 m locally.

The Santa Fe consists of conglomerate, sandstone and mudstone, mostly of local derivation. It was deposited primarily in fault-controlled basins associated with the Rio Grande rift. Depositional environments include fluvial, alluvial, eolian and lacustrine. Some of the best studied Neogene vertebrate fossil collections have come from the Santa Fe (Galusha and Blick, 1971; Kues and Lucas, this guidebook).

QUATERNARY

Quaternary units in the Hagan area include pediment deposits, terrace deposits, alluvial-fan deposits and valley alluvium. A detailed discussion of these complex and interesting units is beyond the scope of this paper.

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