Devonian Shelf to Basin Facies Distributions and Preliminary Shale Geochemistry for South-central and Southwestern New Mexico*

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Abstract

The often poorly exposed Devonian section in southern New Mexico contains complex vertical and lateral ramp-to-basin facies changes that culminate in an elongate trough filled with up to 76 m of black shale. The trough trends east-west for over 350 km, and ranges from a width of ~30 km near Las Cruces to ~100 km near Deming. To the north, Middle-Late Devonian-aged ramp carbonates, sandstones, siltstones, and shales of the Oñate (Givetian), Sly Gap (Frasnian), and Contadero (Frasnian-Fammenian) formations crop out in the San Andres and Sacramento mountains. These formations grade southward into the Percha Formation black shale facies. Due to the largely barren nature of the shales, it is difficult to determine exact correlations. The Percha Formation is divided into two members, the black, fissile, barren Ready Pay and the more calcareous and fossiliferous Box. Fossils from the upper Box Member indicate a Fammenian age. South of the trough, the oldest Devonian units comprise the cherty shelf carbonate Canutillo Formation (Middle-Late Devonian), which is both overlain by, and apparently a partial lateral facies equivalent to, the Percha black shales.

Existing 1960's vintage isopach and facies maps are updated with more recent outcrop and subsurface data, and integrated with geochemical data and basin analysis models to characterize better the areal extent, volume, richness, and maturity of the black shale facies. Public-domain geochemical data show potential for the Devonian shales in south-central and southwestern New Mexico to act as source rocks: TOC values locally reach 3.7% and thermal maturities are consistently in the mature to very mature range.

Three goals exist for this ongoing project:

- Better constraints on formation correlations and facies relationships
- Improved characterization of Devonian shales for hydrocarbon source rock potential (richness and maturity trends, kerogen types, and expulsion timing)
- Description of the shales for shale gas reservoir potential.

Introduction

The Devonian succession in southern and southwestern New Mexico has a long history of stratigraphic study (e.g., Nelson, 1940; Stevenson, 1945; Laudon and Bowsher, 1949; Kottlowski et al.,1956; Pray, 1961; Kottlowski, 1963; Rosado, 1970; LeMone, 1982, 1996; Sarouf, 1984; Day, 1988, 1998); however, only a limited number of reports place the complex facies into a regional context (Kottlowski, 1963; Bowsher, 1967; Raatz, 2002) or discuss organic geochemistry and thermal history (Broadhead, 2002). This report updates and re-evaluates stratigraphic data and integrates organic geochemistry, burial history, and other aspects relevant to the Devonian System's hydrocarbon potential. Table 1 lists named well and outcrop locations used in the study, with numbers keyed to locations in Figure 1. A total of 151 locations were used to construct a Devonian isopach map (Figure 2), and from those data points with sufficient information available, a Percent Black Shale map (Figure 3) was generated; the latter is also shown with posted Total Organic Carbon (TOC) data (Figure 4). Burial History models were constructed for the Grim Mobil-32 #1 well in southern Dona Ana County and the McGregor GDP 51-8 well in southwestern Otero County (Figures 5, 6, 7, and 8).

1. Ridgeway AZ 2-13 State
2. Shell 1 Swepi Magnus Mts Federal
3. Shell 1 Swepi Etal State
4. Sun Oil #1 St. Augustine
5. Kelly
6. Lockhart #1
7. Sun Oil Co. #1 Bingham-State
8. Standard Oil Co. Texas #1 Heard
9. San Juan Peak
10. Mockingbird Gap
11. Can Spring
12. Bear Mountain
13. Georgetown
14. Santa Rita
15. Hermosa
16. North Percha Creek
17. Hillsboro/Percha Creek
18. Tierra Blanca Canyon
19. Brenda Canyon
20. Lake Valley
21. Sun Oil Co. #2 Victorio
22. Sun Oil Co. #1 Victorio
23. Reservoir
24. Mud Springs Mt.
25. Burbank Canyon
26. Derry Hills
27. Gulf Sierra
28. Sunray Midcontinent Oil Co. #1-M Federal
29. Martin Tank
30. Johnson Park Canyon
31. CCC Tank
32. Capital Peak
33. Lava Gap/Thurgood Canyon
34. Sly Gap
35. Salinas Peak
36. Mackinson Canyon
37. Rhodes Canyon
38. Cottonwood Canyon
39. Houston State 1453
40. Houston 2 Lewelling
41. Houston 1 Lewelling
42. Houston State 3724
43. Humble Oil Co. #1 State "A"
44. Hembrillo Canyon
45. Rich Rim
46. Lost Man Canyon
47. Dead Man Canyon
48. Mayberry Canyon
49. San Andres Canyon
50. Ash Canyon
51. Salt Canyon
52. Bear Canyon
53. Organ Mts
54. Indian Wells
55. Dry Canyon
56. Marble Canyon
57. Tipi Mound
58. Deadman Canyon
59. Alamo Canyon
60. Southern Prod. Co. #1 Cloudcroft
61. Mule Canyon
62. Muleshoe Canyon
63. San Andres Canyon
64. Dog Canyon
65. Texaco Federal E
66. Texaco Federal G
67. Texaco Federal F
68. Escondido Canyon
69. Moore Ridge
70. Table Top
71. Grapevine Canyon
72. Plymouth Oil Co. #1 Federal (Evans)
73. Sun Oil Co. #1 Pearson
74. Texas Prod. #1 State-Wilson
75. Magnolia Petroleum Co. #1 Black Hills
76. Gulf Oil Co. #1 Chaves "U"
77. Kewanee 1 FM
78. Sun Oil Co. #2 Pinon
79. Gulf Oil Corp. #1 Munson Federal
80. Zapata Petroleum Corp. #1 Federal 14
81. Standard of Texas #1 Scarp
82. Lefors #1 Federal
83. Tri Service #1 Little Dog
84. Continental #1 Bass
86. Campbell #1 Hurley
87. Campbell #1 Spanel
88. Campbell #1 McMillan
89. Coral #1 Warren
90. Union #1 White
91. Turner #1 Evans
92. Flynn, Welch, Yates #1 Donohue
93. Union Oil Co. #1 McMillan
94. Transocean #1 Ablah
95. Campbell #1 Liberman
96. Penzoil #1 Southland State 28
97. Dunigan #1 Alpha Federal
98. Hunt #1 McMillan-Turner
99. McGregor GDP 51-8
100. Seaboard #1 Federal
101. Peloncillo Mts
102. Hatchita Dome #1 Tidball-Berry Fed.
103. Big Hatchet Mts
104. Humble Oil&Refining Co. #1 NM State "BA"
105. Cooks Range
106. Gym Peak
107. Cities Services Corralitos
108. Sinclair Oil&Gas Co. #1 Federal
109. Bishops Cap
110. Grim Mobil-32 #1
111. Anthony Pass
112. Vinton Canyon
113. Maria Canyon
114. California Co. #1 Theissen
115. Magnolia Pet. Co. #1 University 39881
116. Jones #1 Melbreth-Mowry
117. Hunt C.L. Ranch #1
118. Border McAdoo #1
119. Gulf Oil Corp. #1 Burner-State "B"
120. Cockrell #1 Pyramid Federal
121. Cockrell #1 Coyote State
122. Cockrell #1 Playas State
123. Graham Hatchet Federal
124. Yates #1 One Tree Unit
125. Yates #1 Dog Canyon Federal
126. Marathon #1 Mesa Verde Ranch
127. Heyco #1Y Bennet Ranch

Table 1. List of named data points used in this study. Numbers correspond to location map of Figure 1.

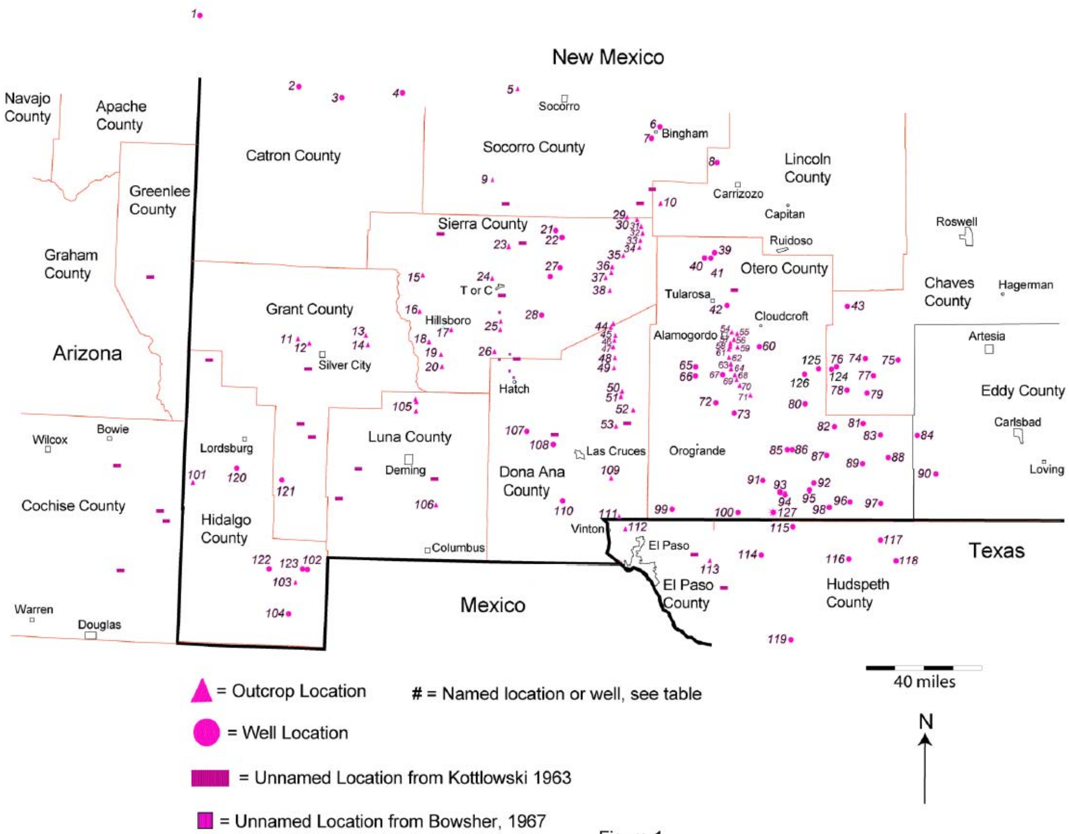

Figure 1. Data source location map, with numbers corresponding to outcrop or well locations listed in Table 1.

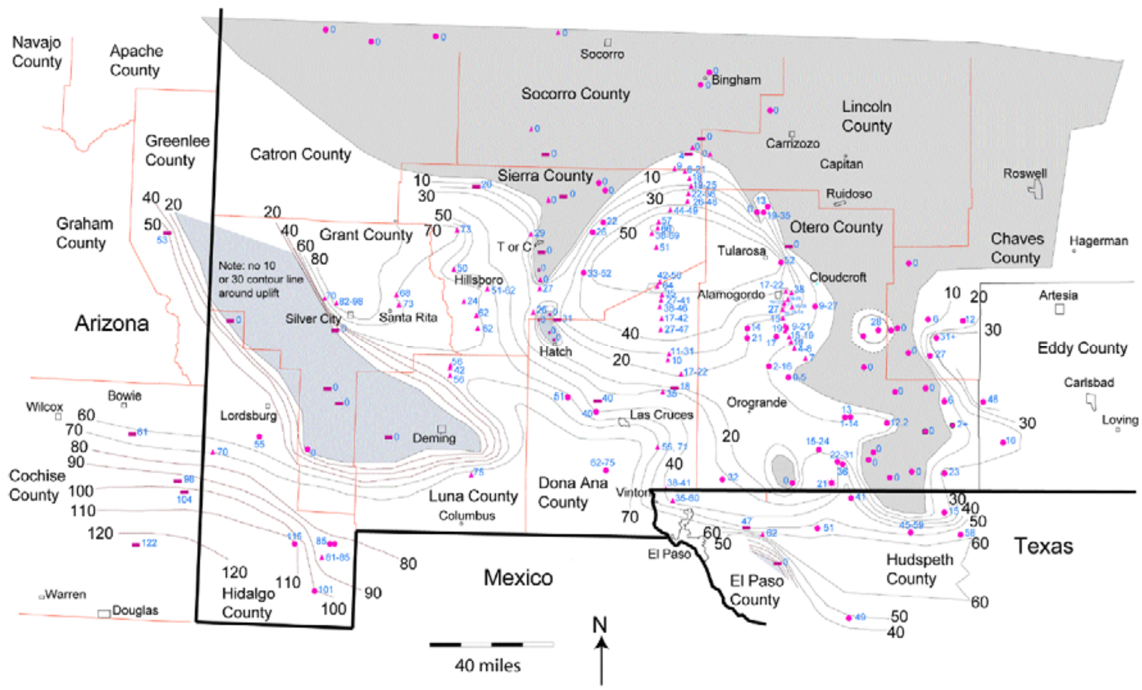

Figure 2. Devonian isopach map for south-central and southwestern New Mexico. Data points, in meters, are provided with a range of values where studies disagree. Contour interval is 10 meters except where noted.

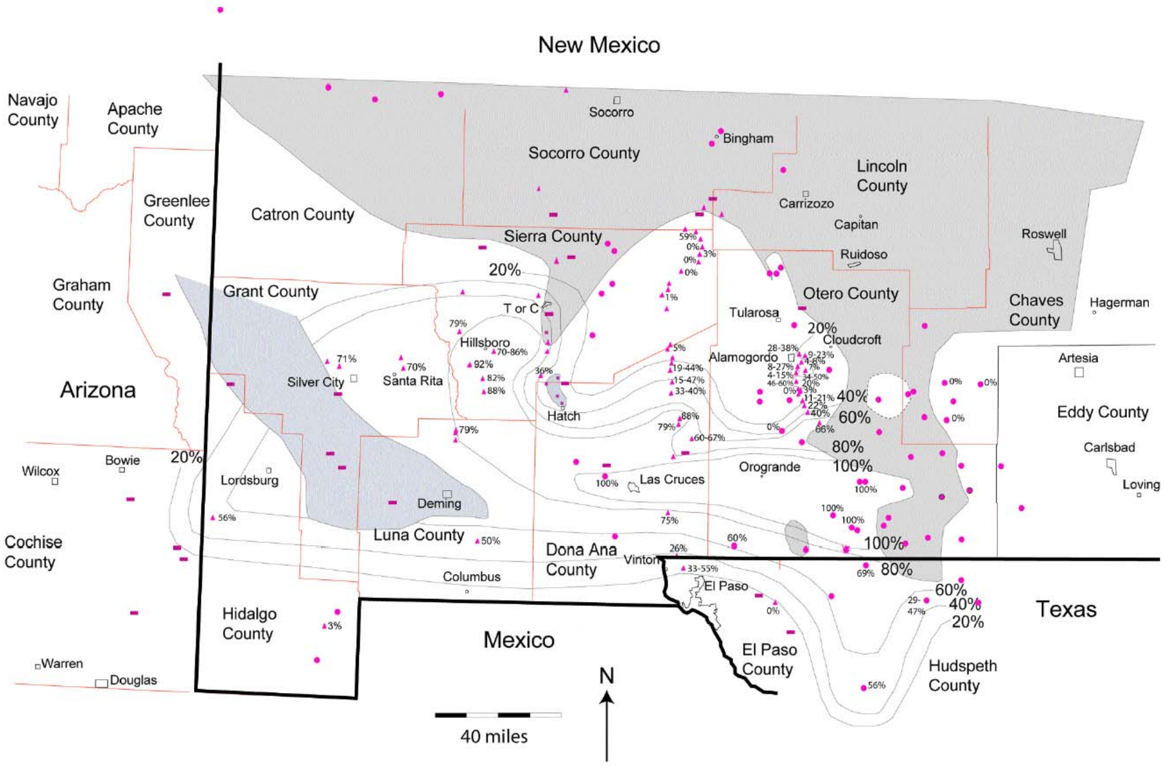

Figure 3. Percent black shale map for south-central and southwestern New Mexico. Data points are provided with a range of values where studies disagree. Contour interval is 20%.

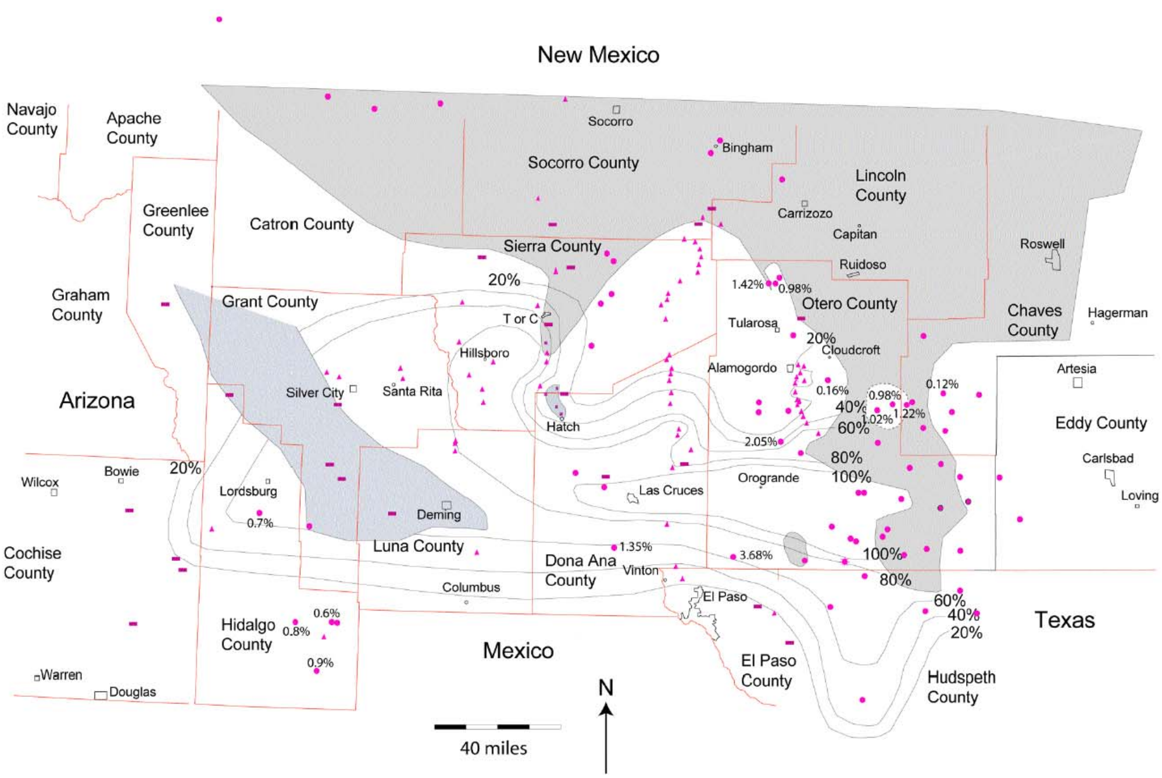

Figure 4. Devonian percent black shale map with maximum Devonian Total Organic Carbon values posted.

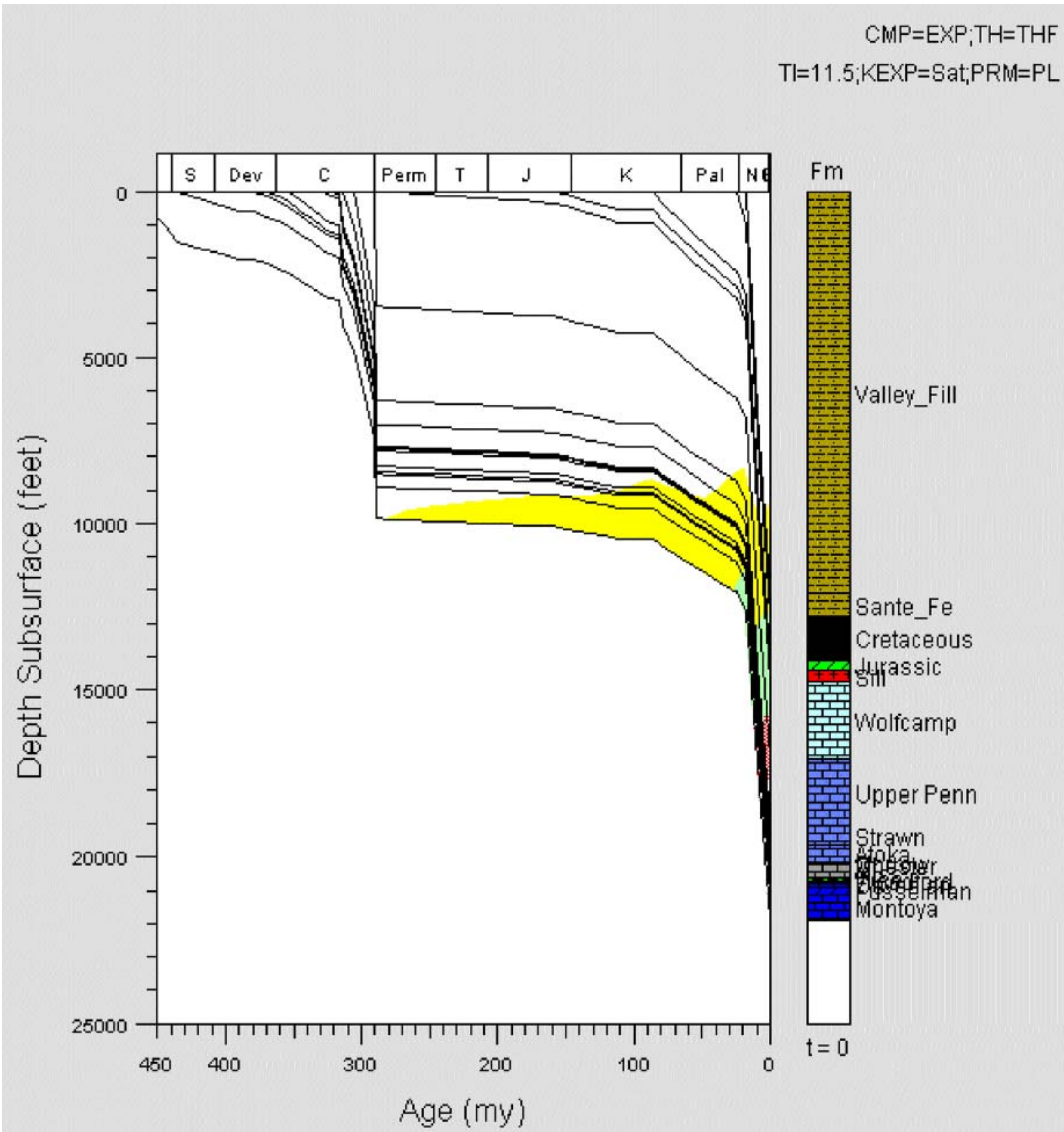

Figure 5. Burial history plot for the Grim Mobil-32 #1 well in south-central Dona Ana County. The color scale is: Yellow = Early Mature (oil) 0.5 – 0.7 %Ro; Green = Mid Mature (oil) 0.7 – 1.0 % Ro; Red = Late Mature (oil) 1.0 – 1.3 % Ro; Stippled red = Main Gas Generation 1.3 – 2.6 % Ro.

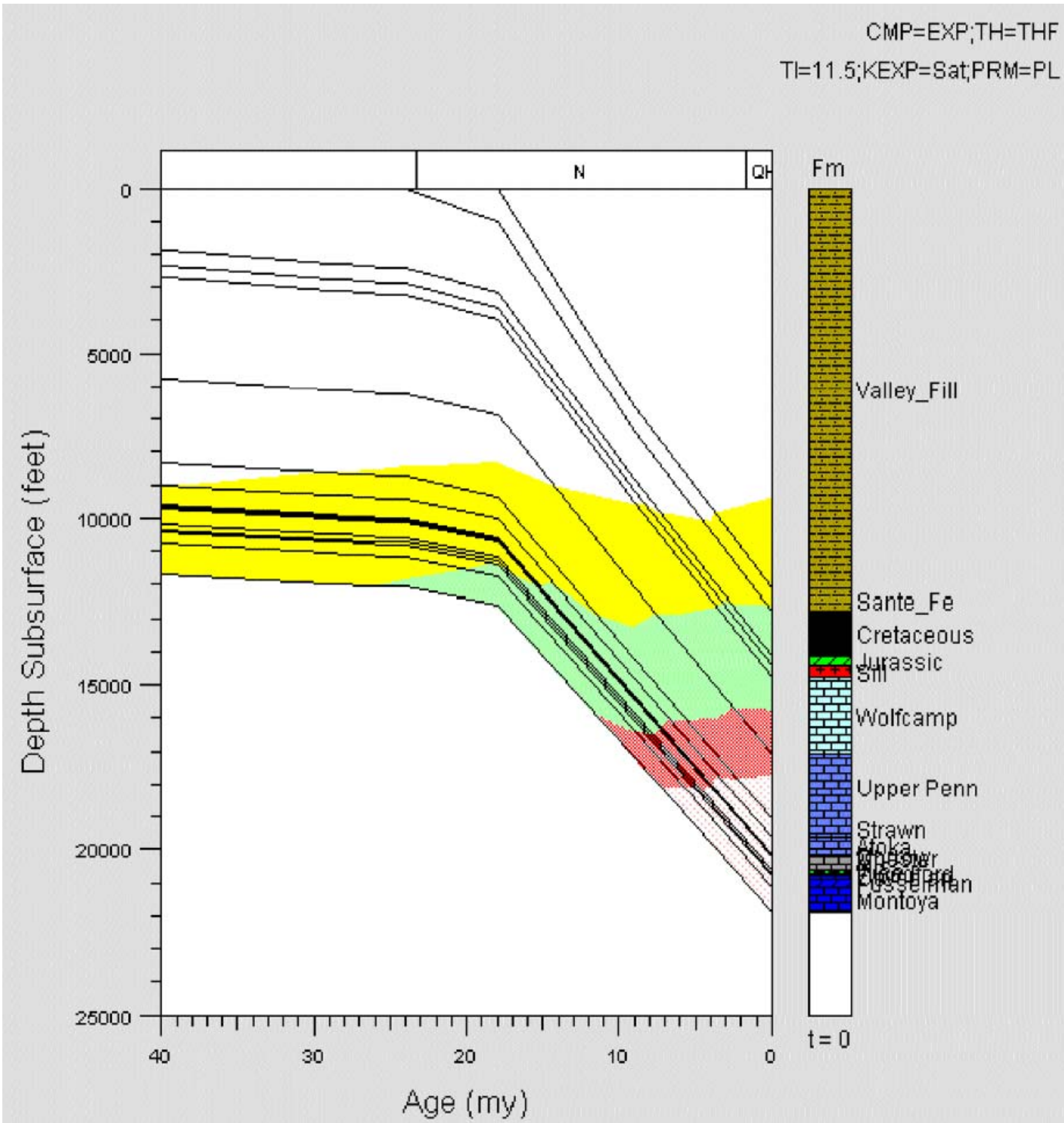

Figure 6. Burial history plot for the Grim Mobil-32 #1 well in south-central Dona Ana County zoomed to show detail from 40 Ma to present. Color scale same as in Figure 5.

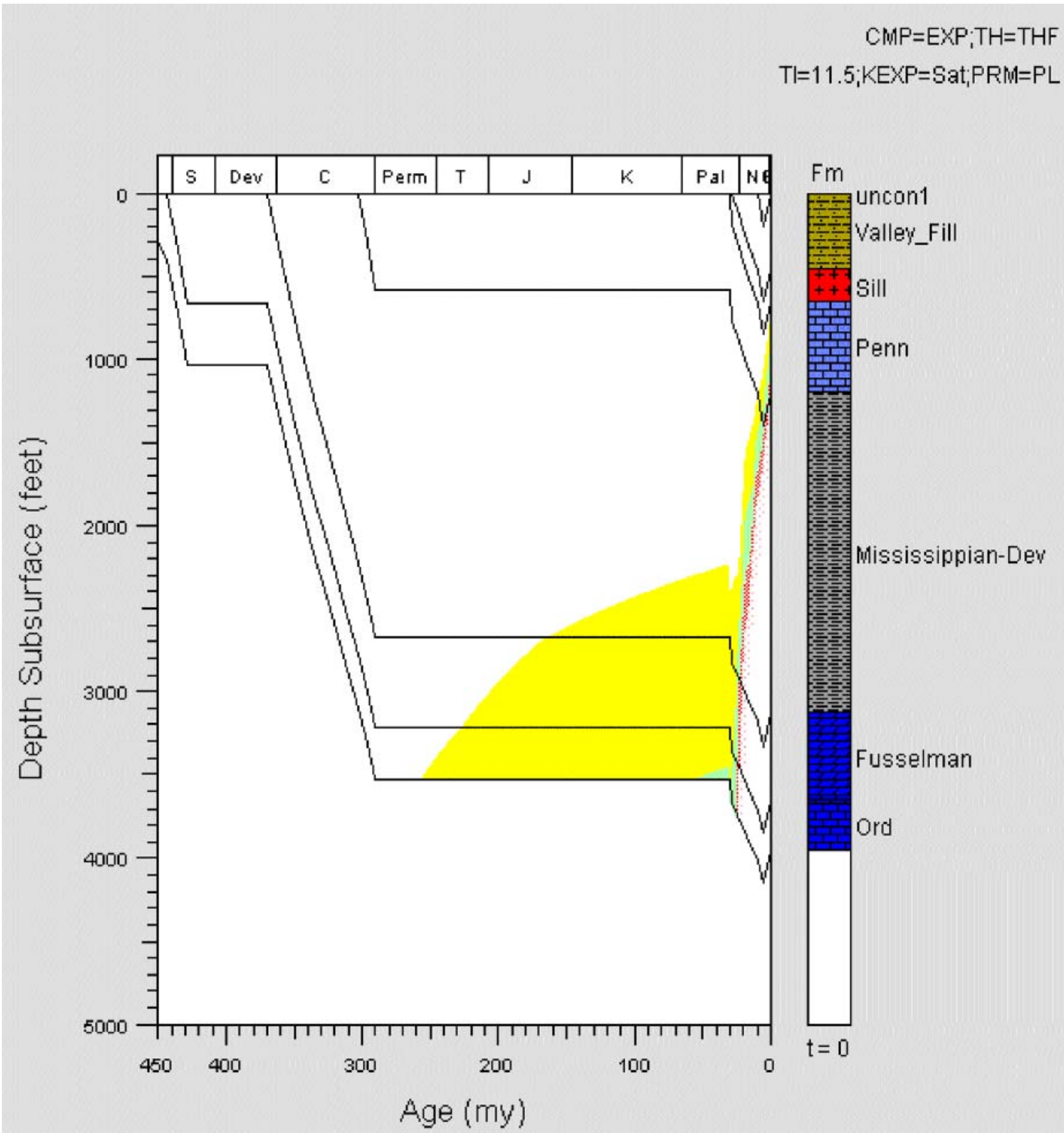

Figure 7. Burial history plot for McGregor GDP 51-8 well in southwestern Otero County. Color scale same as in Figure 5. The elevated heat flow due to Rio Grande Rift tectonics has a dramatic effect on maturity values and expulsion.

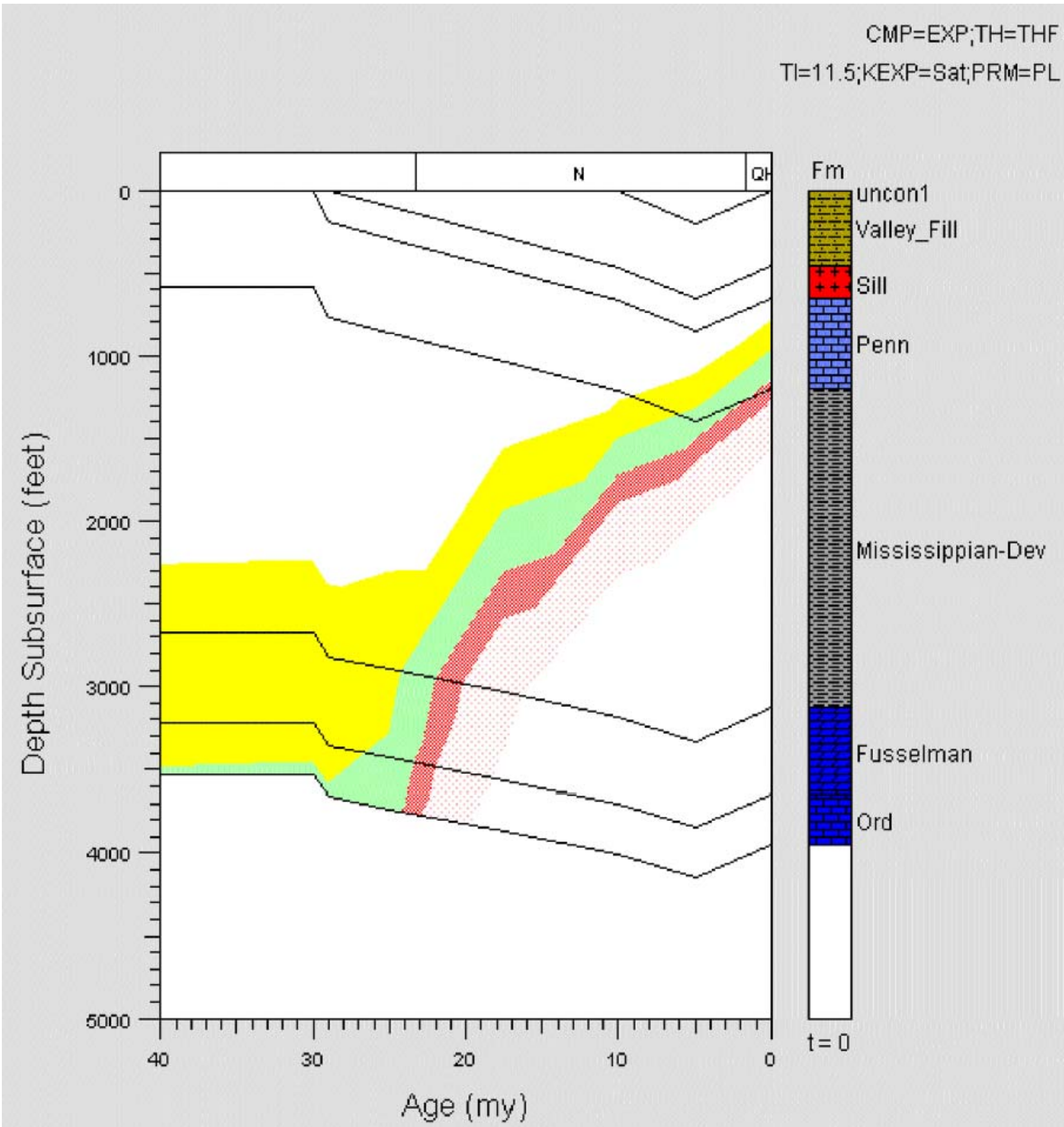

Figure 8. Burial history plot for McGregor GDP 51-8 well in southwestern Otero County zoomed to 40 Ma to present. Color scale same as in Figure 5.

Stratigraphy

The Middle to Upper Devonian formations present in southern New Mexico unconformably overlie the Silurian Fusselman Formation and underlie Mississippian units. They are composed of thin, locally fossiliferous gray to brown shales, siltstones, sandstones, carbonates, and barren anoxic black shales. In the San Andres and Sacramento mountains, Devonian strata representing largely shelf environments can be grossly divided into two major unconformity-bounded packages: the Givetian clastic-dominated Oñate Formation and the upper Frasnian-Famennian mixed clastic/carbonate Sly Gap and Contadero Formations (Day, 1988). Shelf deposits from the Sacramento and San Andres mountains grade southward into an E-W-trending trough located at the approximate latitude of Las Cruces containing anoxic, barren black shales of the Percha Formation (Kottlowski, 1963; Rosado, 1970). Farther south in the Franklin Mountains the Percha black shales grade into and are underlain by the Canutillo Formation, a cherty carbonate. To the west, the black-shale-filled Percha trough widens, extending from northern Grant and Sierra counties southward to Deming and perhaps into Mexico. To the far west, beginning approximately at Lordsburg, the shaley basin facies becomes more sandy and carbonate-rich as it approaches the shelf areas of Arizona and the boot heel of New Mexico, correlating to the Portal and Swisshelm formations.

Interpretation of the environment of deposition responsible for the anoxia and subsequent black shale deposition ranges from shallow lagoon with algal mat covering (Seager, 1981; LeMone, 1982, 1996b; Mack et al., 1998), to “deep water” with anoxia resulting from a density-stratified seaway (Kottlowski et al., 1956; Sorauf, 1984; Day, 1988, 1998). The “deep water” model better fits the general basin physiography of the area and is the preferred interpretation. This “black shale problem” is not restricted to southern New Mexico but is a common interpretive conundrum throughout Devonian epeiric sea deposits in North America (e.g., Grabau, 1915; Brown and Kenig, 2001; Sageman and Arthur, 2001).

Devonian formations are well established within individual mountain ranges, although members continue to undergo revision, and correlation between ranges is not always clear (see Kottlowski et al., 1956; Seager, 1981; Sorauf, 1984; Kottlowski and LeMone, 1994). The oldest Devonian strata present in south-central New Mexico may be the Canutillo Formation (Nelson, 1940) in the Organ/Franklin Mountains. It unconformably overlies the Fusselman Formation and underlies and is a partial lateral facies equivalent to the Percha Formation, which in the southern area includes shaley facies correlative northward to the Oñate and Sly Gap Formations (Seager, 1981). The Canutillo is composed of a lower dolomitic siltstone and an upper cherty carbonate. The formation thins northward from 26 m in the Franklins to 6 m at Bishop Cap to 1 m in the southern San Andres Mountains. The Oñate Formation (Stevenson, 1945) of the Sacramento and San Andres mountains is of late Givetian age and unconformably overlies the Fusselman, while to the south in the Organ/Franklin Mountains its shaley facies is incorporated within the Percha Formation. In the Sacramento Mountains the Oñate consists of open-marine shelf deposits composed of gray silty dolomite, dolomitic siltstone, and minor sandstone with bryozoans, brachiopods, and local chert (Pray, 1961). It thins from 18 m in the south-central Sacramentos to 6 m in the far northern and southern reaches of the range (Pray, 1961). In the Hueco Mountains, 32 m of sparsely fossiliferous shales, silty shales, and silty limestones may correlate to the Oñate, Sly Gap, and Percha (Kottlowski, 1963). The lower Oñate in the San Andres Mountains is similar to the Sacramento Mountain sections, augmented in the central range by nondolomitized wackestones containing corals, crinoids, brachiopods, and bryozoans. The upper Oñate in the San Andres Mountains is regressive and clastic-rich, with siltstones, shale, and an upper cross-bedded sandstone unit documented (Kottlowski et al., 1956; Sorauf, 1984). The formation thins to the north and south from its maximum of 26 m in San Andres Canyon, becoming sandier to the north and shalier to the south.

The Sly Gap Formation (Stevenson, 1945), of Frasnian age, disconformably overlies the Oñate (Pray, 1961; Day, 1988). It is present in the northern and central Sacramento Mountains, the entire San Andres Mountains, and is incorporated as part of the Percha Formation in the Organ/Franklin Mountains (Pray, 1961; Seager, 1981; Sorauf, 1984). It is interpreted to represent a transgressive-regressive succession deposited in shelf (Sacramento Mountains, northern San Andres Mountains) to basin (southern San Andres Mountains) environments (Day, 1988). In the Sacramento Mountains the Sly Gap Formation contains interbeds of calcareous shale, thin-to-nodular fossiliferous lime mudstone, and lesser black shale, weathering to a distinctive yellowish color (Pray, 1961). Laudon and Bowsher (1941, 1949), Stevenson (1945), and Pray (1961) considered various upper beds of black shale in the southern Sacramento Mountains as belonging to the Percha Formation, although other workers interpreted them as basin facies of the Sly Gap Formation (Kottlowski et al., 1956). In the San Andres Mountains the Sly Gap Formation consists of nodular interbeds of fossiliferous (colonial and solitary corals, brachiopods, crinoids, ammonoids, gastropods, stromatoporoids), calcareous, silty shale, silty limestone, and calcareous siltstone (Kottlowski et al., 1956; Sorauf, 1984; Kottlowski and LeMone, 1994). In the southern San Andres Mountains the Sly Gap is composed almost completely of dark gray to black shales deposited in anoxic environments (Kottlowski et al., 1956; Day, 1988).

The Contadero Formation (Stevenson, 1945) is recognized in the northern San Andres Mountains and originally incorporated all strata between the Sly Gap and the Mississippian, but it was revised by Flower (in Kottlowski et al., 1956) to include what were originally upper Sly Gap units and also exclude upper dark shales with Fammenian fauna, which were placed in the Percha Formation. Sorauf (1984) revised Flower’s member nomenclature to include: the Salinas Peak Member (sea-level highstand shale to sandstone, with upper coral-bearing nodular limestone); Thurgood Sandstone Member (regressive, fine-grained, well indurated sandstone with calcareous cement and brachiopod fragments); and Rhodes Canyon Member (Fammenian-aged shales and burrowed siltstones with brachiopods, correlative to the Ready Pay Member of the Percha Formation). The Contadero Formation, which is not recognized in the Sacramento or the Franklin Mountains, may have formed in a narrow structural re-entrant largely limited to the San Andres Mountains area (Day, 1988).

In the Organ/Franklin Mountains the Percha Formation is used to include all Middle-Upper Devonian shales above the Canutillo Formation, including strata that are age-equivalent to the Oñate, Sly Gap, and Contadero formations (Seager, 1981). To the north, when used at all, the Percha is constrained to only those dark shales of Fammenian age. The Percha is divided into two members: the Ready Pay (black, fissile, barren shale) and the Box (shale with nodular limestone concretions and limited fauna). As discussed, Pray (1961) considered the uppermost dark shales in the southern Sacramentos to be lower Percha, rather than Sly Gap, based partly on a dark shale “channel-filling” unit with angular contacts between the Sly Gap and Mississippian. Dark shales in the extreme southern Sacramento Mountains are variously interpreted as Percha or Sly Gap/Oñate basin equivalents (Kottlowski et al., 1956; Pray, 1961). Fammenian-aged shales in the San Andres Mountains are included in the Rhodes Canyon Member of the Contadero Formation (Sorauf, 1984).

In southwestern New Mexico Devonian strata are composed of dark fissile and carbonaceous shale facies from the basin environment and are considered the Percha Formation regardless of age. Barren dark shales of the Ready Pay Member overlie Fusselman carbonates and, in turn, are overlain by dark green to black calcareous shale with shaley nodular limestones of the Box Member. Laudon and Bowsher (1949) offer an excellent description of Devonian stratigraphy and paleontology for this basin facies throughout the southern and southwestern area.

Organic Geochemistry

Organic geochemistry data for Devonian units in south-central and southwestern New Mexico is spotty and of varying vintage and quality (New Mexico Bureau of Geology and Mineral Resources Digital Data Series- Database DDS-DB2; New Mexico Bureau of Geology (Mines) and Mineral Resources Open File Reports 92, 153, 202, 206, 237, 263, 328, 362, and 456). Figure 4 posts public domain Devonian TOC values on a % black shale map. Future work will focus on expanding this database with respect to both source rock richness and maturity.

Burial History

Burial history and basin analysis studies are not common for this region. Two major problems exist in constructing accurate models: (1) data quantity and quality, and (2) the complex heat-flow history of this area that has experienced Ancestral Rocky Mountain tectonism, the Laramide orogeny, and Rio Grande rifting.

Although a fair number of well penetrations exist (Table 1, Figure 1), most are of pre-1980 vintage (many significantly older) and contain generally poor log suites. Detailed bolson thickness data and structural styles are poorly constrained; lithologies and lithic percentages can often only be estimated; and formation and age picks are usually performed without the aid of biostratigraphic data or core. Geochemical and thermal data are rare.

Estimate of heat flow through time is a major variable in any burial history model. The Rio Grande Rift area contains one of the more complicated thermal regimes in the world. High-quality regional present- day heat flow maps exist (Reiter et al., 1975), but they must smooth some of the natural heterogeneity derived from spatially complex intrusions and faults. For example, the regional map (Reiter et al., 1975) illustrates a heat flow range of 1.4 to 4.7 hfu over the study area; however detailed local measurements reach as high as 17 hfu (equates to over 700 mWM/m2; New Mexico Bureau of Geology and Mineral Resources Open File Report 456). The fact that this area has some of the best geothermal energy potential in the United States, including a number of existing successful projects, bespeaks to its high and complex heat flow.

Even under ideal circumstances, basin models offer nonunique solutions that fit known data. Due to the data complexities discussed above, a single "best estimate" model is misleading for this area, since a greater than normal number of parameters are poorly constrained. I, therefore, provide two best fit end member models that hopefully bracket much of the area (Figures 5, 6, 7, and 8): (1) Grim Mobil-32 #1, a deep well test below 20,000 feet containing thick Tertiary Rio Grand Rift bolson valley fill but heat flow within regional norms, and (2) McGregor GDP 51-8, with much thinner bolson deposits but anomalously high heat flow.

Petroleum Potential

Numerous oil and gas shows and one significant gas discovery (Harvey E. Yates 1Y Bennett Ranch well, Sec. 14, T.26S., R.12E.) in the study area indicate an active petroleum system exists. Of 83 exploratory wells drilled in the Tularosa Basin, 25 contain shows. Despite this proven potential, the area's large size, the multiple source and reservoir facies, and the complex structural history offering numerous trapping mechanisms, few integrated petroleum systems studies have been undertaken (e.g., Broadhead, 2002). A regional, comprehensive interpretation of this area's petroleum system is needed to understand better its potential and to high-grade primary opportunities.

Source Rocks

Source rocks have been documented for Devonian, Mississippian, Pennsylvanian, and Permian strata (Broadhead, 2002), and for Cretaceous shales and coals in central New Mexico. This paper has concentrated on the thick Devonian black shales, but other units offer viable oil- and gas-prone source facies in a wide range of thermal maturities. Regional richness/maturity trends in Devonian strata indicate that the thick black shale deposits in Hidalgo and Luna counties are of relatively poor quality and overmature (Thompson, 1981). The area should not be condemned, however, due to the sparse dataset. The most prospective area appears to reside in Dona Ana and southern Otero counties. Here, although black shales are thinner than areas to the southwest, increasing organic richness and decreasing maturity create a viable, mixed oil/gas-prone source rock. The shales are interpreted as predominantly gas-prone due to their low HI values

(50-200), visual kerogen data, S2/S3 ratios less than 5, and generally high thermal maturities.

Expulsion timing

For the Ancestral Rocky Mountain Orogrande and Pedregosa basin areas (e.g., central Tularosa Basin between the Sacramento and San Andres Mountains, and in southwestern New Mexico in Hidalgo and southwest Luna counties) oil-prone source rocks of Lower Paleozoic and possibly Upper Paleozoic age became early to moderately mature during Late Pennsylvanian through Permian time. Outside of the Ancestral Rocky Mountain basin depocenters, it is less likely thermal maturities reached levels for major expulsion. It is difficult to ascertain the effect of the Laramide orogeny on the eastern area since little Mesozoic section is preserved and no detailed vitrinite profiles have been located in the public domain to quantify the extent of Mesozoic deposition and subsequent erosion. In the western area, thick preserved Cretaceous deposits may have caused a second expulsion event. The Rio Grande Rift, with its elevated heat flows, igneous intrusions, and thick bolson deposits brought all graben-area source rocks to maturity or post-maturity, resulting in minor(?) oil and potentially major gas expulsion beginning ~28 Ma and continuing today. Horst areas vary from immature to post-mature, depending on the stratigraphic interval and extent of uplift associated with specific blocks. It is likely that over the large study area hydrocarbons have been continually expulsed from Late Paleozoic time until Recent, with pulses centered around the three major orogenic events.

Reservoirs

Numerous potential reservoir facies exist, including: fractured Precambrian basement, Cambro-Ordovician sandstones (Bliss Formation), karsted Ordovician carbonates (El Paso Formation), Silurian dolomites (Fusselman Formation), Devonian sandstones (northern area), Devonian shales (southern area), Mississippian carbonate bioherms (including large Waulsortian mounds), Pennsylvanian (Morrowan/Atokan) sandstones, Upper Pennsylvanian phylloid-algal mounds (correlative to the Holder Formation outcrops in the Sacramento Mountains), Lower Permian (Wolfcampian) basin margin mounds and breccia debris flows, Upper Permian (San Andres and Yeso Formation) backreef limestones and dolomites, Cretaceous sandstones (Dakota Formation) and coalbed methane, and Tertiary (Eocene) fractured igneous sills (the major reservoir for the Otero Mesa Harvey E. Yates gas discovery). Recovered fluids from existing wells include oil, gas, saline water, and fresh water.

Traps/seals

The large study area has undergone multiple tectonic episodes and also has numerous documented stratigraphic pinch-outs, creating a wide range of trapping styles and mechanisms, many analogous to the neighboring prolific Permian Basin. Ancestral Rocky Mountain block faults, many reactivated during Rio Grande Rift extension, potentially juxtapose reservoir facies against units with low permeability or against fault planes with clay smear/cataclasis effects. Structural roll-on horsts near major normal faults also add dip closure. Low-angle Laramide thrust faults and rollovers are documented in outcrop (e.g., Pray, 1961) and the subsurface; for example, a major thrust-fault-induced rollover was encountered in the McGregor 51-8 well. Stratigraphic traps include Devonian shale gas, large biohermal mounds in the Mississippian, Pennsylvanian, and Permian sections, carbonate debris flows off basin margins sealed (and potentially sourced) with basinal shales, Pennsylvanian, and Permian stratigraphic pinch-outs onlapping Ancestral Rocky Mountain uplifts, Lower Paleozoic pinch-outs of strata onlapping the Transcontinental Arch, Cretaceous coalbed methane, and fractured Eocene igneous sills intruded into tight carbonates and shales.

Seal integrity is a concern in the eastern Sacramento Mountain uplift area. Major fracture systems have breached some horst block units, flushing reservoirs with fresh water. This negative does create an opportunity for fresh-water exploration in this growing, water-starved area.

Preliminary Comments on Most Prospective Areas

Integrating previous studies and new work, the most prospective area for Devonian-sourced hydrocarbons appears to be the south-central portion of the study area, bounded approximately by the latitudes of Hatch to the north and El Paso to the south, and longitude of Deming to the west and extending eastward beyond the study area. This area has adequate organic richness, thermal maturity, reservoir intervals, and trapping mechanisms to create a viable petroleum (predominantly gas) system. To the north, Devonian organic richness lessens, due to the influx of shelf clastics; to the west source-rock richness decreases, due to unknown reasons and maturities increase to post mature. To the south richness decreases, due to a facies change into the cherty carbonate Canutillo Formation.

Conclusions

South-central New Mexico contains the necessary ingredients for economic discoveries of hydrocarbons sourced by Devonian black shales. Poor data and a complicated geologic history pose challenges, but continued studies that focus on quantifying and high-grading local and regional aspects of the petroleum system will reduce risks and lead to more exploration activity. Available data, both well and outcrop, have not yet been utilized to their maximum potential. As part of this ongoing study, data will be re-evaluated and incorporated into a comprehensive petroleum systems framework.

Acknowledgments

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