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OIL AND GAS EXPLORATION IN THE HAGAN EMBAYMENT OF THE ESPAÑOLA BASIN

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Abstract—The first oil and gas test drilled in the Hagan embayment was spud in 1954. No additional activity took place for the next 26 years. More recent oil and gas exploration in the Hagan embayment, inspired by oil shows seen in uranium core holes and surface indications of oil, began in the mid 1970s (Black, 1979a). In the intervening 23 years, 12 oil and gas tests have established the presence of source rocks, maturity, reservoir quality rock and probable traps in the area. Future exploration, utilizing the existing well control and additional seismic, will find both stratigraphic and structural trap potential in this unique and underexplored sub-basin of the Española basin in the Rio Grande rift.

INTRODUCTION

In the 1970s, oil and gas exploration in the Hagan embayment was a logical extension to the exploration efforts ongoing in the Rio Grande rift, both east of the Hagan area in the Santa Fe embayment of the Española basin, and to the southwest in the Albuquerque basin. Drilling activity in the Hagan area was accelerated in the mid 1970s by reported oil shows in several of the uranium exploration core holes that were drilled by Union Carbide on the Diamond Tail Ranch.

Colorado Plateau Geological Services (CPGS) had previously taken oil and gas leases over most of the embayment. CPGS confirmed the reported sample shows by visiting the core hole sites at night and viewing the samples laid out on the surface with a portable UV light. Several of the holes did in fact have oil shows in the samples that were not rig-related oil. The depths of these shows and the mixed lithologies were recorded. Subsequent exploration resulted in 12 oil and gas exploration tests through 1998 (Fig. 1).

HISTORY OF OIL AND GAS EXPLORATION

The Associates Oil and Gas Co. Virgil No. 1, drilled in 1954 in sec. 14, T12N, R6E, was the first well drilled in the Hagan embayment (Black, 1989). This 1201 ft well was spud and tded in Paleozoic rocks at the extreme southern end of the embayment and is still the only Paleozoic test in the area. No detailed data are available on this old shallow test, and no oil or gas shows were reported.

The second oil test in the embayment was spud by Colorado Plateau Geological Services on July 4, 1976, as the CPGS Bi-Centennial Freedom Federal No. 1 in sec. 35, T13N, R6E. The well was designed to offset one of the Union Carbide uranium core holes, which had oil shows at approximately 1000 ft. The well was spud in Quaternary terrace gravels. It topped the Tertiary Galisteo at 80 ft, and the Cretaceous Menefee at 355 ft. The well cut an apparent fault at 1060 ft with mixed Cretaceous and Morrison lithologies from 1060 ft to td at 1415 ft. No producible hydrocarbons were found, but numerous live oil and gas shows were logged below 1069 ft.

Three additional shallow offset wells, the Bi-Centennial Freedom No's 2, 3, and 4 were drilled later in 1976 in an attempt to establish production from this faulted interval, but these were also unsuccessful. All of these shallow tests had excellent live oil shows in the interval of interest, however, the lithologies in each were mixed. It was concluded that the wells were drilled into a major fault zone in which oil from deeper source rocks was apparently migrating from depth.

This fault may be exposed on the outcrop, 2 mi south of these wells, in the southern part of sec. 2, T12N, R6E. Here, major north–south faulting in Arroyo Cuchillo has down faulted the Cretaceous against the Jurassic Todilto Formation and the Entrada Sandstone. Both the Entrada Sandstone and parts of the Todilto are heavily oil stained, and the Entrada Sandstone is oil saturated adjacent to the fault over much of the area (Fig. 2). At this location, there is also an unusual facies in the Todilto limestone which, unlike the usual, thin, organically laminated-limestone beds, appears to be a grainstone limestone breccia or small reefal buildups of boundstone algal plate debris with high porosity that is also oil-stained locally (Fig. 3). This oil-stained outcrop is described in more detail in the mini-paper of the first-day log in this guidebook.

The next exploration attempt in the basin was a three-well program drilled by Helton Engineering and Geological Services. The Helton No. 1 Diamond Tail Ranch was spud in May, 1978, and tested the Cretaceous section near the center of the main, northeasterly-plunging synclinal fold of the Hagan embayment in the southwest corner of sec. 29, T13N, R6E. The well td was at 1874 ft in the top of the Morrison.

Only minor gas and oil shows were reported in the Mancos and the Dakota. Helton followed this test, with two additional wells in June and July of 1978, on a small, complex, easterly-dipping nose in the foot wall of the Diamond Tail fault in sec. 19 T13N, R6E. The first and deepest of these two wells was the No. 3 Diamond Tail Ranch with a td at 2070 ft after penetrating the Cretaceous rocks and the Jurassic Morrison, Todilto, and the top of the Entrada. Oil shows were noted in the Mancos, Dakota, and the Entrada. The Helton No. 5 was drilled immediately up dip of the No. 3 well and its td was in the Morrison at 765 ft. This well also saw significant shows of oil in the Mancos and the Dakota (Fig. 4).

Following up on the numerous shows seen in the area Pelto Oil Co. spud, the No. 1 Harmon in April, 1981, in sec. 18, T13N, R6E. This well was designed to spud near or in the hanging wall of the westerly dipping Diamond Tail fault (Black, 1979b), and test the Dakota and Entrada in the footwall up-dip of the oil shows seen in the earlier Helton wells.

The Harmon No.1 penetrated the top of the Dakota at 310 ft and cut 50 ft of oil shows in the Dakota sands. The well cut the top of the Morrison at 510 ft and the top of the Entrada at 1290 ft. The well's td was at 1398 ft. An 18-ft core was cut in the Entrada, and 17.5 ft were recovered with minor oil stain and cut fluorescence. Because of the extensive shows in the Dakota, the rig was skidded 50 ft up dip to the west, and the Harmon 1A was drilled to the top of the Dakota, where it was cored from 311 ft to 347 ft. The entire core had residual oil saturations that ranged from less than 1% to 14%.

Subsequent field work and on strike projections of the Dakota to the surface, 0.5 mi north of the drill site location (using the 30° dips of the core and nearby outcrop control), show a potential breach of the Dakota and the Diamond Tail fault beneath the surface gravels at the junction of Arroyo Coyote and Arroyo Tongue. The Dakota projects to crop out at an elevation of about 5520 ft. The current elevation of the gravel surface of the junction is 5520 ft! The Dakota in the footwall therefore probably subcrops beneath the Quaternary gravels in this vicinity. If so, the potential trap against the Diamond Tail fault has been breached in the near past by arroyo down cutting through the fault and into the top of the Dakota in the footwall.

Oil cannot enter the pore spaces of water saturated reservoir rocks with a given porosity and permeability without overcoming the

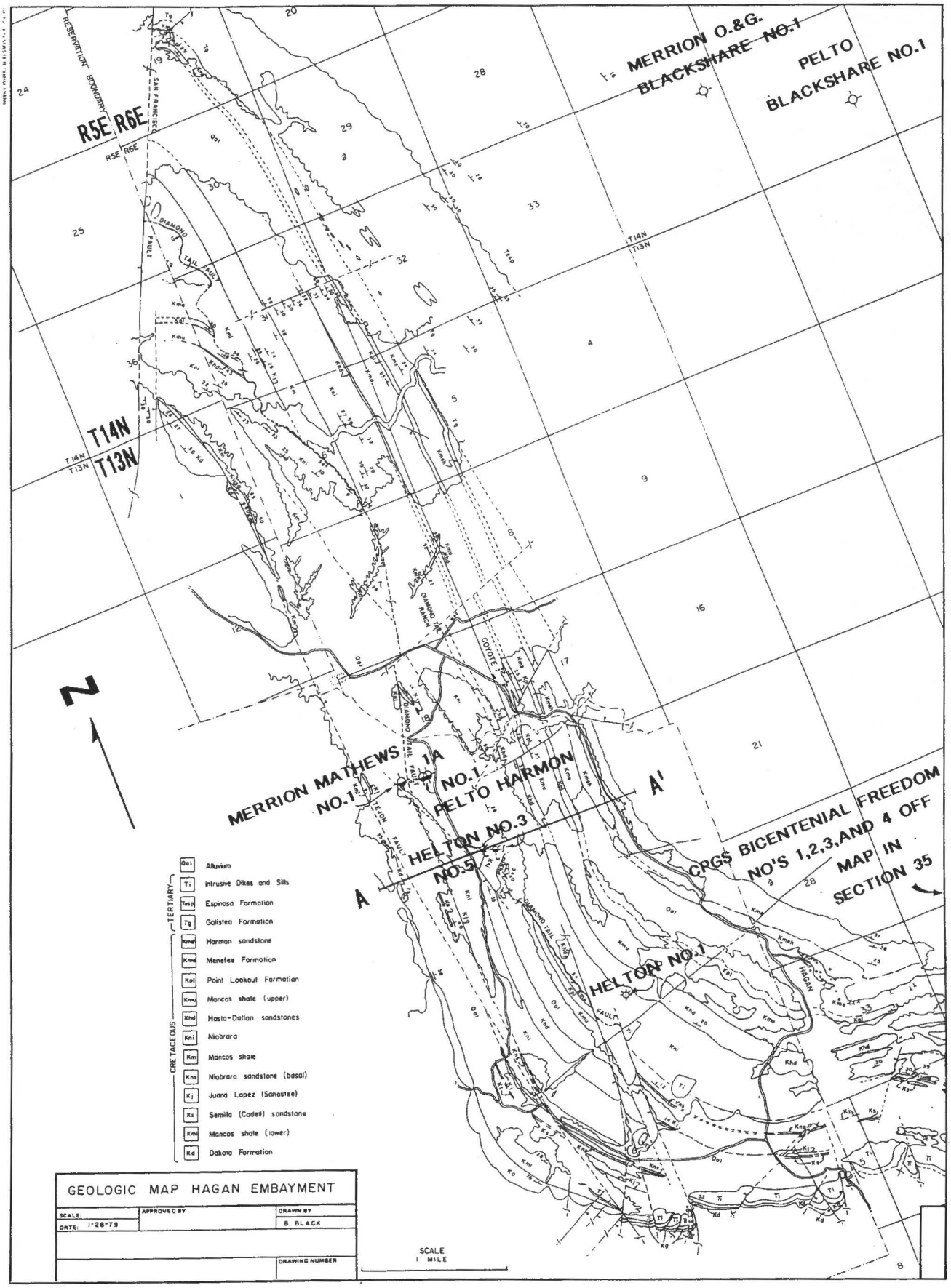

FIGURE 1. Geologic surface map of part of the Hagan embayment, showing location of oil and gas tests.

FIGURE 2. Oil-stained and oil-saturated Entrada Sandstone beneath Todilto Formation limestone in area adjacent to a large normal fault in Arroyo Cuchillo. Coca Cola can on top of Todilto Formation for scale.

FIGURE 3. Oil-stained limestone microbreccia(?) overlying thinly laminated Todilto limestone in Arroyo Cuchillo. Note hammer for scale.

required capillary pressures. Because every inch of the Dakota sands cored in the Harmon well (even the very low porosity and poor permeability sands with very high capillary pressures) had residual oil saturations, it is apparent that these sands must have taken an oil charge under high pressure and with enough force to overcome the considerable capillary pressures needed to fill even the poorest reservoirs. To do this, a very long oil column, or deep high pressures, or both, were required to emplace the oil present and suggest the oil migrated into the Dakota in what must have been high saturations (and probably commercial amounts) at some time in the past.

From log analysis of the Dakota in the Helton No. 3 well, which had a deep resistivity of 113 ohms in 16% porosity rock, it is apparent this well also has a high residual oil saturation (although no cores are available in this well). The Pelto Harmon had 78 ohms in 13–20% porosity from the Dakota, and the cores proved the residual oil saturations. These data show us that a sizeable early oil field existed in this area and that it was at least large enough to encompass the area of the Helton wells and the Pelto Harmon well. Using average San Juan Basin Dakota reservoir parameters, a reasonable estimate of more than 20 million barrels of Dakota oil in place in a minimum of 640 acres probably existed at one time, and would probably have been a commercial accumulation had it not been breached and leaked in the recent past.

Based on the reconstructed total stratigraphic section that overlies the Cretaceous rocks in the Hagan embayment and on lopitan diagrams, the Mancos shales in the Hagan area entered the mature oil window in the mid to late Tertiary. Like the same rocks at similar depths in the San Juan Basin, the Dakota in this area apparently became oil and gas saturated and probably stratigraphically trapped at that time.

It appears we were several hundred thousand years too late to find a shallow Dakota oil field. This is a classic example of how important timing is in the search for commercial oil and gas accumulations. As they say, "TIMING IS EVERYTHING!!"

Three months later, in June 1981, Pelto Oil spud the Blackshare No. 1. This first deep well (7025 ft) in the embayment was designed to test

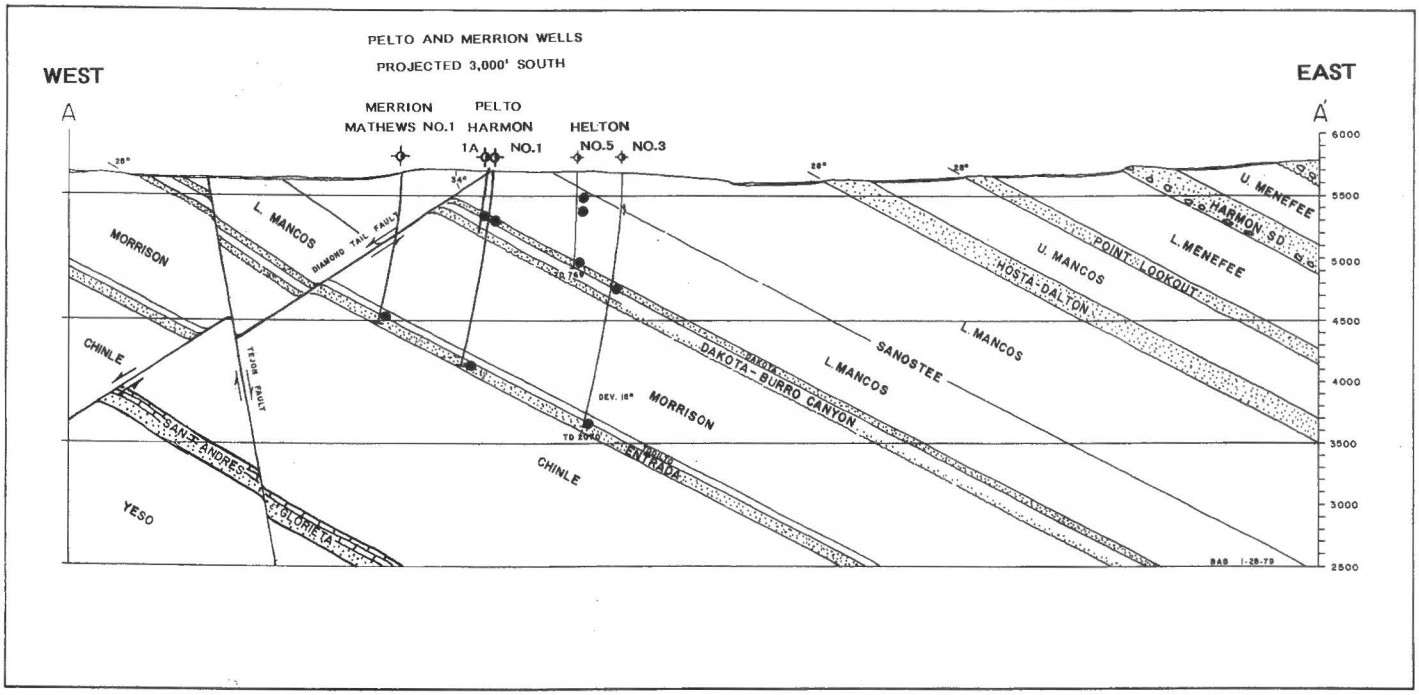

FIGURE 4. Cross-section showing the relationship of the rotated, west-dipping Diamond Tail fault to the present, easterly-dipping west flank of the Hagan embayment.

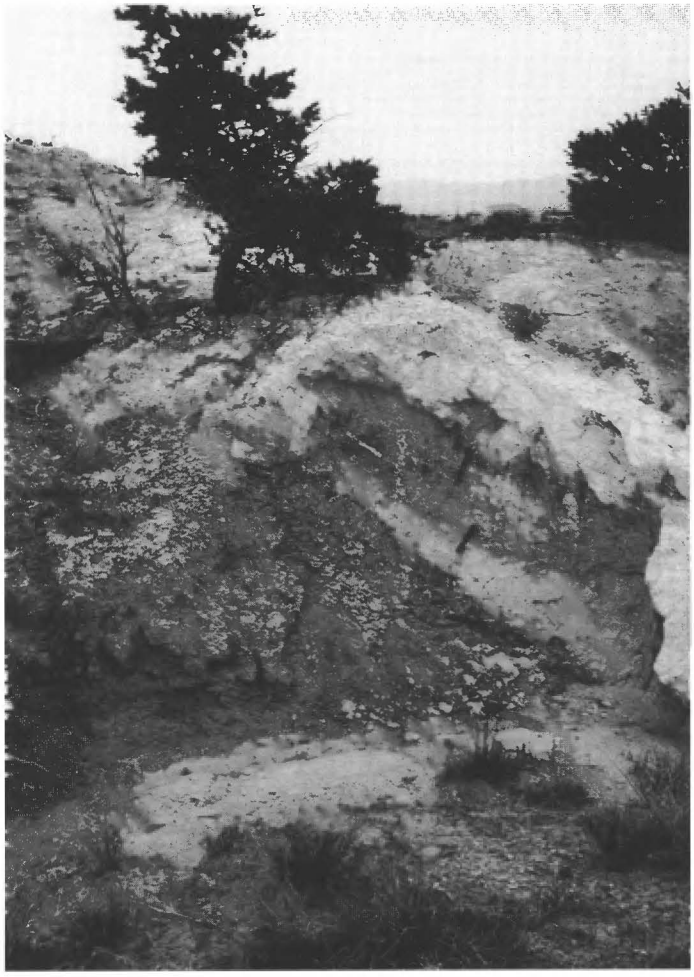

FIGURE 5. View south of 34°, west-dipping Diamond Tail fault. Menefee sands in the hanging wall are down-faulted against Niobrara Shale. Note geology picks on fault contact for scale.

the Dakota and Entrada on a seismic anomaly on the eastern edge of the basin in sec. 35, T14N, R6E. The well encountered thick, unexpected igneous sills and a faulted Cretaceous section, which were not apparent on the seismic profiles. The primary objective was the Dakota section, but it was faulted out of the well. The Entrada was a secondary objective and did have shows of heavy oil, but it was not on a structural high and was apparently wet.

Ten years elapsed before the next well was drilled in the basin. This was a shallow test up dip of the Harmon locations in an attempt to test the deeper Entrada potential in the footwall block of the Diamond Tail fault. The Merrion O&G No. 1 Mathews was spud in April, 1991, and cut the Diamond Tail fault as expected at 310 ft where it went from Mancos into the Morrison. The top of the Entrada was cut at 990 ft. Minor oil shows were seen in the base of the Todilto and at the top of the Entrada. The well was production tested and was wet.

Three years later, on 31 January 1994, Merrion O&G drilled the latest test in the embayment. The No. 2 Blackshare was drilled to 6820 ft in sec. 34, T14N, R6E. Like the Pelto No. 1 Blackshare, thick intrusive sills were penetrated in the interval between the Tertiary and the Cretaceous. The well's total depth was in the Mancos Shale at 6820 ft with no significant shows.

CONCLUSIONS

Oil and gas in significant quantities has been generated and trapped in the Hagan embayment area in the past. Structural faulting, fracturing, folding,and easterly tilting of the section since original migration and entrapment has helped altered, remigrate and destroy original oil and gas accumulations. The majority of this structural activity was associated with the mid to late Tertiary opening of the Rio Grande rift in this part of central New Mexico. The Diamond Tail and associated faults have a movement history post-dating Galisteo-pre-easterly rotation of the Hagan embayment history.

The Diamond Tail fault is a striking example of an early normal fault associated with the beginning of rifting that has been subsequently rotated to its present low dipping position. At the northern end of the embayment, where it dips <2° to the west, it places the Menefee against the lower Mancos for a throw of more than 2000 ft. At the southern end of the embayment, 6 mi away, it dips 34° to the west and faults the basal Menefee and the Point Lookout approximately 1500 ft down against the lower Niobrara (Fig. 5).

Because this displacement took place pre-rotation of the embayment's west flank, and did so contemporaneous with the maturation of the Cretaceous and Jurassic source rocks in the area, it became an important structural barrier to oil migration when the subsequent eastward rotation of the embayment flank took place. We know from the recent drilling that there was an apparent oil accumulation in the Dakota prior to its recent breaching, and the Diamond Tail fault may have acted as an up-dip trap. Deeper potential reservoirs (in the Jurassic and Paleozoic) faulted against the Diamond Tail fault remain untested and may provide excellent future targets in structural traps at depth.

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