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1979, pp. 101-105. https://doi.org/10.56577/FFC-30.101

in:

Santa Fe Country, Ingersoll, R. V. ; Woodward, L. A.; James, H. L.; [eds.], New Mexico Geological Society 30 th Annual Fall Field Conference Guidebook, 310 p. https://doi.org/10.56577/FFC-30

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STRUCTURE AND STRATIGRAPHY OF THE HAGAN EMBAYMENT: A NEW LOOK

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INTRODUCTION

In the Hagan embayment and the Sandia Mountains block, the full stratigraphic section of this area of central New Mexico is exposed. This area gives us a unique opportunity to study early Tertiary normal faulting which apparently was active prior to the late Tertiary easterly rotation of the Sandia and Hagan basin area.

The Cretaceous rocks exposed in this area help document the Cretaceous facies relationships on the east side of the Rio Grande rift and allow projection of certain Cretaceous facies across the alluvial-covered rift system.

STRATIGRAPHY

The Cretaceous of the Hagan embayment has been described previously by several workers; however, no published attempt has been made to correlate directly certain units within the Hagan area to the well known facies in the San Juan Basin across the Albuquerque basin. This has been due primarily to the lack of subsurface control across the intervening rift system. However, since 1972, several new exploration wells have penetrated the pre-Tertiary section in the Albuquerque basin, and in the Hagan and Santa Fe embayments (see Black, this guidebook).

Six post-1972 oil and gas tests have been drilled in the Albuquerque basin and eleven (10 shallow Mesozoic tests and 1 Pennsylvanian test) wildcats have been drilled in the Hagan and Santa Fe embayments. This new control has permitted correlations in the Cretaceous from the south end of the Albuquerque basin north to the area of Lamy in the Santa Fe embayment, and has enabled northwest-to-southeast correlations from the San Juan Basin easterly across the rift and into the Hagan-Santa Fe areas.

It also is possible to correlate the outcrops on both the east and west sides of the Albuquerque basin with this new well control, and to predict the general Cretaceous facies which should occur in the northern end of the Albuquerque basin, the Santo Domingo basin, and the Hagan and Santa Fe embayments.

Many previous writers have described the Cretaceous facies in the San Juan Basin area. Molenaar (1973) has documented and illustrated in detail the major Cretaceous facies trends in the San Juan Basin. Figure 1 is a simplified stratigraphic cross section through the available well control which depicts some of these facies in the subsurface of the Albuquerque basin, and the Hagan and Santa Fe embayments. Figure 2 was constructed based on this section and the outcrop control in the Hagan and Santa Fe embayments. It is a depiction of the extension of Molenaar's facies trends into and across the Albuquerque-Belen and Santo Domingo basins, and into the Hagan and Santa Fe embayments.

Gallup Sandstone

As seen in the wells and shown diagramatically in Figure 1, the Gallup Sandstone becomes younger to the northeast. The massive Gallup and the overlying Dilco nonmarine facies pinch out just southwest of the Shell Santa Fe Pacific No. 3 in the northwest part of the Albuquerque basin. Figure 2 shows in map view this projected pinchout, which also probably passes just south of Albuquerque. The Gallup pinchout is not seen on outcrop on the east side of the Albuquerque basin due to removal by erosion.

Hosta Dalton

Stearns (1953) described a massive sandstone in the Hagan basin which he used for the base of the Mesaverde Formation (Group). He named this the Cano Sandstone member (formation) of the Mesaverde. It now can be shown by both outcrop and well correlations that his Cano Sandstone is, in fact, the Dalton-Hosta "turnaround" formed by the seaward pinchout of the Dalton regression and the subsequent Hosta transgression. The Hosta-Dalton relationships can be seen in the Shell wells in the Albuquerque area, and are shown diagramatically in Figure 1 between the Shell Oil Laguna Wilson Trust No. 1, and the Shell Oil Santa Fe No. 1. This pinchout is exposed clearly in the Hagan embayment. Here, more than 200 ft (60 m) of massive fossiliferous marine sandstones, which are exposed south and west of Hagan, can be followed for five mi (8 km) north where they entirely pinchout into silty sandstones and siltstones, and eventually silty shales at the extreme north end of the Hagan embayment in section 30 of T14N, and R6E (fig. 3). No intervening nonmarine paludal-deltaic sediments have been seen on the outcrop in the Hagan area, and thus, the Hosta cannot be separated clearly from the Dalton at this point. A nonmarine section is present, however, in the subsurface in the Shell Oil Co. Laguna Trust No. 1 wildcat and the other Shell wells to the south (fig. 1). It is not present in the Shell Santa Fe No. 3, and only the marine merger of the Hosta and Dalton, which is similar to the Hagan outcrops, is present at this point. In the subsurface in the Albuquerque basin, the pinchout occurs just several kilometers north of the Shell Santa Fe No. 1. Approximately 50 ft (15 m) of the Hosta-Dalton also are exposed poorly in the Placitas area where it crosses the highway a mile (1.6 km) west of Placitas. In the Galisteo monocline to the northeast, the Cretaceous outcrops show no vestige of the Hosta-Dalton pinchout.

Basal Niobrara Sandstones

Both Stearns (1953) and Molenaar (1973) reported the presence of basal Niobrara sandstones in the south end of the Hagan embayment. These lenticular crossbedded sandstones range up to 20 ft (6 m) thick and are found approximately 300 ft (90 m) above the Juana Lopez. Molenaar (1973) also

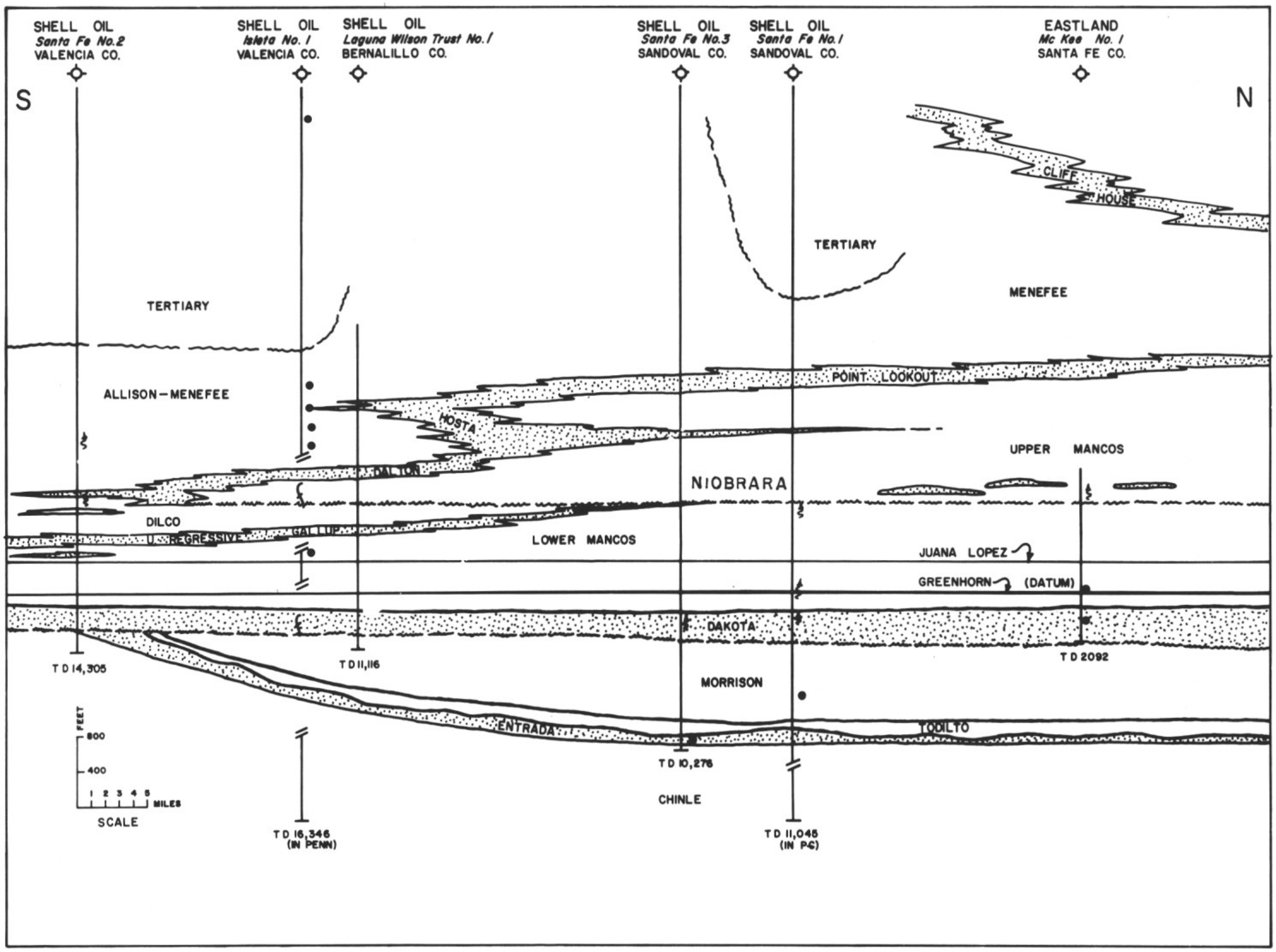

Figure 1. Simplified stratigraphic cross section through the subsurface of the Albuquerque basin, and the Hagan and Santa Fe embayments. See Figure 2 for location.

recognized the Niobrara Sandstone in a single outcrop in the Tijeras syncline 12 mi (19 km) east of Albuquerque.

The author has looked for, but has not found these basal Niobrara sandstones in the Placitas section. These basal Niobrara sandstones evidently have not been penetrated by the Shell wells in the Albuquerque basin. However, based on their known presence in the Tijeras area and in the Hagan embayment, these sandstones also could be expected to occur intermittently throughout the north end of the Albuquerque-Belen basin. They probably will be found slightly northeast of the projected seaward limit of the regressive Gallup (fig. 2) as they are in the San Juan Basin.

SemiIla Sandstone

Stearns (1953) briefly commented on the occurrence of thin and persistent sandstone beds which occur about 200 ft (60 m) below the Juana Lopez member in the Hagan embayment. He also mentioned sandstones 25 ft (7.6 m) below the Juana Lopez both in the Hagan area and in the Galisteo monocline, where some of these sandstones approach 30 ft (9 m) in thickness. These various sandstone bodies, which range in grain size from very fine to coarse (with some granular fragments), are believed by the author to be time-equivalent to the Semilla Sandstone member of the San Juan Basin. They are fossiliferous, crossbedded and lenticular marine-bar sandstones. The SemiIla in the San Juan Basin is considered by Molenaar (1977) to be time-equivalent to, but separated from, the CodeII Sandstone of the Raton basin to the northeast. Because the sandstones can be carried northeast out of the Hagan area by both outcrop and well control as far north as Lamy, the author believes that they may not only be time-correlative, but also may be continuous with the CodeII in the Raton basin area, and may have been derived from a source in this area. This sandy zone can be seen in all of the wells drilled in the Hagan and Galisteo areas.

STRUCTURE

The Hagan basin also provides a unique opportunity to study post-Galisteo normal faulting which predates the eastward tilting of the Sandia Mountains and the Hagan embayment. Previous workers (Kelley, 1977; Stearns, 1953) recognized that Cretaceous and basal Tertiary units had been re-

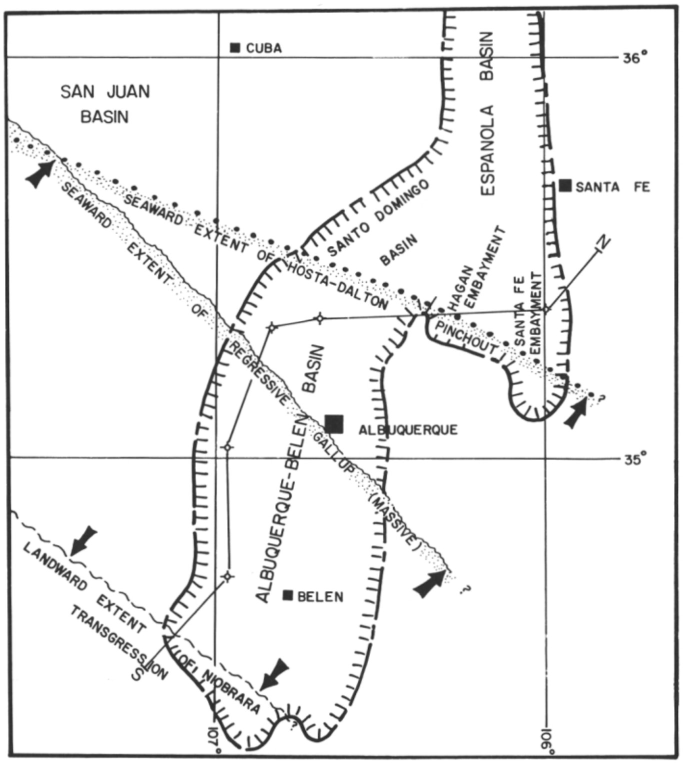

Figure 2. Location map showing extension of Molenaar's (1973) facies trends into and across the Albuquerque-Belen and Santo Domingo basins, and into the Hagan and Santa Fe embayments.

peated by normal faulting. However, previous maps of the Hagan basin (Harrison, 1949; Kelley, 1977; Kelly and Northrop, 1975; Stearns, 1953) either have not recognized or only have hinted at the unusual nature of some of this faulting, and no mention of the low-angle nature of this faulting has been made. Figure 3 is a map of part of the Hagan basin (from the Cretaceous Dakota to the Tertiary Galisteo) which details the distribution of the Cretaceous facies discussed earlier, and shows the trace of the low-angle Diamond Tail fault.

Diamond Tail Fault

The Diamond Tail fault is unlike any of the other faults found in the Hagan embayment. When first recognized in the field, it was suspected to be a Laramide thrust fault or a gravity slide because of the low angle of the fault plane which, along its trace, can be seen to dip from 150 to 40° to the west. Its true nature as an originally high-angle normal fault can be deduced from drag folding in both the hanging-wall and footwall blocks, and other evidence to be discussed. It can be followed from the east half of section 30, T14N, R6E along its undulating surface exposure 2.5 ml (4 km) south as far as the south center of section 6, T13N, R6E. For the next 2.25 mi (3.6 km), it generally is covered by alluvial terrace materials, but its trace can be inferred from outcrops of various Cretaceous facies in both the hanging wall and the footwall of the fault. It again is exposed well in the south center of projected section 19, Ti 3N, R6E, on the Tejon Grant, where it can be followed south for another mile (1.6 km). The south terminus of the fault trace on the surface takes place where it is truncated by the north-south Largo fault in the southeast corner of projected section 30, T13N, R6E.

Drag folding on both sides of the fault indicates that the hanging wall on the west is downthrown, with younger rocks overlying older rocks. In the extreme northern exposures, the fault dips from 15° to 25° west where the Tertiary Galisteo Formation has been down-faulted against (on top of) the Cretaceous lower Mancos Shale. At one point in the west half of section 30, T14N, R6E, two exposures of Gal isteo red beds in the down-thrown block form small hills and rest almost flat on the underlying Diamond Tail fault, and consequently, on the underlying lower Mancos. Here, the "klippen" of Galisteo are surrounded completely by Mancos, and the contact of the Galisteo on the Mancos can be walked completely around the small hills. The Diamond Tail fault plane itself is well exposed in several arroyo exposures a mile (1.6 km) to the south. In the west half of section 31, T14N, R6E, an arroyo cuts the fault and exposes the fault plane where the Menefee and the Point Lookout lie in fault contact on the lower Mancos. Here, the Point Lookout and the Menefee dip 20° to the northeast and show decreasing dip (caused by drag) into the fault. The underlying Mancos dips 25° to the east. Decreasing dip due to drag also is apparent in the underlying Mancos adjacent to the fault plane. At one place, Menefee coal beds above the fault plane abut lower Mancos Shale below, with the fault dipping 25° to the west between the two formations.

At this point, the throw on the Diamond Tail fault is approximately 2000 ft (610 m) based on the apparent stratigraphic separation. To the south, the stratigraphic separation decreases. A mile (1.6 km) north of the Diamond Tail ranch, the throw is closer to 800 ft (245 m) where possible Hosta-Dalton sandstones and the upper Niobrara are faulted down against the lower Niobrara. This suggests that the Diamond Tail fault was hinging to the south; however, the next clear outcrops in the south end of the basin in projected section 19, Ti 3N, R6E show the Menefee and Point Lookout down-faulted against the Niobrara with a throw of approximately 1600 ft (490 m) indicated. Here, the fault dips 38° to the west, with the underlying Niobrara dipping 25° to the east. Because of these relationships, it is quite possible that the north and south segments of the Diamond Tail fault are two separate but related faults, both of which have the same strike and dip. Unfortunately, the critical central part of the fault or faults is covered.

It is obvious that the large displacements on both fault segments could not have taken place as normal faults along the present low angles of dip which range from almost flat in the north to up to 45° in the southern exposures. By rotating out the present 25° to 30° of dip seen in the footwall block of the Hagan basin, the Diamond Tail fault plane rotates back to 50° to 65° dips to the west throughout most of its length.

The very flat dips observed on the fault at the north end are believed to be a result of both the late Tertiary eastward tilt, and later additional flattening due to drag folding associated with a left-lateral component of movement along the San Francisco fault.

The youngest rocks cut by the Diamond Tail fault are the basal beds of the Tertiary Galisteo Formation, thus dating the fault as post-basal-Galisteo, but pre-east-rotation of the Hagan basin which possibly took place after early to middle Santa Fe time (Kelley and Northrop, 1975).

The author believes that the Diamond Tail fault is thus an Oligocene or Miocene (or possibly later Tertiary) high-angle normal fault(s) which was (were) associated with incipient rifting in the Rio Grande graben. It is possible that the faulting

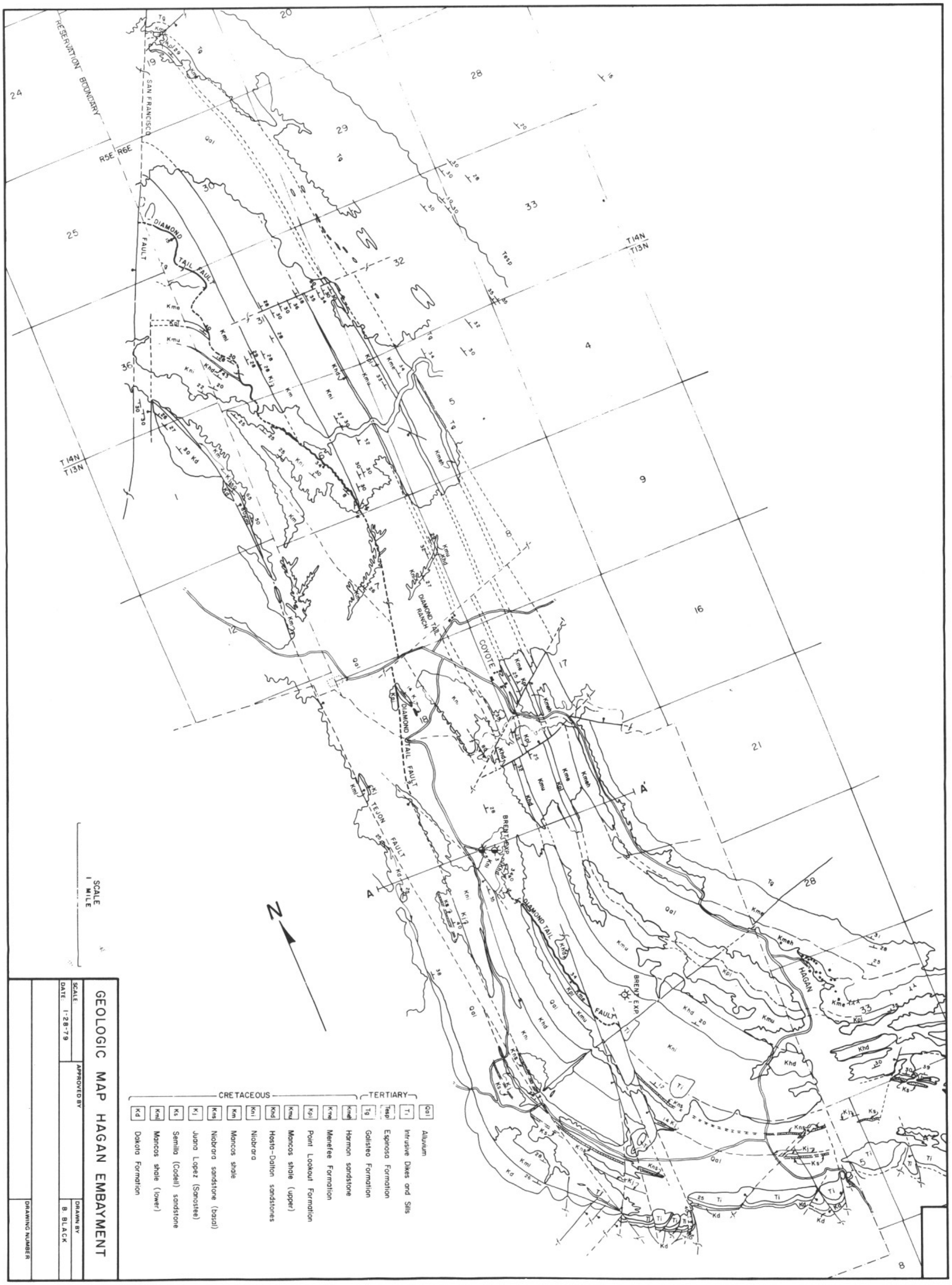

Figure 3. Geologic map of part of the Hagan basin, showing details of the distribution of Cretaceous facies, the trace of the low-angle Diamond Tail fault, and other features.

occurred in Espinaso time and may be associated with the tectonic episode which gave rise to the Oligocene intrusives several kilometers to the east.

The Diamond Tail fault had major displacements in middle to late Tertiary time, and subsequently, was rotated from near 600 westerly dip to its present low angles of dip during the rotation of the Sandia block and the Hagan basin, thus leaving an unusual undulating and low-dipping normal-fault trace. In the north end of the Hagan embayment, the footwall of the Diamond Tail fault is easily discernible from the hanging wall in aerial views, and on aerial photographs. The angular divergence of the strike of the beds on either side on the fault is obvious, and the color contrast where the Galisteo, Menefee and Point Lookout in the hanging wall abruptly abut the gray lower Mancos along the undulating Diamond Tail fault trace is striking.

Late Tertiary normal faulting has served to complicate the history of the Hagan embayment by further faulting the Cretaceous section and the Diamond Tail fault. Because of the complex faulting and extensive alluvial cover, not all of the features mapped in the Hagan area are understood fully. In the northeast quarter of projected section 30, Ti 3N, R6E another "klippe"-like outcrop of Hosta-Dalton sandstone rests in apparently nearly horizontal fault contact with the underlying Niobrara which entirely surrounds the topographic hill held up by the Hosta-Dalton outcrop. Likewise, the area in the vicinity of the Brent Exploration No. 3 and No. 5 wells in projected section 19, T13N, R6E contains Hosta-Dalton and Niobrara outcrops, which are in fault contact with the Hosta-Dalton to the west, and are folded and structurally anomalous.

CONCLUSIONS

The Hagan embayment area is much more complex both stratigraphically and structurally than would appear at first glance. It is an excellent example of how a basic understanding of the stratigraphy is needed to unravel the structure, and conversely, how an understanding of the structural style is imperative to the correct interpretation of the stratigraphy.

Structurally, the area is important in documenting post-Galisteo and pre-eastward tilting, high-angle Tertiary normal faulting. Stratigraphically, the Cretaceous rocks in the area hold the key to an understanding of the distribution of several of the important Cretaceous facies both here and to the west in the Albuquerque basin.

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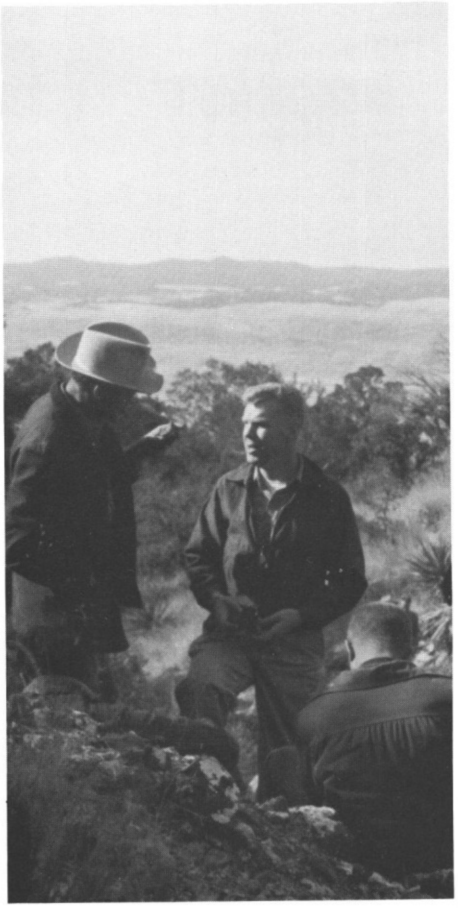
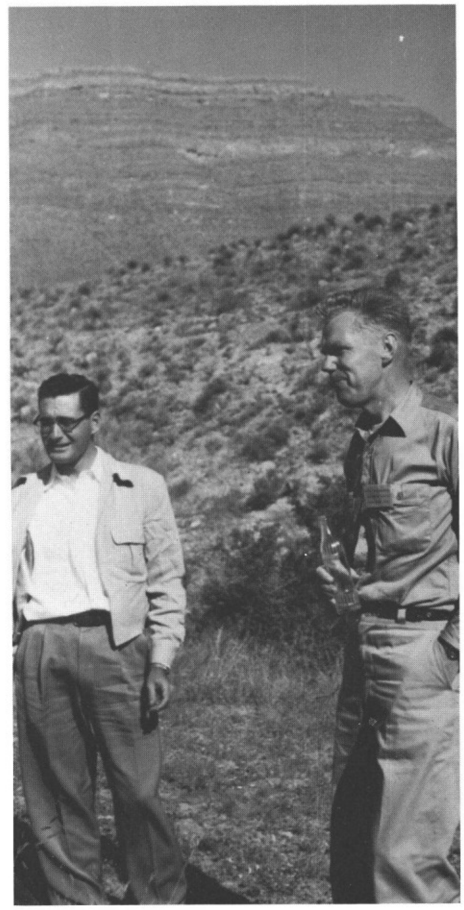
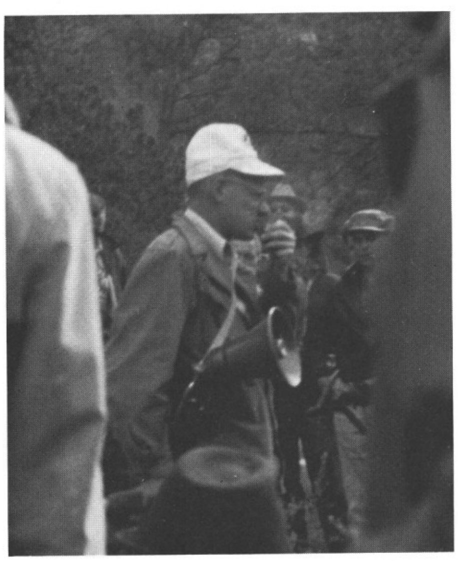


Philip T. Hayes, Caravan Chairman, and J. Paul Fitzsimmons, General Chairman, at Iron Mountain stop, November 12, 1955.—R. L. Borton.

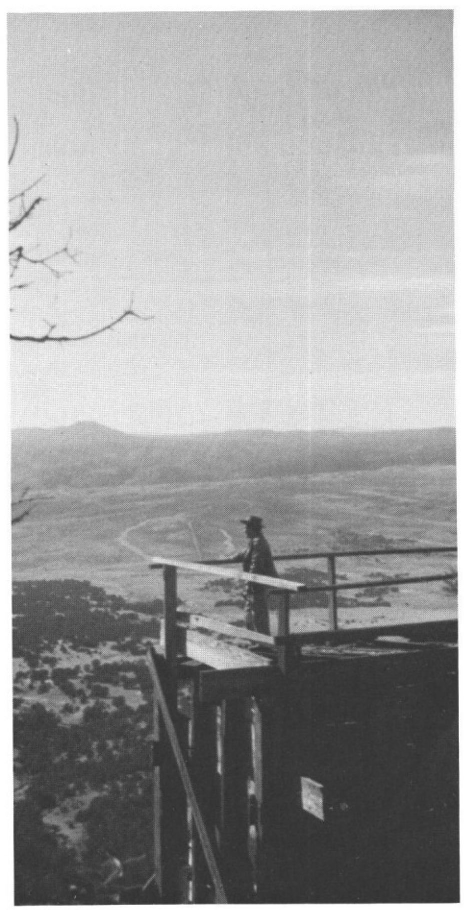
Caswell Silver assisting Vincent Kelley who is describing the geology of the Caballo Mountains, November 1955.—E. J. Strawn.



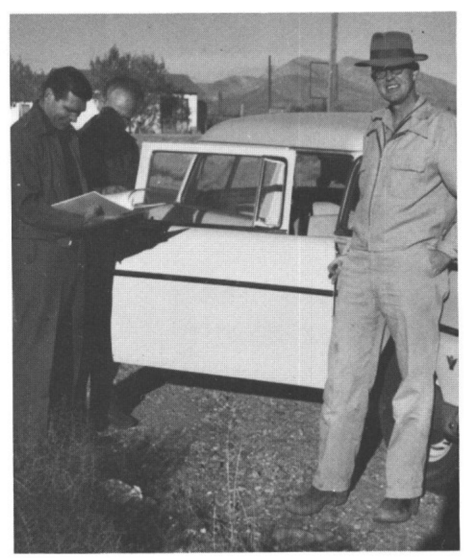
Hugh P. Bushnell, UNM, M.S., now with Humble Oil, and General Co-Chairman, Paul Fitzsimmons after lunch, first day, November 11, 1955, in Rhodes Canyon, San Andres Mountains.—S. A. Wengerd.



R. H. "Dick" Jahns, then California Institute of Technology, now Stanford University, lecturing at Iron Mountain stop, November 12, 1955.—R. L. Borton.



Robert L. "Bob" Borton on head frame of fluorite mine. Iron Mountain; Black Range in distance, November 12, 1955.—R. L. Borton.



Denham and Mills read the Guidebook to find out where south-central New Mexico is located while Vince Kelley is confident that he knows because he helped prepare the road logs. 7:45 a.m., November 11, 1955, start of trip at Truth or Consequences.—S. A. Wengerd.