Play Analysis of Major Oil Reservoirs in the New Mexico Part of the Permian Basin: Enhanced Production Through Advanced Technologies

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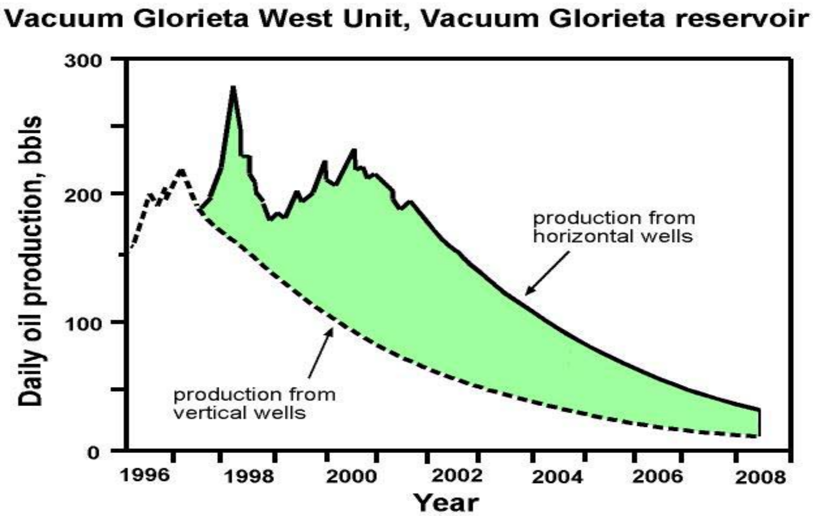

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1. Document Title: Play Analysis of Major Oil Reservoirs in the New Mexico Part of the Permian Basin: Enhanced Production Through Advanced Technologies

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ABSTRACT

Approximately 300 reservoirs in the New Mexico part of the Permian Basin have cumulative production of more than 1 million bbls oil (MMBO). These 300 reservoirs had produced a total of 4.5 billion bbls oil at the end of 2000. The reservoirs have been grouped into 17 plays based on geologic parameters, including reservoir stratigraphy, lithology, depositional environment, tectonic setting, and trapping mechanism. There are 10 Permian plays that have a cumulative production of 3506 MMBO, two Pennsylvanian plays with a cumulative production of 424 MMBO, three Siluro-Devonian plays with a cumulative production of 440 MMBO, and two Ordovician plays with a cumulative production of 86 MMBO. During 2000, 40 MMBO were produced from the Permian plays, the Pennsylvanian plays yielded 6.4 MMBO, the Silurian-Devonian plays yielded 1.4 MMBO, and the Ordovician plays gave up 0.35 MMBO.

Most production in the basin has been obtained from reservoirs located on the Northwest Shelf and on the Central Basin Platform. There are 13 plays productive from shelf, platform and ramp settings. These 13 plays have produced a cumulative total of 4231 MMBO and 39 MMBO during 2000 from 249 reservoirs. In contrast there are four plays that are productive from reservoirs deposited in basinal settings. These four plays have 50 reservoirs with more than 1 MMBO production and produced a cumulative total of 226 MMBO; 9.0 MMBO were produced from the basinal plays during 2000.

A wide variety of advanced management techniques have been applied in the Permian Basin in order to enhance or stimulate production from already discovered reservoirs. Waterfloods have increased recovery and produced substantial volumes of oil in both shelf and basinal reservoirs. Pressure maintenance projects have increased production in solution gas drive reservoirs. In some cases, horizontal drilling has been successfully applied to produce oil not in communication with vertical wells in horizontally compartmentalized reservoirs or to produce oil that was unswept by waterfloods in old, mature reservoirs. Other old reservoirs have benefited from completions in bypassed pay that remained unproduced behind casing. Yet other reservoirs did not attain full field development for years after discovery because development was undertaken on the basis of misconceptions regarding trapping mechanism. In yet other cases, exploratory objectives were overlooked in favor of drilling targets in other stratigraphic units. It appears that advanced reservoir

management techniques have been successful in many plays but not always widely applied, leaving potentially productive oil in the ground.

INTRODUCTION

This paper summarizes work developing a play portfolio of major oil-productive reservoirs in the Permian Basin of west Texas and southeastern New Mexico (Fig. IN-1). The project, funded by the U.S. Department of Energy under the Preferred Upstream Management Practices (PUMP) program (contract DE-FC26-02NT15131), was a joint effort between the Bureau of Economic Geology at the University of Texas at Austin and the New Mexico Bureau of Geology and Mineral Resources at New Mexico Institute of Mining and Technology (New Mexico Tech). The objectives of this PUMP project are to: 1) develop an up-to-date portfolio of oil plays in the Permian Basin of West Texas and southeast New Mexico; 2) study key reservoirs of some of the largest or most active plays and incorporate information on improved practices in reservoir development and management within the portfolio; and 3) widely disseminate the play portfolio to the public via CD-ROM, the internet, and other media. Results of this project have been previously presented in project reports submitted to the U.S. Department of Energy (Dutton et al., 2003; Dutton et al., 2004).

Reservoirs and plays in the New Mexico part of the Permian Basin are summarized in this report. For the project as a whole, data from reservoirs with more than 1 MMBO cumulative production were mapped and compiled in a Geographic Information System (GIS). Nonassociated gas reservoirs and associated gas reservoirs with less than 1 MMBO cumulative production were not included in this study. In addition to the 299 reservoirs identified in New Mexico, approximately 1000 reservoirs with more than 1 MMBO cumulative production were identified in the Texas part of the Permian Basin. These 1300 reservoirs were grouped into 33 plays, 17 of which are partially or wholly located in New Mexico (Table IN-1). In New Mexico, there are 10 Permian plays, two Pennsylvanian plays, three Siluro-Devonian plays, and two Ordovician plays. The 10 Permian plays have a cumulative production of 3506 MMBO from 194 reservoirs. The two Pennsylvanian plays have a cumulative production of 424 MMBO from 47 reservoirs. Three Siluro-Devonian plays have cumulative production of

440 MMBO from 48 reservoirs and two Ordovician plays have cumulative production of 86 MMBO from 10 reservoirs.

This report is meant to complement a report soon to be published by the Bureau of Economic Geology at the University of Texas at Austin. That larger report, also to be

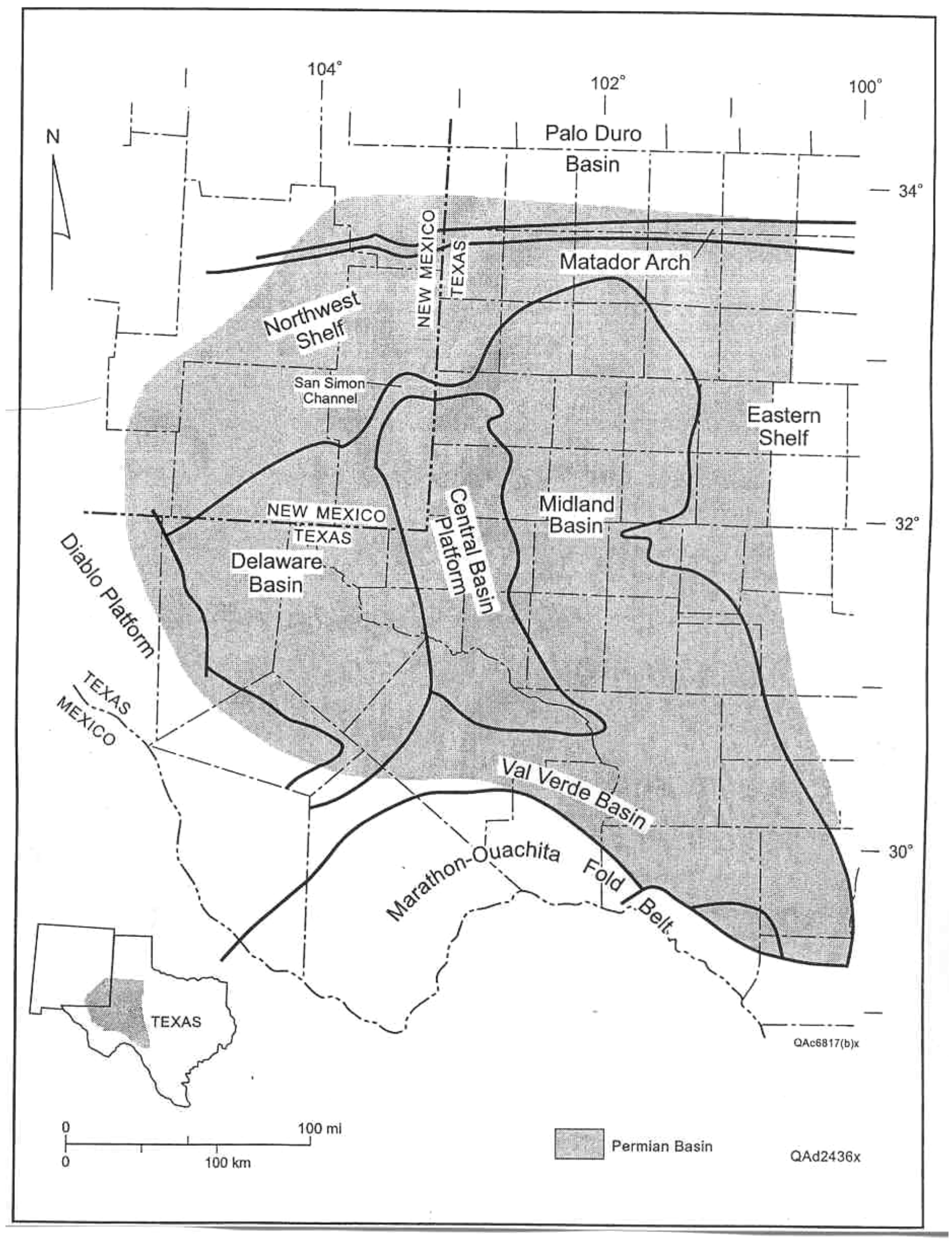

Figure IN-1. Major boundaries and subdivisions of the Permian Basin in west Texas and southeastern New Mexico (from Dutton et al., 2003, as modified from Hills, 1984 and Frenzel et al., 1988). The Permian Basin is subdivided into the Northwest Shelf Delaware Basin, Central Basin Platform, Midland Basin, Val Verde Basin, and Eastern Shelf.

Table IN-1. List of Permian Basin oil plays. ***Play codes shown in parentheses***.

	Plays in Texas	Plays in New Mexico
Permian		
	Guadalupian	
	Artesia Platform Sandstone **(132)**	Artesia Platform Sandstone **(132)**
	Queen Tidal-Flat Sandstone **(131)**	
	Delaware Mountain Group Basinal Sandstone **(130)**	Delaware Mountain Group Basinal Sandstone **(130)**
	Grayburg High-Energy Platform Carbonate—Ozona Arch **(129)**	
	Grayburg Platform Carbonate **(128)**	
	Grayburg Platform Mixed Clastic/Carbonate **(127)**	
	Grayburg Lowstand Carbonate **(126)**	
		Upper San Andres and Grayburg Platform Mixed—Artesia Vacuum Trend **(125)**
		Upper San Andres and Grayburg Platform Mixed—Central Basin Platform Trend **(124)**
	San Andres Platform Carbonate **(123)**	
	San Andres Karst-Modified Platform Carbonate **(122)**	
	Eastern Shelf San Andres Platform Carbonate **(121)**	
	Northwest Shelf San Andres Platform Carbonate **(120)**	Northwest Shelf San Andres Platform Carbonate **(120)**
	Leonardian	
	Spraberry/Dean Submarine-Fan Sandstone **(119)**	
		Bone Spring Basinal Sandstone and Carbonate **(118)**
	Leonard Restricted Platform Carbonate **(117)**	Leonard Restricted Platform Carbonate **(117)**
	Abo Platform Carbonate **(116)**	Abo Platform Carbonate **(116)**
	Wolfcampian	
	Wolfcamp/Leonard Slope and Basinal Carbonate **(115)**	Wolfcamp/Leonard Slope and Basinal Carbonate **(115)**
	Wolfcamp Platform Carbonate **(114)**	Wolfcamp Platform Carbonate **(114)**
Pennsylvanian		
	Upper Pennsylvanian and Lower Permian Slope and Basinal Sandstone **(113)**	
	Pennsylvanian and Lower Permian Horseshoe Atoll Carbonate **(112)**	
	Pennsylvanian Platform Carbonate **(111)**	
		Northwest Shelf Upper Pennsylvanian Carbonate **(110)**
		Northwest Shelf Strawn Patch Reef **(109)**
Mississippian		
	Mississippian Platform Carbonate **(108)**	
Devonian		
	Devonian Thirtyone Ramp Carbonate **(107)**	
	Devonian Thirtyone Deepwater Chert **(106)**	Devonian Thirtyone Deepwater Chert **(106)**
Silurian		
	Wristen Buildups and Platform Carbonate **(105)**	Wristen Buildups and Platform Carbonate **(105)**
	Fusselman Shallow Platform Carbonate **(104)**	Fusselman Shallow Platform Carbonate **(104)**
Ordovician		
	Simpson Cratonic Sandstone **(103)**	Simpson Cratonic Sandstone **(103)**
	Ellenburger Karst-Modified Restricted Ramp Carbonate **(102)**	Ellenburger Karst-Modified Restricted Ramp Carbonate **(102)**
	Ellenburger Selectively Dolomitized Ramp Carbonate **(101)**	

issued on CD-ROM, will present data, information and play analyses that cover the entire Permian Basin. Many of the plays discussed in this report cross the New Mexico-Texas border and the play descriptions presented in the Bureau of Economic Geology report cover aspects of the plays and associated reservoirs that are apparent in Texas. The Bureau of Economic Geology report will also include an interactive Geographic Information System (GIS) project that allows the user to utilize geographically mapped reservoir locations, play boundaries, and reservoir data in digital format.

One of the major goals of the project was to identify reservoir management and production practices that have been successfully applied to substantially increase recovery from existing oil reservoirs in the Permian Basin. By grouping reservoirs into plays on the basis of common geologic parameters including reservoir stratigraphy, reservoir lithology, depositional environment, tectonic setting, and trapping mechanism it is hoped that management practices which have increased oil recovery in one reservoir in a play may be possibly applicable to other reservoirs in that play. The management practices identified in this report are not comprehensive and successful management practices may have been omitted from the play descriptions. The management practices chosen for inclusion were those that could be thoroughly documented from published reports or other data supplied by industry geologists and engineers.

Assignment of reservoirs to plays

Oil and gas reservoirs (pools) in New Mexico are named according to rules promulgated by the Oil Conservation Division (OCD) of the New Mexico Energy, Minerals and Natural Resources Department. Each reservoir, or pool, has two components to its name. The first part of the reservoir name is the field name; the field name is geographic and denotes an areally continuous oil or gas accumulation. The second part is stratigraphic and is derived from the principal stratigraphic unit (formation) from which the pool is productive (Fig. IN-2).

Ideally, in the definition of a reservoir, all productive zones in the defined reservoir should be restricted to a single stratigraphic unit and should be in pressure communication with each other. In practice, however, a well may be completed in several isolated zones in a formation and production from these zones is commingled. Production from each zone is not tracked separately. Therefore, production units recognized as

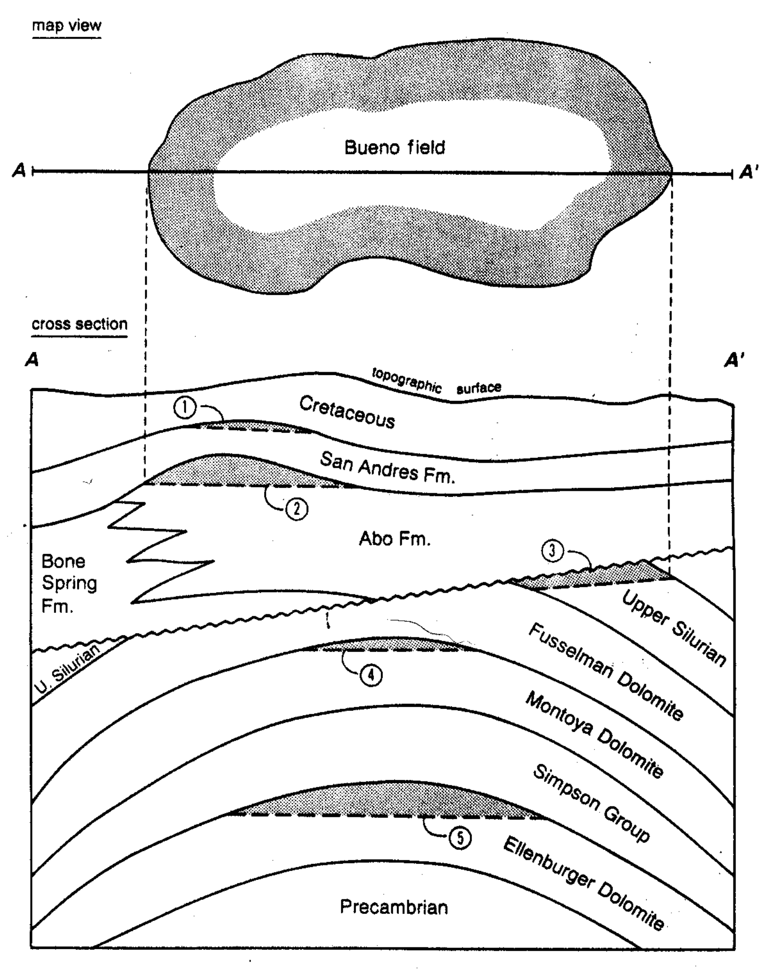

Figure IN-2. Relationship between a field and its constituent reservoirs. The field name is Bueno. The five reservoirs are: 1) Bueno San Andres, 2) Bueno Abo, 3) Bueno Upper Silurian, 4) Bueno Montoya, and 5) Bueno Ellenburger. From Broadhead (1993).

reservoirs often approximate the ideal definition of a reservoir, but sometimes produce from multiple hydraulically isolated zones within a single formation (Fig. IN-3).

For most New Mexico reservoirs, most or all production has been obtained from a single stratigraphic unit or formation. In these cases, the assignment of a reservoir to a play is straightforward because most plays have a stratigraphic component to their definition. In some reservoirs, however, the OCD has permitted significant commingling of oil and gas production across formational boundaries. In these cases, the stratigraphic component of the pool name contains two or more formational names (for example, the Justis Blinebry Tubb Drinkard pool). In cases where two or more formational names have been assigned to the same play (for example, production from the Blinebry, Tubb, and

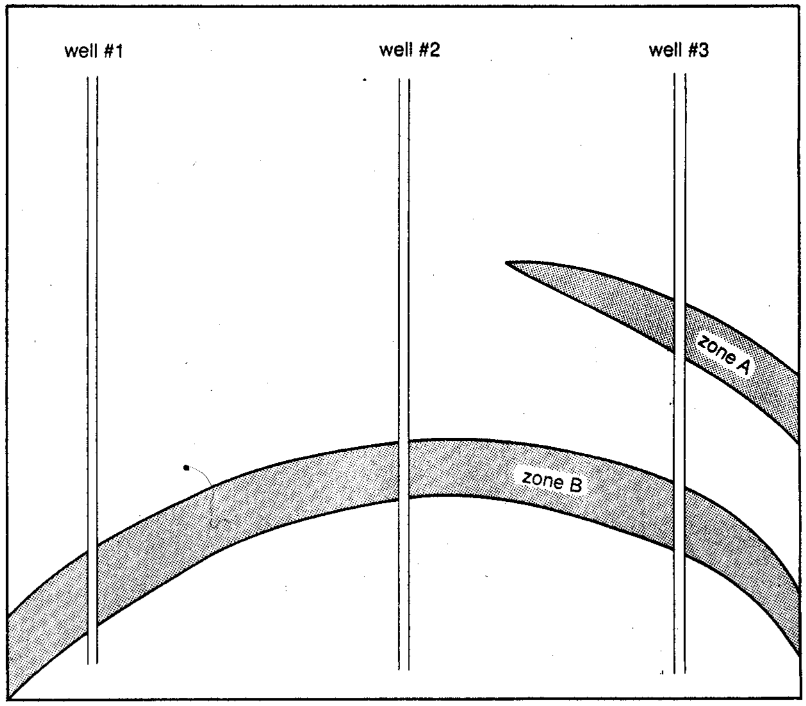

Figure IN-3. All production from a reservoir may not be in pressure communication. In this case wells 1, 2, and 3 produce from zone B and are in pressure communication with each other. However well 3 has commingled production from zones A and B that are hydraulically isolated from each other. In this case, the reservoir is considered to consist of both zones A and B because production from each of the two zones is not recorded separately because of the commingled production in well 3.

Drinkard members of the Yeso Formation are assigned in entirety to the Leonardian Restricted Platform Carbonate Play), assignment of the reservoir to a play is straightforward.

However, if the formations were assigned to different plays (for example the Loco Hills Queen Grayburg San Andres pool), then production from the reservoir is divided between two plays. For these pools, records of numerous individual wells were examined to ascertain if one constituent formation provided the overwhelming percentage of the production or if all the listed formations contributed major percentages of production. In most cases, it was found that one formation contributed the dominant amount of production and the pool was assigned to the play associated with that formation. This is apparent if only a few wells were completed in a second formation or if wells completed solely in one of the formations recovered only minor volumes of oil (stripper-type wells).

In a few cases however, it became apparent that multiple formations are major contributors to production from a single pool. In these cases, the plays were easily defined and included multiple pays because it is not possible to assign fractional parts of commingled production to a single reservoir stratum (for example play 125 – *Upper San Andres and Grayburg Platform Mixed-Artesia Vacuum Trend play*).

Finally, a complication occurs in some lower Paleozoic reservoirs (mainly Devonian and Silurian) where the formational name is inaccurate with respect to modern stratigraphic interpretations. For example, productive stratigraphic units in reservoirs that produce from what is now recognized as the Wristen Formation (Silurian) have been historically called "Devonian", "Siluro-Devonian", or "Silurian" and these stratigraphic names are used in the play tables. Since these name designations are part of the official name of the reservoir, they are left unchanged in the play tables, but were assigned to plays based upon current stratigraphic nomenclature and analyses.

Play codes

Each play was assigned a numeric play code for the joint Bureau of Economic Geology – New Mexico Bureau of Geology and Mineral Resources project that covered both the New Mexico and Texas parts of the Permian Basin (Table IN-1). In order to avoid conflicts with previous play codes (Galloway et al., 1983; Kosters et al., 1989; New Mexico Bureau of Geology and Mineral Resources, 1993) a new set of play codes was devised starting at 101. Plays with reservoirs of older geologic age were assigned the lowest numbers. While a number of the plays cross the New Mexico-Texas border, several are present only in Texas and several are present only in New Mexico. Because there are plays that are present in Texas but not in New Mexico, there are gaps in the sequential numbering of plays used in this report (for example, play 126 *Grayburg Lowstand Carbonate* is not present in New Mexico).

Procedure used for obtaining cumulative production for New Mexico reservoirs

The following approach was used to determine cumulative production data for each reservoir.

1. Cumulative production data for each reservoir were obtained from the 1993 Annual Report of the New Mexico Oil and Gas Engineering Committee. The cumulative production data tabulated by reservoir are available only in this

hardcopy report and are not available digitally. The production data were entered into an Excel spreadsheet along with the reservoir name and the productive stratigraphic unit. Cumulative production data tabulated by reservoir in pre-1994 reports of the New Mexico Oil and Gas Engineering Committee are valid. The 1993 report lists cumulative data as of December 31, 1993.

2. Annual oil production data for each reservoir for years subsequent to 1993 were obtained from the 1994, 1995, 1996, 1997, 1998, 1999, and 2000 Annual Reports of the New Mexico Oil and Gas Engineering Committee. These data were entered into the Excel spreadsheet that contains the 1993 cumulative production data. The annual production data in the post-1993 reports, as tabulated by reservoir, are valid. However, cumulative production data by reservoir, as tabulated by reservoir, in the post-1993 reports are not valid in most cases because they do not include historical production from several types of wells, including:
    a. Older wells that had formerly produced from the reservoir but were subsequently plugged and abandoned;
    b. Older wells that had formerly produced from the reservoir but were subsequently recompleted to another zone;
    c. Some production from wells whose operator had changed during the lifetime of the well; in some cases, production prior to an operator-name-change is not included in the cumulative production data for a well or for wells in a reservoir.

   The problems with post-1993 cumulative production data result from a change in the New Mexico production data system in 1994 which omitted data described in a, b, and c above.

3. Cumulative production for each reservoir was calculated by taking the annual production from 1994 through 2000 and adding it to the cumulative production data obtained from the 1993 annual report. Reservoirs in the New Mexico part of the Permian Basin having cumulative production >1 MMBO are listed in the data tables provided for each play description with producing formation, discovery date, and depth.

Overview of production from plays in the New Mexico part of the Permian Basin

Total cumulative production from the 299 reservoirs that have each produced more than 1 MMBO in southeastern New Mexico is 4.46 billion bbls oil (BBO). These 299 reservoirs produced 48.2 million bbls oil (MMBO) during 2000, or 1.08 percent of cumulative production. These 299 large reservoirs are estimated to have produced 94 percent of the oil produced in the New Mexico part of the Permian Basin; the other 1700 reservoirs have produced the remaining 6 percent of the oil.

The 17 plays documented in this report range in size from the Upper San Andres and Grayburg Central Basin Platform Trend with 809 MMBO cumulative production to the Devonian Thirtyone Deep Water Chert play, which barely cuts across the southeasternmost part of the state, with 9 MMBO cumulative production from one New Mexico reservoir (Table IN-2). Guadalupian (Upper Permian) plays have yielded the most oil, 2402 MMBO or 54 percent of the total produced in the New Mexico part of the Permian Basin (Table IN-3). Leonardian (Lower Permian) plays account for most of the remainder of production. Guadalupian and Leonardian reservoirs dominate present day production, with percentage of annual basinal production at 55 percent and 26 percent respectively during 2000. The two Pennsylvanian plays provided 13 percent of production during 2000 and 9.5 percent of cumulative production, demonstrating the increasing importance of Pennsylvanian reservoirs to overall oil production from the basin. Ordovician, Silurian, and Devonian plays, with the oldest and generally deepest reservoirs in the basin, have declined in importance significantly during 2000 when compared to cumulative production (Table IN-3). Plays that have increased in importance in terms of productive yield include the Delaware Mountain Group Basinal Sandstone play (12.1 percent of 2000 production from the basin as compared to 2.6 percent cumulative production from the basin; Table IN-4), the Upper San Andres and Grayburg Platform play along the Artesia-Vacuum arch, the Leonard Restricted Platform Carbonate play, and the Northwest Shelf Upper Pennsylvanian Carbonate play. Plays that have diminished somewhat in importance include the Artesia Platform sandstone play, the Upper San Andres and Grayburg Platform play on the Central Basin Platform, and the Wristen Buildups and Platform Carbonate play.

Most production in the New Mexico part of the Permian Basin has been obtained from reservoirs deposited in shelf, platform and ramp settings (Table IN-5). These reservoirs have provided 95 percent of cumulative oil production whereas reservoirs

Table IN-2. Production and geologic data for oil plays in the New Mexico part of the Permian Basin.

Play code	Play name	Age	Primary reservoir lithology	Earliest discovery (1 MMBO reservoirs)	Number reservoirs with > 1 MMBO production	2000 production MMBO	Cumulative production MMBO	2000 production as percent of cumulative production
132	Artesia Platform Sandstone	Guadalupian	sandstone	1926	38	2.98	586.97	0.51%
130	Delaware Mountain Group Basinal Sandstone	Guadalupian	sandstone	1951	33	5.78	114.56	5.05%
125	Upper San Andres & Grayburg Platform - Artesia Vacuum Trend	Guadalupian	carbonate	1923	13	11.39	796.42	1.43%
124	Upper San Andres & Grayburg Platform - Central Basin Platform Trend	Guadalupian	carbonate	1928	8	5.79	808.96	0.72%
120	Northwest Shelf San Andres Platform Carbonate	Guadalupian	carbonate	1958	13	0.52	94.78	0.55%
118	Bone Spring Basinal Sandstone & Carbonate	Leonardian	sandstone & carbonate	1959	16	2.46	70.70	3.48%
117	Leonard Restricted Platform Carbonate	Leonardian	carbonate	1944	34	6.19	430.88	1.44%
116	Abo Platform Carbonate	Leonardian	carbonate	1948	14	3.68	454.94	0.81%
115	Wolfcamp/Leonard Slope & Basinal Carbonate	Wolfcampian	carbonate	1962	9	0.69	31.69	2.18%
114	Wolfcamp Platform Carbonate	Wolfcampian	carbonate	1950	16	0.57	116.32	0.49%
110	Northwest Shelf Upper Pennsylvanian Carbonate	Pennsylvanian	carbonate	1949	34	4.87	353.85	1.38%
109	Northwest Shelf Strawn Patch Reef	Pennsylvanian	carbonate	1944	13	1.54	70.34	2.19%
106	Devonian Thirtyone Deep Water Chert	Devonian	chert	1952	1	0.07	9.18	0.76%
105	Wristen Buildups and Platform Carbonate	Silurian	carbonate	1948	36	1.08	368.82	0.29%
104	Fusselman Shallow Platform Carbonate	Silurian	carbonate	1947	11	0.25	62.01	0.40%
103	Simpson Cratonic Sandstone	Ordovician	sandstone	1947	3	0.25	21.98	1.14%
102	Ellenburger Karst-Modified Restricted Ramp Carbonate	Ordovician	carbonate	1945	7	0.10	64.29	0.16%
TOTALS					**299**	**48.21**	**4456.69**	**1.08%**

Table IN-3. Cumulative and annual oil production by geologic age of plays in the New Mexico part of the Permian Basin.

Age	Number reservoirs with > 1 MMBO production	2000 production MMBO	Cumulative production MMBO	2000 production from play as percent of total 2000 production	Cumulative production from play as percent of total cumulative production from all plays
Guadalupian	105	26.46	2401.69	55.88%	53.89%
Leonardian	64	12.33	956.52	25.58%	21.46%
Wolfcampian	25	1.26	148.01	2.61%	3.32%
Pennsylvanian	47	6.41	424.19	13.30%	9.52%
Silurian-Devonian	48	1.40	440.01	2.90%	9.87%
Ordovician	10	0.35	86.27	0.73%	1.94%
TOTALS	**299**	**48.21**	**4456.69**		

deposited in basinal settings have provided 5 percent of cumulative production. The basinal reservoirs are increasing in importance, however. During 2000, basinal reservoirs provided 19 percent of annual production from the New Mexico part of the Permian Basin, or more than three times the historical cumulative percentage.

Although long-term decline in oil production from southeastern New Mexico is perhaps inevitable, the play descriptions in this report document that a variety of techniques have been employed to successfully increase ultimate production from existing reservoirs. Management practices that have been successfully used to increase production from reservoirs are wide and varied and include enhanced recovery (waterflooding and possibly CO_2 flooding), early implementation of pressure maintenance, the targeting of bypassed pay that resides behind casing in older fields, the drilling of lateral and horizontal wells that tap unproduced reservoir compartments or bypassed/unswept oil, and the incomplete exploitation of stratigraphic traps that were initially developed on the premise of structural entrapment. In most of the plays discussed in this report, there is at least one well-documented example of a management technique or concept that that has been applied to an existing reservoir to increase production significantly from that reservoir. The presence of similar reservoirs within each play is suggestive that the management practices successfully applied to one reservoir within that play may have the potential to be successfully applied to other reservoirs within the play with the goal of producing oil that otherwise may remain unproduced. ***It is the premise of this research that techniques or concepts used to enhance or increase production in one reservoir in a play have the potential to increase production from***

other reservoirs in that same play and merit consideration for being applied to other reservoirs in the play. Application does not have to be limited to reservoirs that produced more than 1 MMBO, although incremental recovery will almost certainly be greater within the larger reservoirs.

Table IN-4. Cumulative and 2000 annual production of plays as a percentage of cumulative and annual production from all plays calculated for reservoirs with more than 1 MMBO cumulative production.

Play code	Play name	Age	Number reservoirs with > 1 MMBO production	Cumulative production from play as percent of total cumulative production from all plays	Annual production from play as percent of total annual production from all plays
132	Artesia Platform Sandstone	Guadalupian	38	13.2%	6.2%
130	Delaware Mountain Group Basinal Sandstone	Guadalupian	33	2.6%	12.0%
125	Upper San Andres & Grayburg Platform - Artesia Vacuum Trend	Guadalupian	13	17.9%	23.6%
124	Upper San Andres & Grayburg Platform - Central Basin Platform Trend	Guadalupian	8	18.2%	12.0%
120	Northwest Shelf San Andres Platform Carbonate	Guadalupian	13	2.1%	1.1%
118	Bone Spring Basinal Sandstone & Carbonate	Leonardian	16	1.6%	5.1%
117	Leonard Restricted Platform Carbonate	Leonardian	34	9.7%	12.8%
116	Abo Platform Carbonate	Leonardian	14	10.2%	7.6%
115	Wolfcamp/Leonard Slope & Basinal Carbonate	Wolfcampian	9	0.7%	1.4%
114	Wolfcamp Platform Carbonate	Wolfcampian	16	2.6%	1.2%
110	Northwest Shelf Upper Pennsylvanian Carbonate	Pennsylvanian	34	7.9%	10.1%
109	Northwest Shelf Strawn Patch Reef	Pennsylvanian	13	1.6%	3.2%
106	Devonian Thirtyone Deep Water Chert	Devonian	1	0.2%	0.1%
105	Wristen Buildups and Platform Carbonate	Silurian	36	8.3%	2.2%
104	Fusselman Shallow Platform Carbonate	Silurian	11	1.4%	0.5%
103	Simpson Cratonic Sandstone	Ordovician	3	0.5%	0.5%
102	Ellenburger Karst-Modified Restricted Ramp Carbonate	Ordovician	7	1.4%	0.2%
TOTALS			**299**	**100.0%**	**100.0%**

Table IN-5. Number of reservoirs and cumulative annual production of plays as a function of depositional setting.

Depositional setting of play	Number of plays	Number reservoirs with > 1 MMBO production	2000 annual production (MMBO)	Cumulative production (MMBO)
Shelf/platform/ramp plays	13	249	39.21	4230.56
Basinal plays	4	50	9.00	226.13

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STRATIGRAPHY

The following stratigraphic charts (Figs. ST-1, ST-2) summarize the stratigraphy in the basin and also place the plays discussed in this report in a stratigraphic framework. Within the New Mexico part of the Permian Basin, the stratigraphy in the Delaware Basin differs from the stratigraphy on the Northwest Shelf and on the Central Basin Platform (Figs. ST-1, ST-2). Detailed stratigraphic columns are presented in the play descriptions for selected plays that produce from stratigraphically complicated reservoirs.

PLAY DESCRIPTIONS

Descriptions of the 17 plays present in the New Mexico part of the Permian Basin follow. Each play description contains a location map of the play boundary and reservoirs in the play that have produced more than 1 MMBO. In addition, the descriptions contain a table that lists the reservoirs, discovery dates and depths of the reservoirs, the cumulative oil production of the reservoir during 2000 and the cumulative oil production of each reservoir through the end of 2000. Other illustrations included are a curve of annual oil production from the 1 MMBO reservoirs from 1970 until 2000 and various figures that explain the geology and/or stratigraphy of the play, trapping mechanisms, and advanced management techniques that have enhanced production from reservoirs within the play. The text discussion concentrates on an overview of the petroleum geology of the play, history of play development and, where appropriate, advanced management techniques that have enhanced production from reservoirs in the play. A list of basic references is given for each play. The plays are presented in reverse stratigraphic order, with the stratigraphically youngest plays presented first.

The play boundary maps contain the locations of several geologic elements: the Abo shelf edge, the Wolfcamp shelf margin, the Capitan reef trend, and the deg of the Central basin platform. The location of the Abo shelf edge is modified from LeMay (1960). The location of the Wolfcamp shelf margin is from Malek-Aslani (1970). The Capitan reef trend is from Hiss (1975) and Garber et al. (1989). The location of the edge of the Central Basin Platform is adapted from Haigler and Cunningham (1972) and Stipp and Haigler (1957).

Each play description is accompanied by a data table that lists, among other parameters, the discovery year and depth to production for each reservoir. Sources of data for discovery year and depth to production were mainly the magnificent oil and gas field summaries published by the Roswell Geological Society (Roswell Geological Society, 1956, 1960, 1967, 1977, 1988, 1995). For a large number of reservoirs, data was not available in the Roswell Geological Society volumes; in these cases, well completion records and state regulatory orders available at the new Mexico Bureau of Geology and Mineral Resources were examined to determine discovery year and depth to production.

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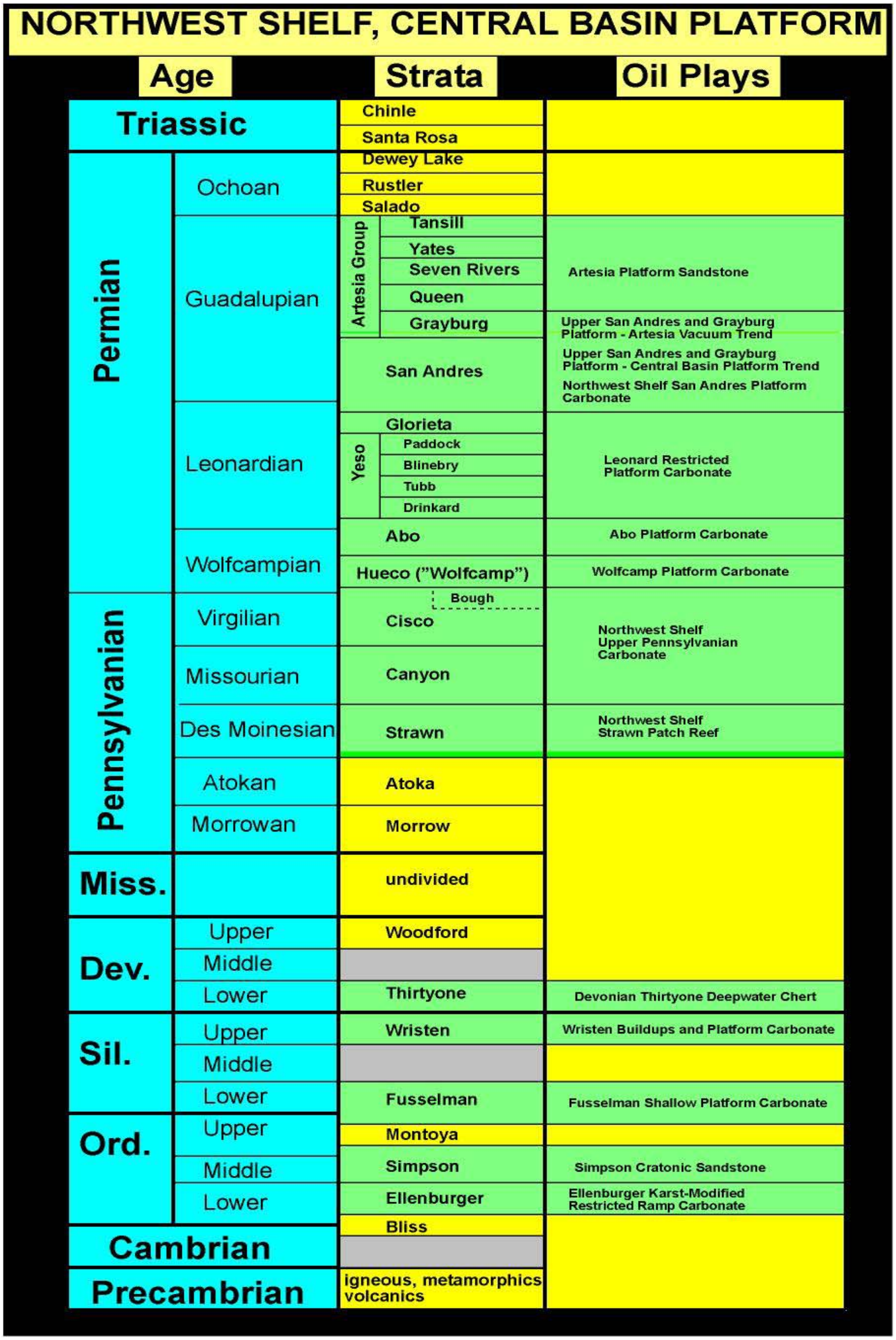

Figure ST-1. Stratigraphic chart for the Northwest Shelf and the Central Basin Platform. Plays that are present on the Northwest Shelf and Central Basin Platform are listed next to their appropriate stratigraphic units.

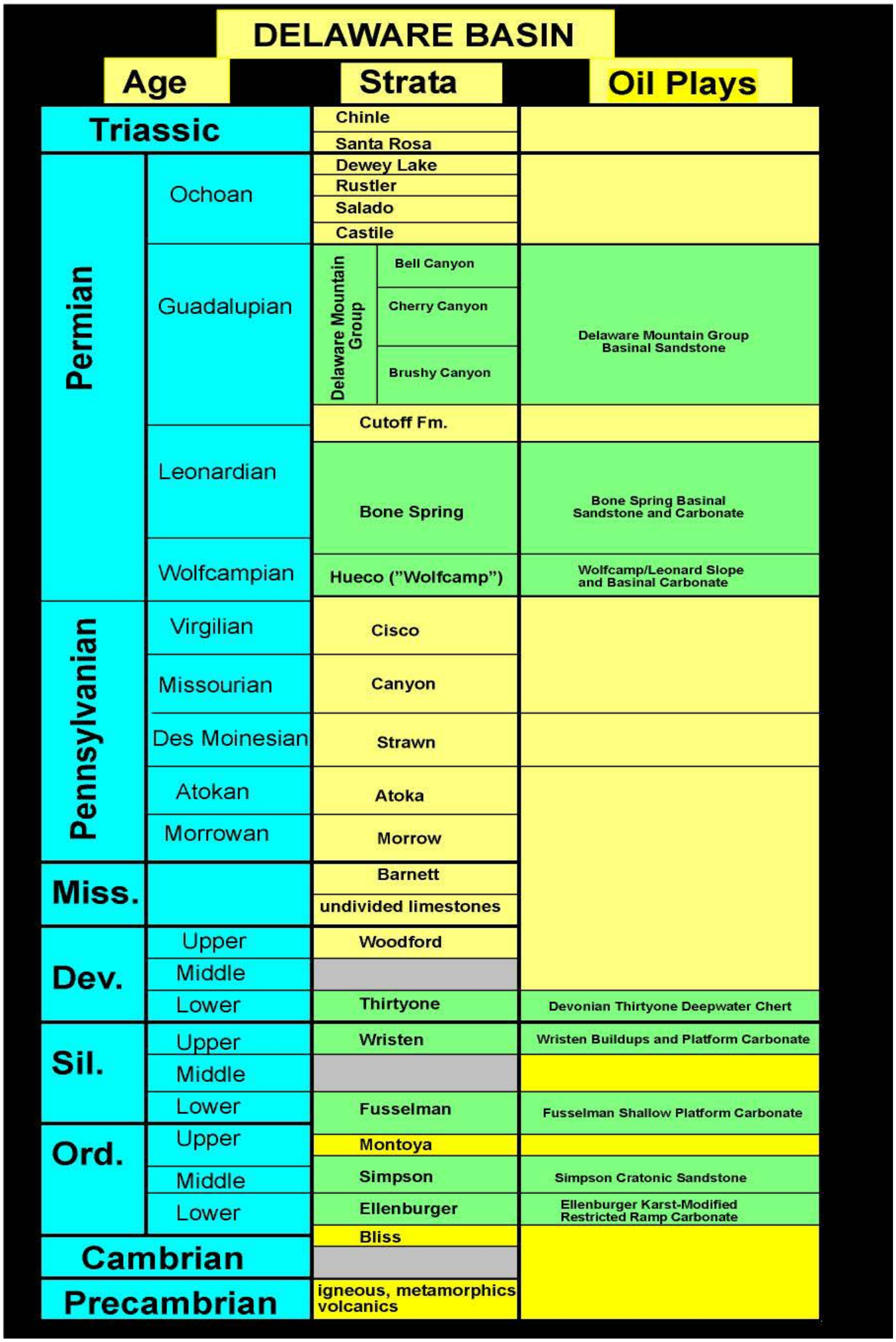

Figure ST-2. Stratigraphic chart for the Delaware Basin. Plays that are present on the Delaware Basin are listed next to their appropriate stratigraphic units.

Play 132 - Artesia Platform Sandstone Play

Reservoirs of the Artesia Platform sandstone play are stretched across the Northwest Shelf of the Permian Basin and across the western flank of the Central Basin Platform (Fig. 132-1). There are 170 known, discovered Artesia Platform Sandstone reservoirs within New Mexico, 38 of which have produced more than 1 MMBO (Table 132-1). Cumulative production from these 38 reservoirs was 587 MMBO as of 2000. Annual production from these 38 reservoirs was 2.98 MMBO during 2000. This play has been in gradual decline over the past 30 years (Fig. 132-2).

Reservoirs are sandstones in the Artesia Group (Permian: Guadalupian). The Artesia Group is subdivided into five formations (descending; Fig. 132-3): Tansill, Yates, Seven Rivers, Queen, and Grayburg. Principal productive sandstones are in the Yates and Queen Formations, although sandstones of the Seven Rivers Formation provide significant production in some reservoirs. Reservoirs that produce principally from the Grayburg Formation are considered to be part of the *San Andres and Grayburg Mixed Clastic/Carbonate plays* (Plays 124, 125). Dolostones of the Queen, Seven Rivers, Yates, and Tansill Formations form secondary reservoirs. Production from the dolostones is generally commingled with production from the more prolific sandstones in many reservoirs.

Reservoirs productive solely from Queen sandstones occur along and north of a trend that extends from Hobbs to Artesia (Fig. 132-1). The Queen sandstones were deposited in coastal sandy braided streams, fluvial sand flats and fluvial-dominated coastal sabkhas, and poorly channelized sheet deltas that filled in lagoonal areas (Mazzullo, 1992). Traps are largely stratigraphic, with porosity plugged in an updip direction by evaporates (Ward et al., 1986; Malisce and Mazzullo, 1990). Productive Queen sandstones are fine to medium grained; average reservoir porosities range from 17 to 22 percent.

Productive Yates sandstones are poorly consolidated, silty, and fine grained with porosities of 15 to 28 percent (Borer and Harris, 1991a, 1991b). Clean productive sandstones are interbedded with argillaceous sandstones that form poor reservoirs. The sandstones occur in a clastic-rich belt on the middle shelf that separates an evaporitic inner shelf to the north from a carbonate-rich outer shelf to the south. Depositional processes that formed the reservoir sandstones are poorly understood (Borer and Harris, 1991a). Traps are largely stratigraphic with an updip seal formed by evaporitic facies of the inner shelf.

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Table 132-1. Reservoirs in the Artesia Platform Sandstone play that had produced 1 MMBO as of the end of 2000. **Reservoir unit (NMOCD)** is the stratigraphic unit from which production is obtained, as designated by the New Mexico Oil Conservation Division. **O/G** indicates whether the reservoir is designated as an oil(O) reservoir or as a gas (G) reservoir. Cumulative production is through the end of 2000.

Reservoir Name	Reservoir Unit (NMOCD)	County	Discovery Year	Depth (feet)	O/G	2000 oil production (MMBO)	Cumulative production (MMBO)
Barber	Yates	Eddy	1937	1442	O	<0.01	1.97
Benson North	Queen Grayburg	Eddy	1954	2844	O	0.02	3.47
Bowers	Seven Rivers	Lea	1935	3553	O	0.01	4.23
Caprock	Queen	Chaves & Lea	1940	3030	O	0.02	74.21
Corbin	Queen	Lea	1938	4258	O	<0.01	1.55
Corbin Central	Queen	Lea	1985	4228	O	0.03	1.09
Dollarhide	Queen	Lea	1952	3670	O	0.04	6.74
Dos Hermanos	Yates	Eddy	1955	1631	O	<0.01	1.61

	Seven Rivers						
Double L	Queen	Chaves	1969	1980	O	0.01	3.51
E-K	Yates Seven Rivers Queen	Lea	1954	4387 (Queen)	O	0.17	6.56
E-K East	Queen	Lea	1957	4387	O	0.01	1.32
Empire	Yates Seven Rivers	Eddy	1926	1600	O	0.01	1.29
Eumont	Yates Seven Rivers Queen	Lea	1929	2950	O&G	0.34	75.07
Eunice South	Seven Rivers Queen	Lea	1930	3610	O	0.01	32.42
Fren	Seven Rivers	Eddy	1943	1940	O	0.00[1]	6.68
Getty	Yates	Eddy	1927	1343	O	0.00	1.82
Hackberry North	Yates Seven Rivers	Eddy	1959	2047	O	0.02	3.47
High Lonesome	Queen	Eddy	1939	1800	O	0.01	4.61
Hume	Queen	Lea	1956	3950	O	0.00	1.39
Jalmat	Tansill Yates Seven Rivers	Lea	1928	2800	O&G	0.40	77.34
Langlie Mattix	Seven Rivers Queen Grayburg	Lea	1935	2852	O	0.73	136.87
Leonard South	Queen	Lea	1948	3400	O	<0.01	2.10
Lynch	Yates Seven Rivers	Lea	1929	3730	O	0.08	15.94
Mesa	Queen	Lea	1962	3350	O	<0.01	1.70
Millman East	Queen Grayburg San Andres	Eddy	1959	2413	O	0.21	8.31
Pearl	Queen	Lea	1955	4830	O	0.11	22.41
Pearsall	Queen	Lea	1940	3685	O	0.02	2.97
Querecho Plains	Queen	Lea	1972	3910	O	0.04	1.29
Red Lake East	Queen Grayburg	Eddy	1960	1560	O	0.01	1.44
Rhodes	Yates Seven Rivers	Lea	1927	3040	O&G	0.03	14.23
Scarborough	Yates Seven Rivers	Lea	1929	3050	O	0.01	17.44
Shugart	Yates Seven Rivers Queen Grayburg	Eddy	1937	3440	O	0.39	28.51
Sulimar	Queen	Chaves	1968	1960	O	0.01	2.33
Teas	Yates Seven Rivers	Lea	1929	3343	O	0.05	3.56
Teas West	Yates Seven Rivers	Lea	1959	3225	O	0.07	1.97
Turkey Track	Seven Rivers Queen Grayburg San Andres	Eddy	1950	1655	O	0.05	3.89
Wilson	Yates Seven Rivers	Lea	1928	3815	O	<0.01	9.30
Young	Queen	Lea	1945	3765	O	0.06	2.37
TOTALS						**2.98**	**586.97**

[1] Production from Fren Seven Rivers reservoir included with production from the Grayburg Jackson Seven Rivers Queen Grayburg San Andres reservoir (Play 125) after 1996, so annual production for 2000 is shown as 0 in this report. By 1996, annual oil production from the Fren reservoir was only 49,357 bbls from 82 active wells that were active at the end of 1996.

Artesia Platform Sandstone Play

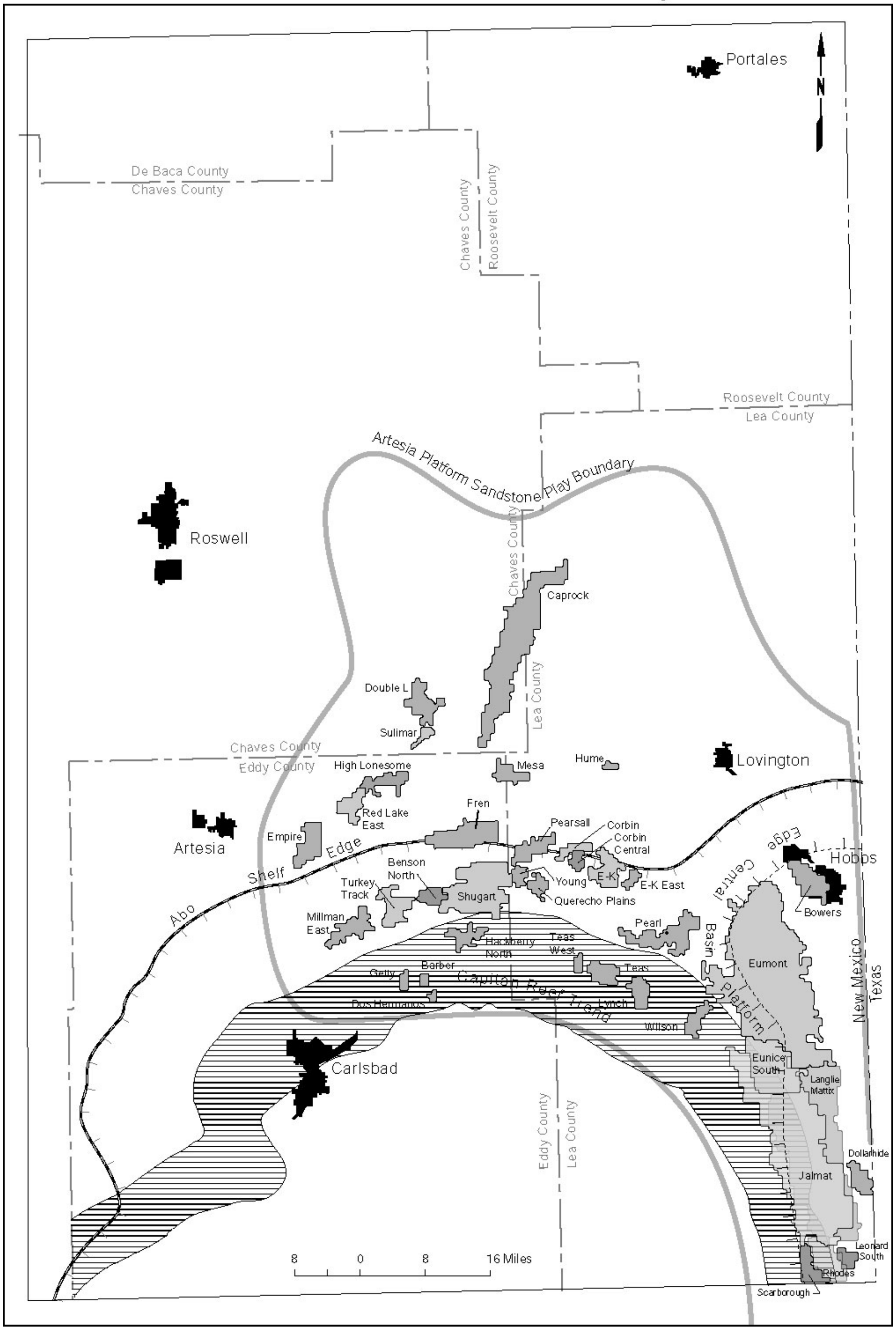

Figure 132-1. Location of reservoirs with more than 1 MMBO cumulative production in the New Mexico part of the Artesia Platform Sandstone play.

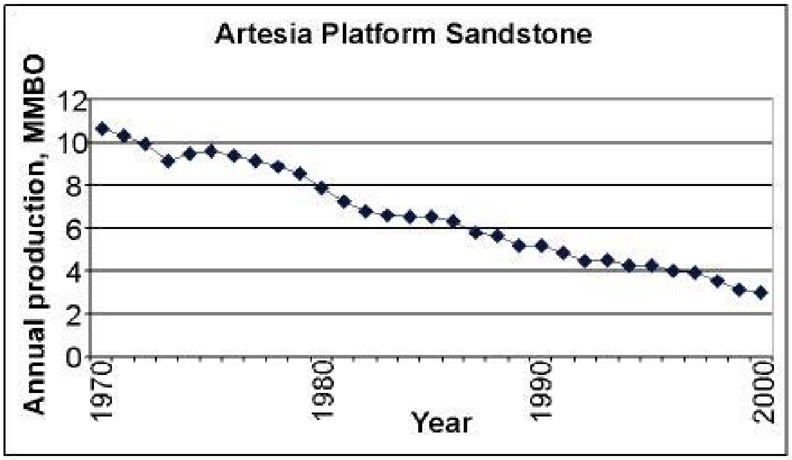

Figure 132-2. Historical annual production in southeast New Mexico from 1970 to 2000 from reservoirs with more than 1 MMBO cumulative production in the Artesia Platform sandstone play.

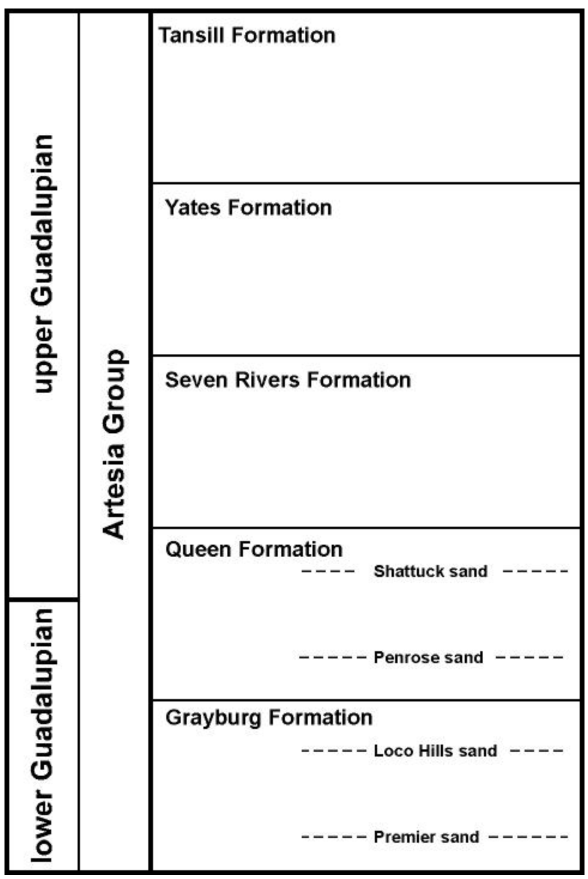

Figure 132-3. Stratigraphic column of Guadalupian Artesia Group, Central Basin Platform and Northwest Shelf. Major, named productive sandstones in the Queen and Grayburg Formations are indicated.

Play 130 - Delaware Mountain Group Basinal Sandstone Play

Reservoirs of the Delaware Mountain Group Basinal Sandstone play lie within the Delaware Basin and stretch from the northern part of the basin in Eddy and Lea Counties, New Mexico (Fig. 130-1) into Texas. There are 155 known discovered Delaware sandstone reservoirs in New Mexico, 33 of which have produced more than 1 MMBO (Table 130-1). Cumulative production from these 33 reservoirs was 115 MMBO as of 2000. The play is currently in decline with production in the New Mexico part of the play having decreased 24 percent from 7.6 MMBO per year during 1997 to just under 5.8 MMBO per year during 2000 (Fig. 130-2).

Reservoirs are submarine fan sandstones in the Delaware Mountain Group (Permian: Guadalupian). The Delaware Mountain Group is subdivided into three formations (descending; Fig. 130-3): Bell Canyon Formation, Cherry Canyon Formation, and Brushy Canyon Formation. The reservoir sandstones were deposited by turbidity currents and density flows in channels and on the lobes of submarine fans (Jacka, 1979; Harms and Williamson, 1988). Bell Canyon and Cherry Canyon reservoirs are formed mostly by channel-shaped sands (Meissner, 1972; Berg, 1975; Jacka, 1979; Harms and Williamson, 1988; Montgomery et al., 2000). Brushy Canyon reservoirs are formed by channel-shaped sands and sands deposited on fan lobes (Fig. 130-4; May, 1996; Broadhead et al, 1998; Montgomery et al., 1999). Traps are predominantly stratigraphic. Reservoir sandstones are complexly interbedded with non-reservoir siltstones and lower-permeability sandstones. Reservoir sandstones may also exhibit complex lateral relationships with non-reservoir facies. As a result, production is typically obtained from multiple separate sandstone layers within a single reservoir. Reservoirs are thought to have no single oil-water contact but rather have multiple oil-water contacts within a single complex reservoir (Montgomery et al., 1999).

Development of the Delaware Mountain Group Basinal Sandstone play began with the shallowest reservoirs. It is only within the last 15 years that exploration and development has concentrated on the deeper zones. Bell Canyon reservoirs lie at depths of 2500 to 5000 ft in the New Mexico part of the Delaware Basin. Cherry Canyon reservoirs lie at depths of 3000 to 6000 ft. Brushy Canyon reservoirs lie at depths of 6000 to 8500 ft. Most Bell Canyon reservoirs were discovered prior to 1970. The dramatic increase in production from the play during the early 1990’s (Fig. 130-2) resulted from the discovery and development of deeper reservoirs, primarily in the Brushy Canyon but also in the Cherry Canyon.

Delaware sandstone reservoirs produce via solution gas drive. Initial production may typically exceed 2500 bbls per month in a well, but will rapidly decline to a few hundred bbls a month (or less) after four years (Fig. 130-5) as the solution gas is produced and reservoir pressures decrease below the bubble point. Only about 10 percent of the original oil in place is thought to be recovered through primary production (Montgomery et al. (1999). Injection of produced water for pressure maintenance can yield a good production response in some reservoirs (Fig. 130-6). Pressure maintenance should be initiated early so that a secondary gas cap is not allowed to form (Mark Murphy, personal communication, 2003).

Waterflooding of selected Delaware sandstone reservoirs has yielded good results with secondary recovery reserves equal to as much as 80 percent of primary recovery reserves in some cases (Fig. 130-7). Again, for optimum efficiency, water injection should ideally commence before reservoir pressures decline to the point where a secondary gas cap is formed. The more proximal upper Brushy Canyon and lower Cherry Canyon reservoirs are thought to have less lateral sandstone heterogeneity than other reservoirs in the Brushy Canyon and Cherry Canyon and may be more favorable to waterflooding (Montgomery et al., 1999). In other more heterogeneous, more distal Delaware reservoirs with complex internal sandstone distributions and lower permeability, gas injection may be required for optimum pressure maintenance and carbon dioxide flooding may be needed for enhanced recovery (Montgomery et al., 1999); carbon dioxide flooding has been successful in Twofreds and other reservoirs in the Texas part of the Delaware Basin (see Kirkpatrick and others, 1985; Flanders and DePauw, 1993; Pittaway and Rosato, 1991; Dutton and others, 2003).

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Table 130-1. Reservoirs in the Delaware Mountain Group Basinal Sandstone play that had produced 1 MMBO as of the end of 2000. **Reservoir unit (NMOCD)** is the stratigraphic unit from which production is obtained, as designated by the New Mexico Oil Conservation Division. **O/G** indicates whether the reservoir is designated as an oil (O) reservoir or as a gas (G) reservoir. Cumulative production is through the end of 2000.

Reservoir Name	Reservoir Unit (NMOCD)	County	Discovery Year	Depth (feet)	O/G	2000 oil production (MMBO)	Cumulative production (MMBO)	Productive formations
Avalon	Delaware	Eddy	1980	2550	O	0.25	4.95	Bell Canyon Cherry Canyon Brushy Canyon
Brushy Draw	Delaware	Eddy	1958	3200	O	0.22	6.97	Bell Canyon Cherry Canyon
Cabin Lake	Delaware	Eddy	1987	5625	O	0.18	3.80	Brushy Canyon Cherry Canyon
Catclaw Draw East	Delaware	Eddy	1990	3074	O	0.08	1.22	Brushy Canyon Bell Canyon Cherry Canyon
Cedar Canyon	Delaware	Eddy	1976	5200	O	0.18	1.01	Cherry Canyon Brushy Canyon
Corbin West	Delaware	Lea	1976	5030	O	0.11	2.75	Bell Canyon Brushy Canyon
Cruz	Delaware	Lea	1961	5081	O	0.0008	1.03	Bell Canyon
Double X	Delaware	Lea	1961	4914	O	0.01	1.40	Bell Canyon
El Mar	Delaware	Lea	1959	4550	O	0.03	6.26	Brushy Canyon
Esperanza	Delaware	Eddy	1969	3400	O	0.03	1.27	Bell Canyon Cherry Canyon
Hat Mesa	Delaware	Lea	1989	6834	O	0.26	1.98	Brushy Canyon Cherry Canyon
Herradura Bend	Delaware	Eddy	1977	2460	O	0.03	1.01	Bell Canyon
Herradura Bend East	Delaware	Eddy	1985	6062	O	0.11	1.56	Brushy Canyon
Indian Draw	Delaware	Eddy	1973	3262	O	0.05	3.32	Cherry Canyon
Ingle Wells	Delaware	Eddy	1989	8100	O	0.67	7.46	Brushy Canyon
Lea Northeast	Delaware	Lea	1988	5658	O	0.44	4.00	Cherry Canyon Brushy Canyon
Livingston Ridge	Delaware	Eddy	1989	7091	O	0.36	5.16	Brushy Canyon Cherry Canyon
Livingston Ridge East	Delaware	Lea	1992	7200	O	0.10	1.99	Brushy Canyon Cherry Canyon
Los Medanos	Delaware	Eddy	1990	7825	O	0.18	2.89	Brushy Canyon
Lost Tank	Delaware	Eddy & Lea	1991	6783	O	0.17	2.69	Brushy Canyon Cherry Canyon
Loving East	Brushy Canyon	Eddy	1987	6050	O	0.31	7.07	Brushy Canyon

Lusk West	Delaware	Lea	1987	6450	O	0.16	2.75	Brushy Canyon Cherry Canyon
Malaga	Delaware	Eddy	1951	2770	O	0.01	1.01	Bell Canyon Cherry Canyon Brushy Canyon
Mason East	Delaware	Lea	1962	4370	O	0.02	1.43	Bell Canyon
Mason North	Delaware	Eddy & Lea	1954	4115	O	0.04	4.74	Bell Canyon, Cherry Canyon
Nash Draw	Brushy Canyon	Eddy	1992	6713	O	0.28	1.78	Brushy Canyon
Paduca	Delaware	Lea	1960	4636	O	0.03	13.92	Bell Canyon
Parkway	Delaware	Eddy	1988	4135	O	0.39	3.31	Cherry Canyon Brushy Canyon
Red Tank West	Delaware	Lea	1992	8330	O	0.67	4.87	Brushy Canyon
Sand Dunes	Cherry Canyon	Eddy	1970	6020	O	0.01	1.08	Cherry Canyon
Sand Dunes West	Delaware	Eddy	1992	7820	O	0.32	5.94	Brushy Canyon
Shugart	Delaware	Eddy	1958	4970	O	0.02	1.64	Cherry Canyon
Shugart East	Delaware	Lea	1985	5012	O	0.05	2.31	Cherry Canyon Brushy Canyon
TOTALS						**5.78**	**114.56**	

Delaware Mountain Group Basinal Sandstone Play

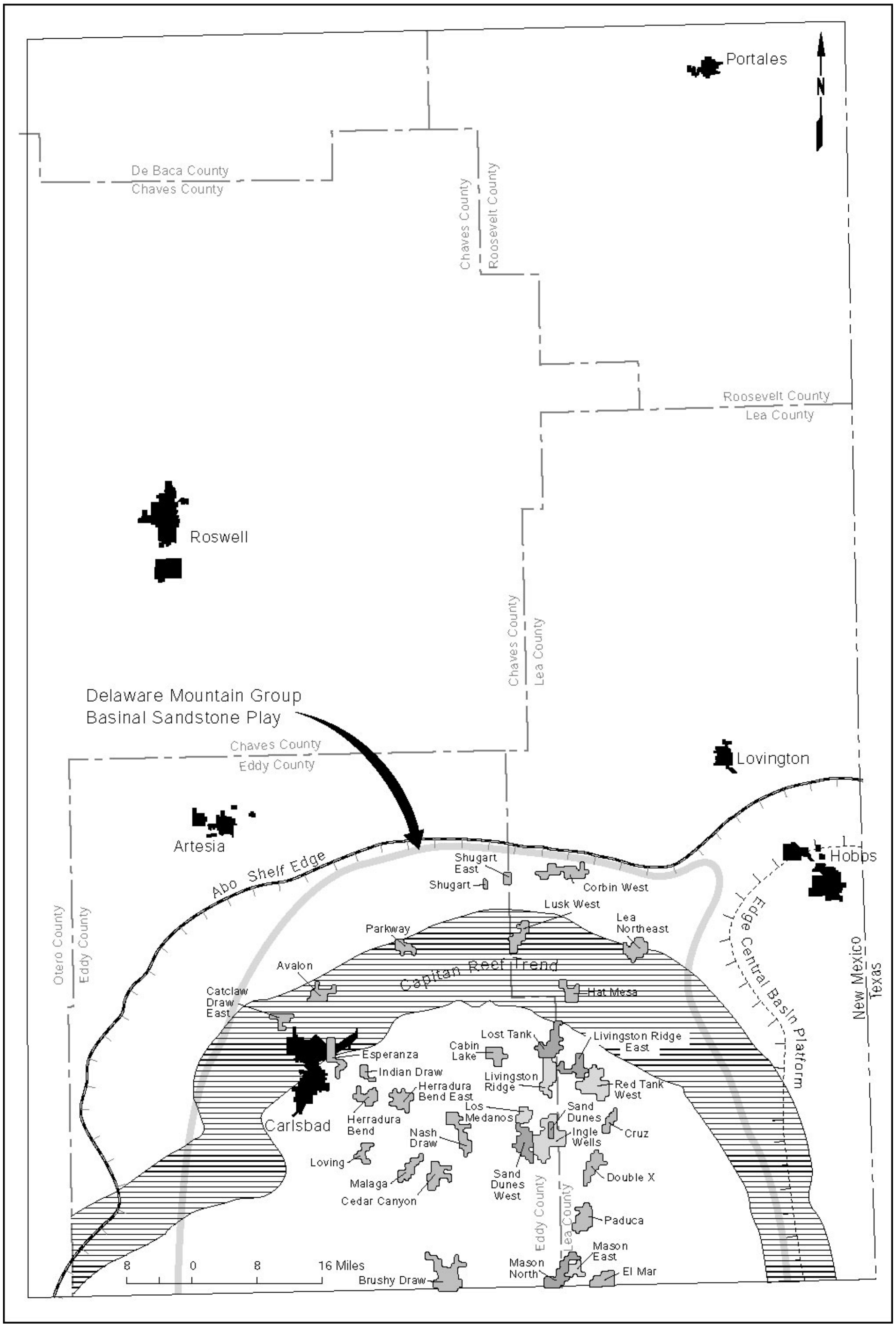

Figure 130-1. Location of reservoirs with more than 1 MMBO cumulative production in the New Mexico part of the Delaware Mountain Group Basinal Sandstone play.

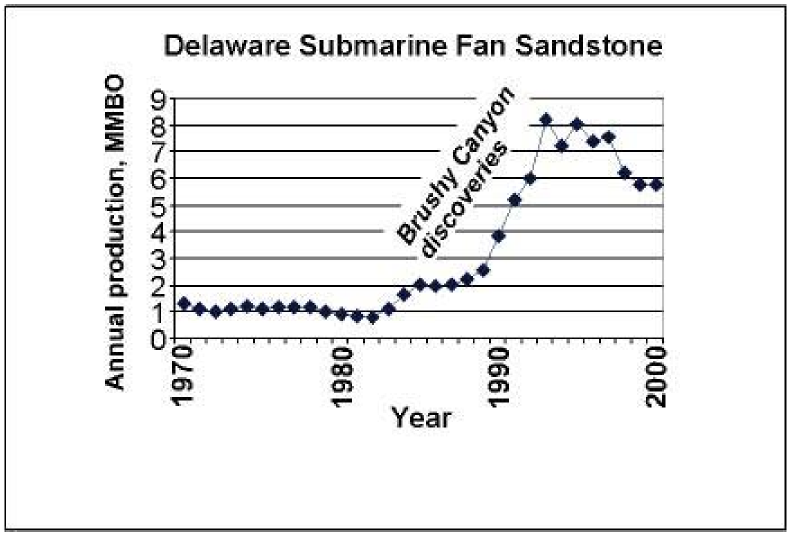

Figure 130-2. Historical annual production from 1970 to 2000 from reservoirs with more than 1 MMBO cumulative production in the Delaware Mountain Group Basinal Sandstone play.

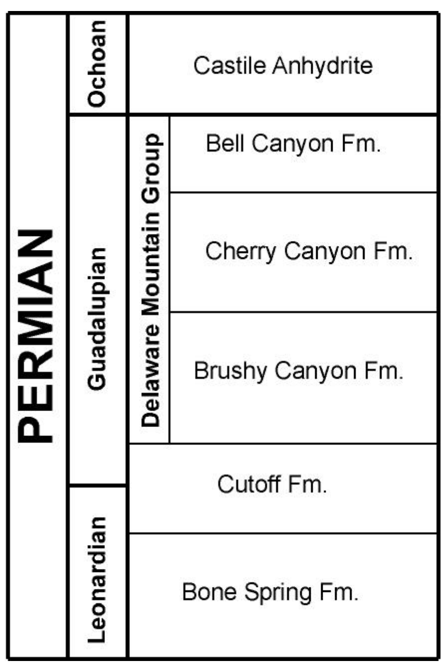

Figure 130-3. Stratigraphic chart of Delaware Mountain Group, Delaware Basin. Compiled from Payne (1976), Grauten (1979), Harms and Williamson (1988), Beaubouef et al. (1999).

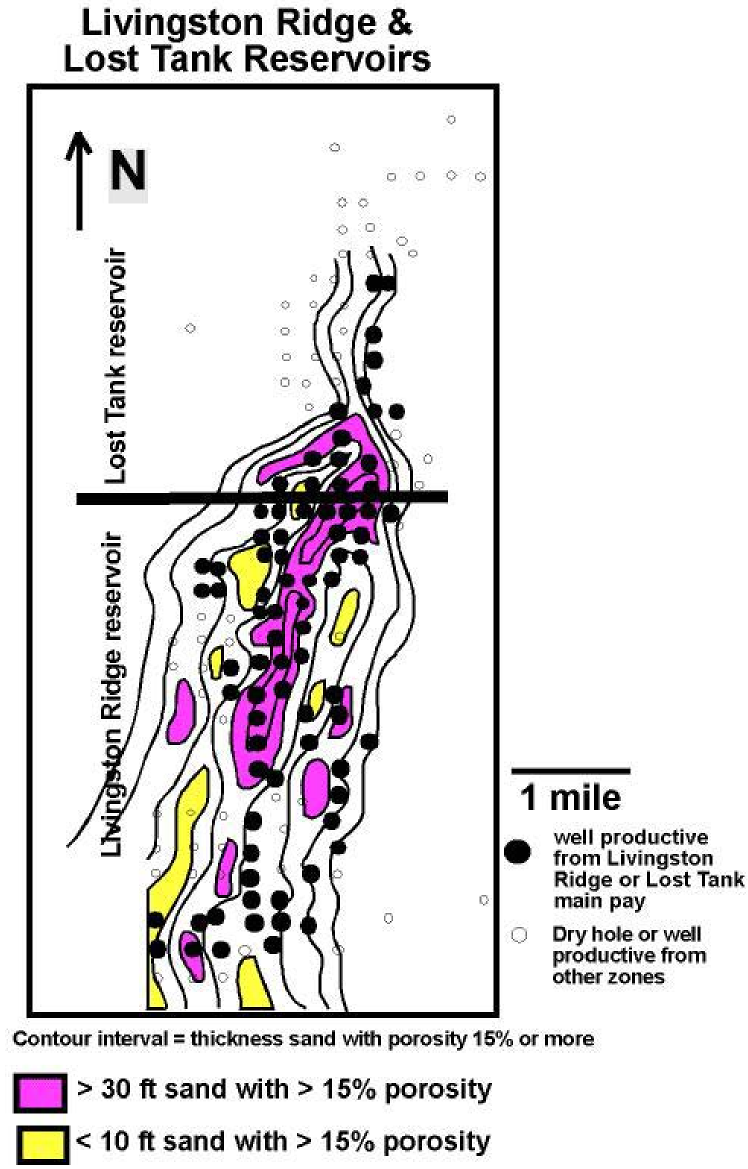

Figure 130-4. Net thickness of sandstone with porosity greater than or equal to 15 percent in the main pay zone at the Livingston Ridge and Lost Tank reservoirs. After May (1996).

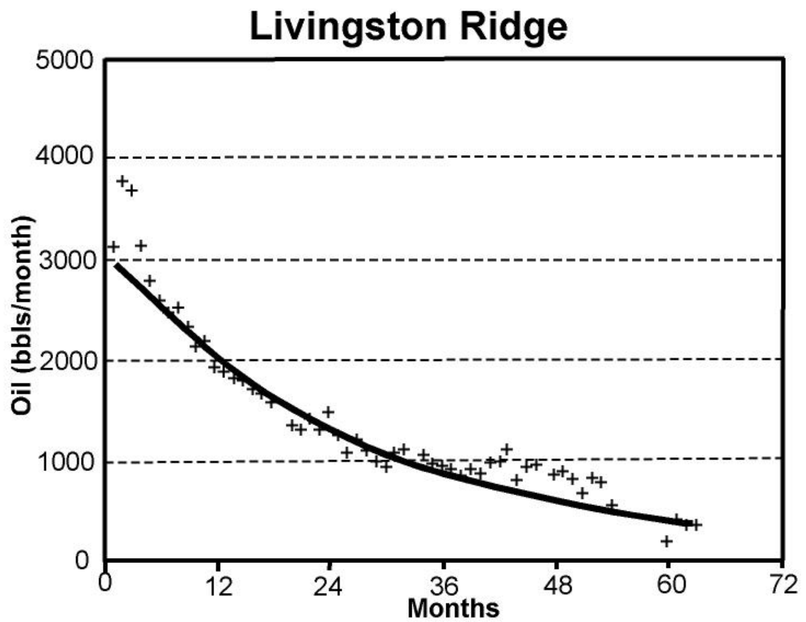

Figure 130-5. Average production decline curve for wells productive from Livingston Ridge main pay, Livingston Ridge and Lost Tank reservoirs. From Broadhead et al. (1998).

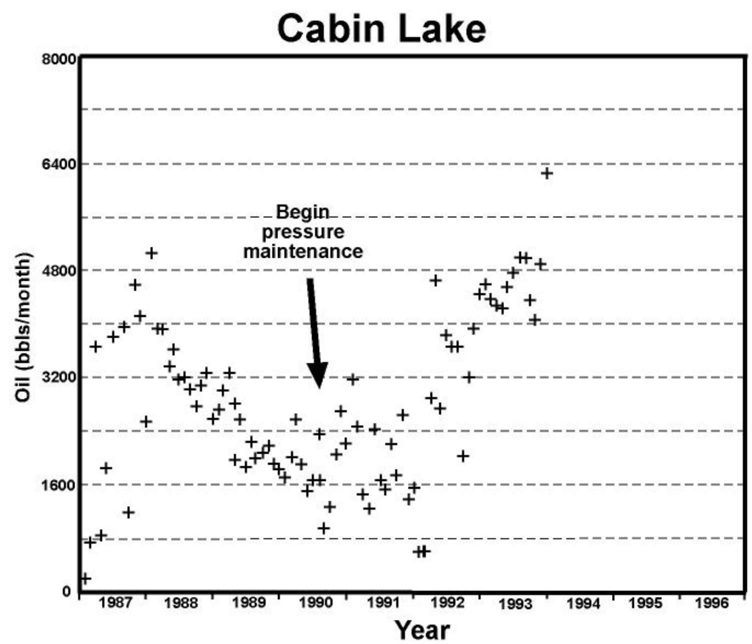

Figure 130-6. Historical monthly production of oil, Phillips Petroleum Company No. 2 James A well, Cabin Lake reservoir. Note the increase in production as a result of water injection for the purpose of pressure maintenance. After Broadhead et al. (1998).

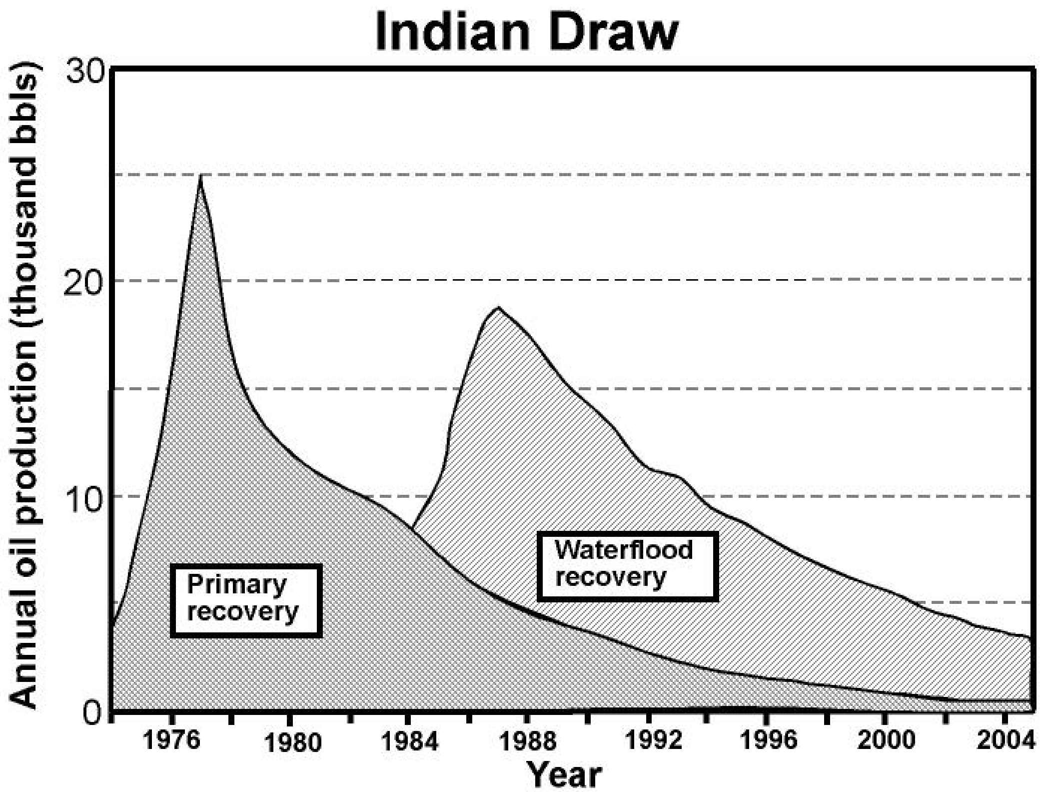

Figure 130-7. Annual production history of the Indian Draw Delaware reservoir, with production curves for primary and secondary (waterflood) recovery, and estimated oil recovery by primary and secondary means. This reservoir is productive from the Cherry Canyon Formation of the Delaware Mountain Group. From Broadhead et al. (1998).

Play 125 - Upper San Andres and Grayburg Platform Mixed-Artesia Vacuum Trend Play

Reservoirs of the Upper San Andres and Grayburg Platform Mixed-Artesia Vacuum Trend play extend in an east-west direction from the city of Artesia to Hobbs in Eddy and Lea Counties, New Mexico (Fig.125-1). The play contains thirteen reservoirs with more than 1 MMBO cumulative production. Cumulative production from these 13 reservoirs was 796 MMBO as of 2000. Production in most reservoirs is commingled from the San Andres and Grayburg Formations (Permian: Leonardian to Guadalupian). Depths to the top of reservoirs range from 1290 to 4700 ft. This is a mature play, especially within the highly productive San Andres carbonates. Production from this play reached a modern peak of more than 18 MMBO per year in the 1980's (Fig. 125-2), mostly as a result of waterflooding the Vacuum reservoir (Fig. 125-3). Recent development of lower permeability Grayburg sandstones in the Grayburg Jackson reservoir during the mid-1990's has been successful to the point of reversing production decline (Figs. 125-2 and 125-4) and is a major focus of current and future development.

The upper San Andres Formation is composed of restricted, backreef dolowackestones, dolopackstones, and dolograinstones (Ward et al., 1986; Purves, 1990). Production in the San Andres is obtained principally from dolostones. Reservoir facies lie between the Guadalupian (Goat Seep) shelf margin to the south and tight evaporites and dolomites of inner shelf and lagoonal environments to the north. The San Andres Formation of the Northwest Shelf is composed of numerous, high-frequency, upward-shoaling carbonate depositional cycles (Purves, 1986; Modica and Dorobek, 1996; Handford et al., 1996; Stoudt and Raines, 2001, Pranter et al., 2004). Cycles consist of permeable subtidal carbonates that are capped by low-permeability peritidal carbonates that vertically compartmentalize the reservoir. Reservoir zones in the San Andres exhibit lateral as well as vertical variation in permeability (Hinrichs et al., 1986).

The Grayburg Formation consists of interbedded sandstones, siltstones, dolomitic carbonates, and evaporites (Handford et al., 1996; Modica and Dorobek, 1996). Production in the Grayburg is obtained largely from sandstones. The sandstones were deposited in coastal, sabka, sandflat, and eolian environments and are the principal reservoirs. The carbonates are subtidal deposits and are generally impermeable. Pores are often plugged by anhydrite.

Reservoirs in this play lie along the Artesia-Vacuum arch. The Artesia-Vacuum arch is a shallow east-west trending structure that overlies the deeper, older Abo shelf edge reef trend and Bone Spring flexure (Broadhead, 1993). Traps are combination structural and stratigraphic, with the Artesia-Vacuum arch providing the structural element. The position of the reservoir with respect to the axis of the Artesia-Vacuum arch dictates whether the Grayburg Formation or the upper part of the San Andres Formation is more productive. Those reservoirs located along the crest (e.g. Maljamar, Vacuum, Grayburg-Jackson) have sufficient structural elevation for the Grayburg and upper San Andres Formations to be in the oil zone, while on the flanks of the structure the San Andres is wet and only the overlying Grayburg is in the regional oil leg. Exact location of some reservoirs is influenced by local structures that may be oriented at an angle to the regional shelf edge (see Purves, 1990). Updip (northerly) porosity pinchouts into tight evaporitic lagoonal facies create the stratigraphic trapping component (Ward et al., 1986). The regional vertical seal is formed by impermeable strata within the overlying upper Grayburg and Queen Formations. Solution gas drive is the primary production mechanism.

The Vacuum San Andres reservoir exhibits complex internal vertical and horizontal segmentation of flow units. As described above, the reservoir is vertically compartmentalized by upward shoaling carbonate cycles. The reservoir is divided into horizontal compartments by numerous high-angle, low-displacement faults (Pranter et al., 2004). Although vertical throw of the faults is less than 25 ft in most cases, it is sufficient to isolate thin permeable beds across the faults, which act as horizontal seals. In addition, significant karsting and development of dissolution features, caves, and solution collapse structures are associated with intraformational sequence boundaries, especially at the prominent sequence boundary that separates the upper part of the San Andres from the lower part of the San Andres (Stoudt and Raines, 2001; Pranter et al., 2004). Although karst development may have enhanced porosity and permeability in some San Andres reservoirs (for example see Hovorka et al., 1993), karst pore systems at Vacuum are filled with impermeable sandstone, collapsed carbonates, or evaporites and act to further compartmentalize the reservoir both vertically and horizontally (Stoudt and Raines, 2001; Pranter et al., 2004). Similarly, destruction of karst-related porosity by anhydrite cementation has been described in the Maljamar reservoir of this play (Modica and Dorobek, 1996). The complex horizontal and vertical compartmentalization of flow units that formed as a result of cyclic deposition of permeable and impermeable facies, faults, and destruction of karst-derived porosity by sand and evaporite plugging as well as solution collapse make full development of reservoirs incomplete with vertical wells drilled on standard 40-acre spacing.

Enhanced recovery techniques have been successful in reservoirs of the Upper San Andres and Grayburg Platform Mixed- Artesia Vacuum Trend Play. Many of the reservoirs in this play have been successfully waterflooded. CO_2 flooding has been employed in portions of the Vacuum reservoir with positive results (Pranter et al., 2004). The presence of complex systems of internal reservoir compartments has resulted in parts of the reservoir being unswept by enhanced recovery operations.

There is significant potential for enhancing production from San Andres carbonates by drilling horizontal laterals from existing vertical wellbores, as has been done by Texaco (now Chevron-Texaco) at the Vacuum reservoir (Pranter et al., 2004). Development of this reservoir, discovered in 1929, is considered mature. Large parts of it have been waterflooded and, as mentioned above, a successful CO_2 flood has been employed in part of the reservoir. Although these enhanced recovery methods have increased production substantially, vertical and horizontal compartmentalization has resulted in significant bypassed pay that has not been drained adequately by vertical wells or completely swept during enhanced recovery. Fault block boundaries and bypassed pay zones have been identified by a combination of 3D seismic surveys and well data (Pranter et al., 2004). Horizontal laterals aimed at intersecting undrained pay were drilled from an existing vertical well and resulted in an increase in production of approximately 20-fold compared to what the pre-existing vertical well yielded (Pranter et al., 2004). Production from existing vertical offset wells was not affected by the newer lateral wells, indicating that the lateral wells penetrated untapped reservoir compartments. Rather than drill the horizontal laterals as flat segments, they were drilled in a serpentine pattern so that multiple vertical reservoir compartments are penetrated by a single wellbore.

Another recent example of a development practice that significantly enhances production is derived from Burnett Oil Company’s lease in Section 13 T17S R30E in the Grayburg-Jackson reservoir (Brian Brister, Personal Communication, 2003). This area is located along the crest of the Artesia-Vacuum arch and has a sufficiently high structural elevation so that the karsted, highly permeable Jackson zone of the San Andres reservoir is above the oil-water contact. Production in the Grayburg-Jackson reservoir was obtained mostly from dolostones in the San Andres from the 1920's until the mid-1990's when these wells were recompleted in Grayburg sandstones. Open-hole logs had never been run in the older wells and the Grayburg was located behind casing. Neutron logs failed to definitively indicate Grayburg pay zones behind casing because of high gas saturations in reservoir zones. Locations of Grayburg pay zones were inferred from regional correlations. Grayburg recompletions targeted the inferred zones. This methodology resulted in significantly increased levels of both gas and oil production (Fig 125-5). Current development practices of completing Grayburg pay separately from San Andres pay will limit production to a more homogenous reservoir than with commingled Grayburg-San Andres completions. One result may be more uniform flooding and improved recovery if enhanced recovery is employed.

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Table 125-1. Reservoirs in the Upper San Andres and Grayburg Platform Artesia Vacuum Trend play that had produced 1 MMBO as of the end of 2000. **Reservoir unit (NMOCD)** is the stratigraphic unit from which production is obtained, as designated by the New Mexico Oil Conservation Division. **O/G** indicates whether the reservoir is designated as an oil (O) reservoir or as a gas (G) reservoir. Cumulative production is through the end of 2000.

Reservoir Name	**Reservoir Unit (NMOCD)**	**County**	**Discovery Year**	**Depth (feet)**	**O/G**	**2000 oil production (MMBO)**	**Cumulative production (MMBO)**
Artesia	Queen Grayburg San Andres	Eddy	1923	2190	O	0.47	32.27
Atoka	San Andres	Eddy	1941	1680	O	0.11	7.00
Eagle Creek	San Andres	Eddy	1959	1292	O	0.04	4.32
Grayburg Jackson	Seven Rivers Queen Grayburg San Andres	Eddy & Lea	1929	2700	O	3.43	128.04
Henshaw West	Grayburg	Eddy	1956	2870	O	0.01	5.02
Loco Hills	Queen Grayburg San Andres	Eddy	1939	2600	O	0.10	48.28
Lovington	Grayburg San Andres	Lea	1939	4700	O	0.07	14.69
Lovington West	Upper San Andres	Lea	1944	4700	O	0.07	13.02
Maljamar	Grayburg San Andres	Eddy & Lea	1926	4050	O	1.00	158.14
Red Lake	Queen Grayburg San Andres	Eddy	1934	1945	O	0.58	12.72
Square Lake	Grayburg San Andres	Eddy	1941	3040	O	0.11	28.34
Square Lake North	Queen Grayburg San Andres	Eddy	1959	3300	O	0.01	2.69
Vacuum	Grayburg San Andres	Lea	1929	4500	O	5.39	341.87
TOTALS						**11.39**	**796.42**

San Andres/Grayburg Mixed Artesia Vacuum Trend Play

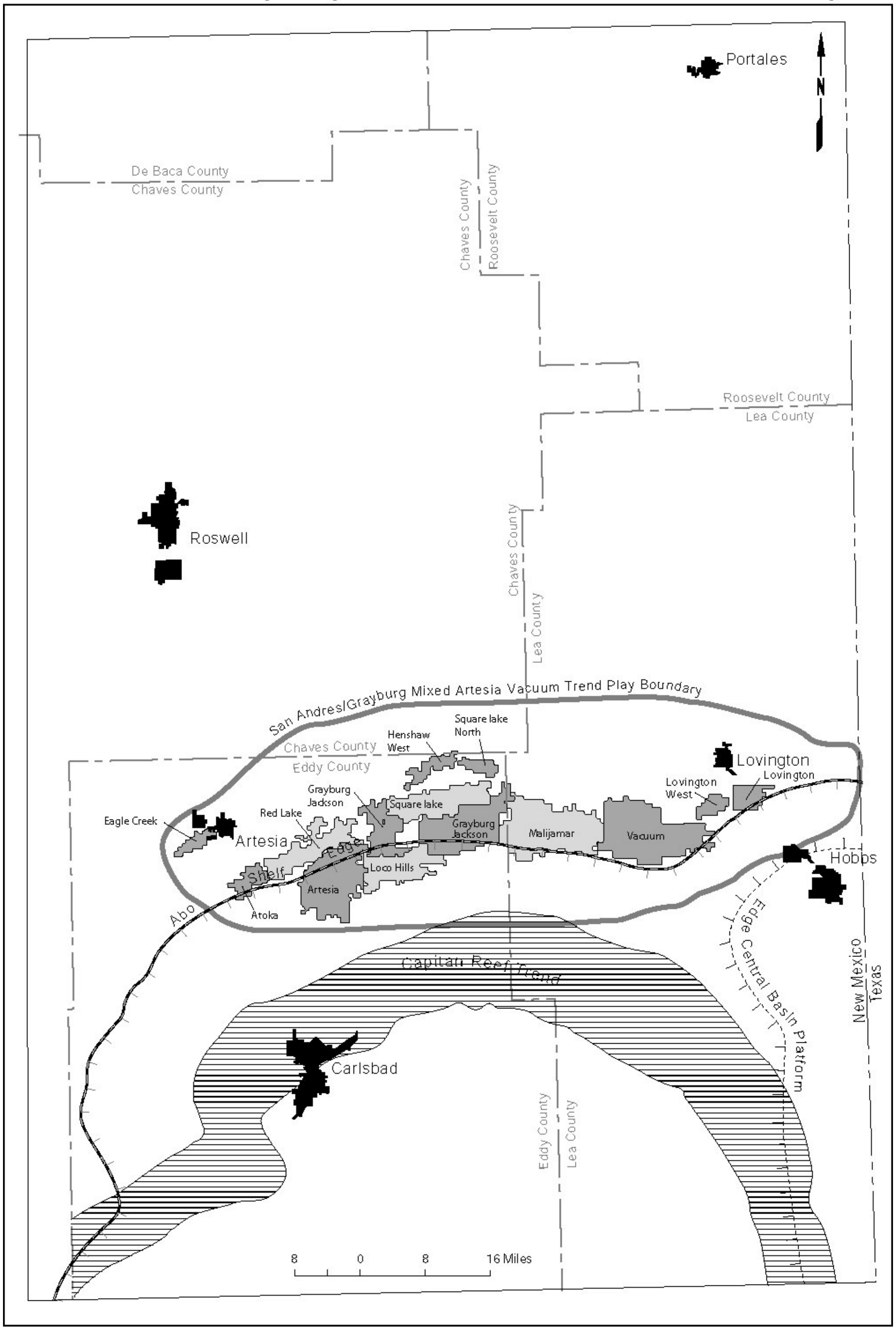

Figure 125-1. Location of reservoirs with more than 1 MMBO cumulative production in the Upper San Andres and Grayburg Platform Mixed-Artesia Vacuum Trend play of southeast New Mexico.

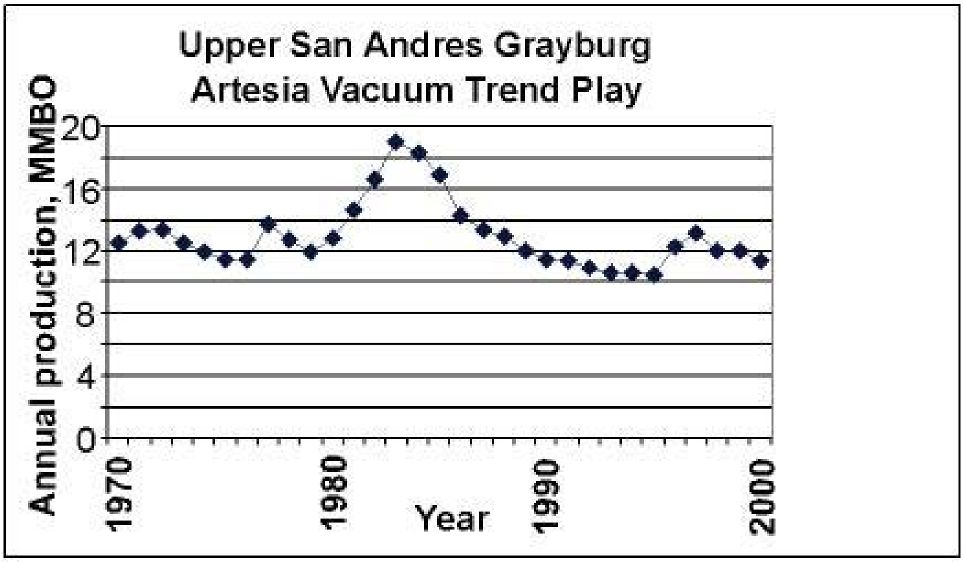

Figure 125-2. Annual production from 1970 to 2000 for the 13 reservoirs within the Upper San Andres and Grayburg Platform Mixed-Artesia Vacuum Trend play that have produced more than 1 MMBO.

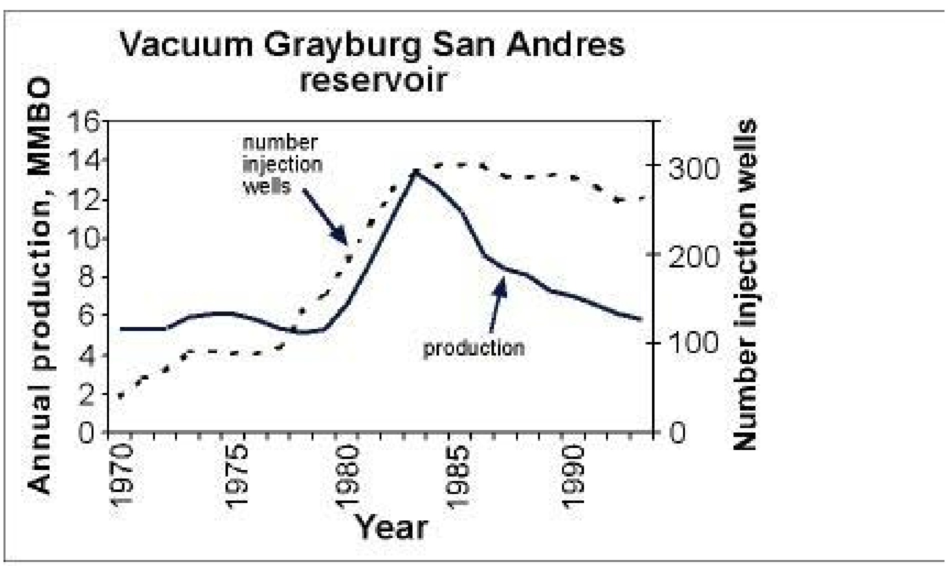

Figure 125-3. Annual oil production and number of injection wells in the Vacuum Grayburg San Andres reservoir from 1970 to 1993, showing the relationship between injection wells used for enhanced oil recovery and oil production. Most injection wells were used for water injection; after several years, a minor number of water injection wells were converted to polymer injection.

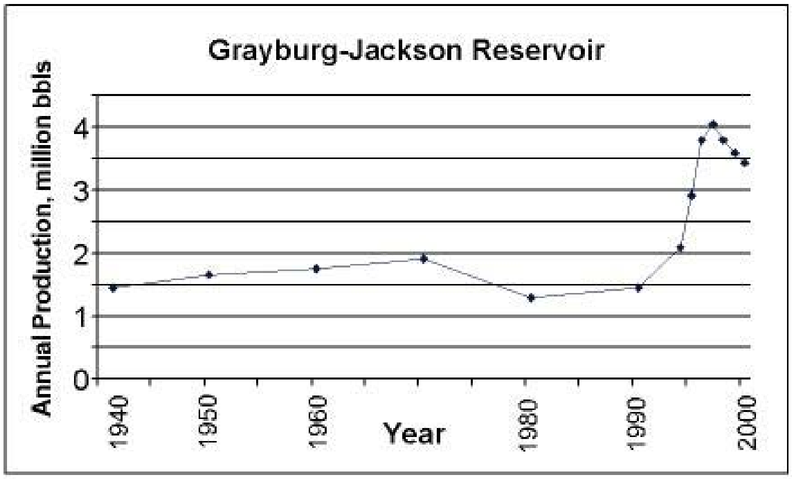

Figure 125-4. Annual production profile for Grayburg-Jackson reservoir, Upper San Andres and Grayburg Platform Mixed-Artesia Vacuum Trend play. The large upturn in production in the mid-1990's is due in part to redevelopment of the Grayburg Formation.

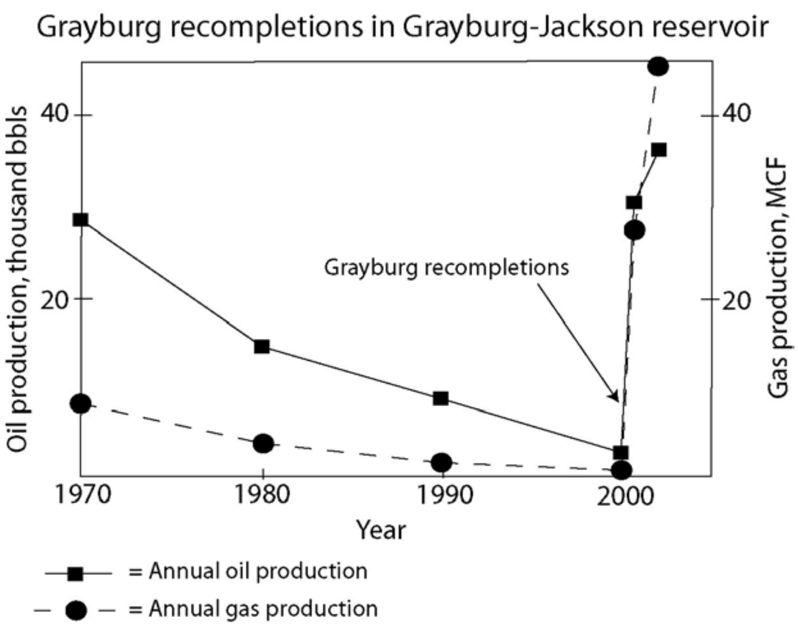

Figure 125-5. Annual combined oil and gas production for 3 wells in the Grayburg-Jackson reservoir, Upper San Andres and Grayburg Platform Mixed-Artesia Vacuum Trend play. These wells originally produced from San Andres zones and were in gradual decline but production was revitalized when they were recompleted in Grayburg pay.

Play 124 -Upper San Andres and Grayburg Platform Mixed- Central Basin Platform Trend Play

The Upper San Andres and Grayburg Platform Mixed—Central Basin Platform Trend play is located on the northwestern part of the Central Basin Platform in Lea County, with some smaller reservoirs (< 1 MMBO cumulative production) located within a few miles of the northwestern edge of the Central Basin Platform in the Delaware Basin (Fig. 124-1). Eight reservoirs have produced >1 MMBO (Table 124-1). Cumulative production from these eight reservoirs was 809 MMBO through 2000. Production is commingled from mixed dolostones and clastics of the upper San Andres Formation and the Grayburg Formation. The play has been in general decline over the last 30 years. An upturn in production during the middle to late 1980's was caused by implementation of several large pressure maintenance projects within the Hobbs Grayburg San Andres reservoir.

Reservoirs of the upper San Andres Formation and Grayburg Formation are high-energy dolograinstones from shoal environments and shallow-marine dolomitic sandstones (Garber and Harris, 1986; Lindsay, 1991). Facies are probably similar to better studied Texas reservoirs that include environments ranging from supratidal to platform margin settings, with wackestone through boundstone textures (see Galloway and others, 1983). Porosity is generally best developed in platform margin grainstone facies, but lower energy facies have locally developed secondary porosity (Galloway and others, 1983). Traps are mainly formed by gentle, north-south trending anticlines. Reservoirs are typically heterogeneous, and reservoir quality and distribution can vary across a single trap-forming structure (Galloway and others, 1983). Vertical seals are formed by impermeable evaporitic facies of the upper Grayburg and lower Queen Formations.

The Eunice Monument reservoir is a combination trap. It is formed by anticlinal closure on the west, north and south. The trap is stratigraphic to the east where porous dolograinstones of a high-energy shoal complex and subtidal dolomitic sandstones are sealed updip by a back-shoal facies consisting of impermeable dolomitic sandstones, dolostones, and evaporites (Lindsay, 1991).

San Andres production from the Hobbs reservoir is from the uppermost part of the San Andres, which shows evidence of karst modification—solution widened fractures, large vugs, and small pockets of breccia (information provided by Charles Kerans, Bureau of Economic Geology at the University of Texas at Austin). High well-test permeability suggests that permeability in the field is strongly influenced by a large interconnected pore system. The Hobbs reservoir has a longer primary production history than most San Andres reservoirs.

The dominant production mechanisms in the play are water drive and solution gas drive. Waterflooding and pressure maintenance have been successfully implemented in many of the reservoirs in this play and have resulted in substantial increases in recovery.

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Table 124-1. Reservoirs in the Upper San Andres and Grayburg Platform Central Basin Platform Trend play that had produced 1 MMBO as of the end of 2000. **Reservoir unit (NMOCD)** is the stratigraphic unit from which production is obtained, as designated by the New Mexico Oil Conservation Division. **O/G** indicates whether the reservoir is designated as an oil (O) reservoir or as a gas (G) reservoir. Cumulative production is through the end of 2000.

Reservoir Name	Reservoir Unit (NMOCD)	County	Discovery Year	Depth (feet)	O/G	2000 oil production (MMBO)	Cumulative production (MMBO)
Arrowhead	Grayburg	Lea	1938	3700	O	0.32	32.92
Carter South	Grayburg San Andres	Lea	1954	5110	O	0.02	2.37
Eunice Monument	Grayburg San Andres	Lea	1929	3950	O	2.39	392.45
Eunice South	San Andres	Lea	1969	3850	O	0.03	1.61
Hobbs	Grayburg San Andres	Lea	1928	4000	O	2.67	340.97
Hobbs East	San Andres	Lea	1951	4450	O	0.14	5.89
Penrose	Skelly Grayburg	Lea	1936	3435	O	0.14	21.62
Skaggs	Grayburg	Lea	1937	3780	O	0.08	11.12
TOTALS						**5.79**	**808.96**

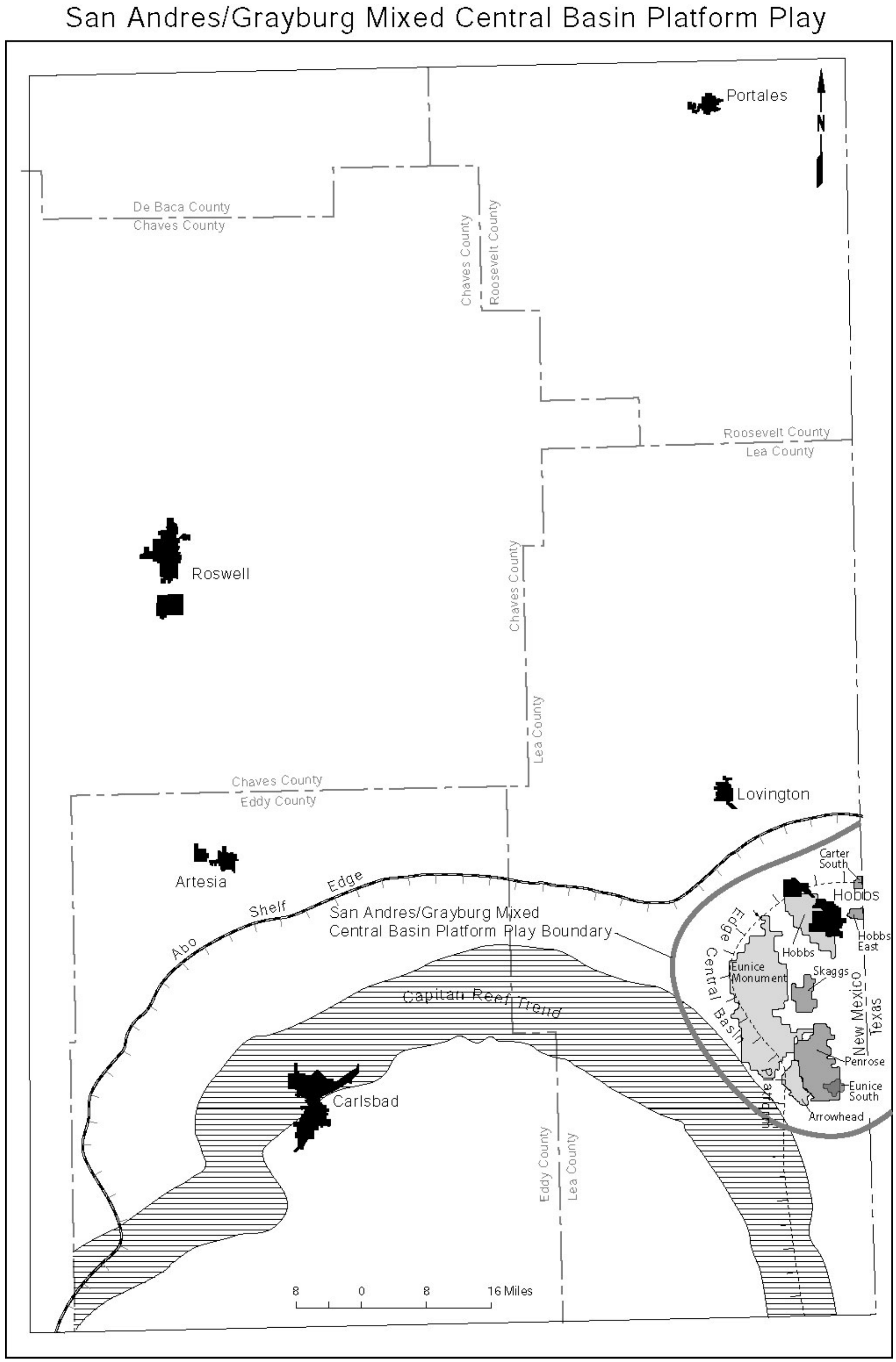

Figure 124-1. Distribution of reservoirs in the Upper San Andres and Grayburg Platform Mixed-Central Basin Platform Trend play with cumulative production more 1 MMBO as of 2000.

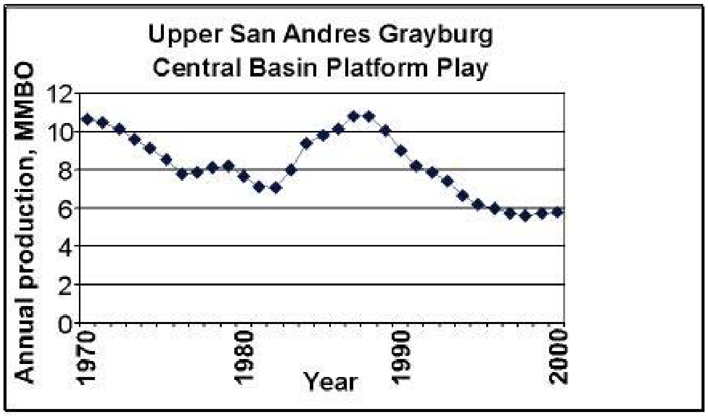

Figure 124-2. Annual production from 1970 to 2000 for the eight New Mexico reservoirs within the Upper San Andres and Grayburg Platform Mixed-Central Basin Platform Trend play that have produced more than 1 MMBO.

Play 120 - Northwest Shelf San Andres Platform Carbonate Play

The Northwest Shelf San Andres Platform Carbonate play is located on the Northwest Shelf in northern Lea, southern Roosevelt, and eastern Chaves Counties (Fig. 120-1). Thirteen New Mexico reservoirs in this play have produced more than 1 MMBO (Table 120-1). Cumulative production from these 13 reservoirs was 95 MMBO as of 2000. Production has declined significantly over the past 30 years, from 5.65 MMBO per year in 1970 to 520 thousand bbls per year in 2000 (Fig. 120-2). Most of the decline in production from the New Mexico part of the play can be attributed to the Chaveroo (Fig. 120-3) and Cato reservoirs.

Reservoirs occur in upward-shallowing cyclic shelf carbonates and evaporites of the lower San Andres Formation (Gratton and LeMay, 1969; Elliott and Warren, 1989). Vertical facies repeat in a model ascending sequence of: 1) open-marine, subtidal limestone; 2) restricted marine subtidal dolostones, the reservoir facies; 3) intertidal and supratidal dolostones, and 4) salina and sabkha anhydrites. Not all of these facies are present in a single sequence. Porosity in the reservoir facies is mostly intercrystalline and moldic. Four major cycles, and therefore four distinct reservoir zones, have been recognized by most workers in the lower San Andres (Gratton and LeMay, 1969; Elliot and Warren, 1989) although some workers have identified five cycles (Pitt and Scott, 1981) or even as many as eight cycles (Cowan and Harris, 1986).

Traps are stratigraphic or combination structural-stratigraphic (Gratton and LeMay, 1969; Yedlosky and McNeal, 1969; Cowan and Harris, 1986; Ward et al., 1986; Keller, 1992). Porosity zones pinchout updip to the north and northwest where porosity is occluded by anhydrite cement. Combination traps are present where zero porosity lines are draped across generally south-plunging structural noses and form the Cato, Chaveroo and Milnesand reservoirs. The cyclic nature of the regressive sequences has led to vertical stacking of porosity zones. In some places, zero-porosity lines in multiple zones are nearly coincident, resulting in production from two or more hydraulically isolated porosity zones within a single reservoir. Evaporite-cemented underseals in some reservoirs prevented oil from secondary migration in structures that were tilted subsequent to entrapment (Keller, 1992), resulting in a tilted base-of-oil. Depths to top of reservoirs in New Mexico range from 2000 to 5000 ft. Solution gas drive is the major production mechanism in reservoirs in the New Mexico part of the play.

Some of the San Andres reservoirs are cut by wrench faults of probable Tertiary age (Scott, 1995). At Cato and Tom Tom, faulting is thought to have enhanced low matrix permeability (Scott, 1995). Therefore it is likely that permeability varies as a function of proximity to the faults that cut the reservoir.

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Table 120-1. Reservoirs in the Northwest Shelf San Andres Platform Carbonate play that had produced 1 MMBO as of the end of 2000. **Reservoir unit (NMOCD)** is the stratigraphic unit from which production is obtained, as designated by the New Mexico Oil Conservation Division. **O/G** indicates whether the reservoir is designated as an oil (O) reservoir or as a gas (G) reservoir. Cumulative production is through the end of 2000.

Reservoir Name	**Reservoir Unit (NMOCD)**	**County**	**Discovery Year**	**Depth (feet)**	**O/G**	**2000 oil production (MMBO)**	**Cumulative production (MMBO)**
Bluitt	San Andres	Roosevelt	1963	4500	O	<0.01	2.50
Cato	San Andres	Chaves	1966	3414	O	0.01	16.25
Chaveroo	San Andres	Chaves & Roosevelt	1965	4184	O	0.07	24.50
Diablo	San Andres	Chaves	1963	2000	O	0.05	1.33
Flying M	San Andres	Lea	1964	4400	O	0.13	11.16
Mescalero	San Andres	Lea	1962	4063	O	0.04	6.95
Milnesand	San Andres	Roosevelt	1958	4554	O	0.05	12.03
Sawyer	San Andres	Lea	1947	5000	O	0.02	1.66
Sawyer West	San Andres	Lea	1969	4950	O	0.03	4.24
Todd	Lower San Andres	Roosevelt	1965	4440	O	0.01	2.95
Tom Tom	San Andres	Chaves	1967	3914	O	0.02	3.54
Tomahawk	San Andres	Chaves & Roosevelt	1977	4144	O	0.02	2.34
Twin Lakes	San Andres	Chaves	1965	2600	O	0.07	5.31
TOTALS						**0.52**	**94.78**

Northwest Shelf San Andres Platform Carbonate Play

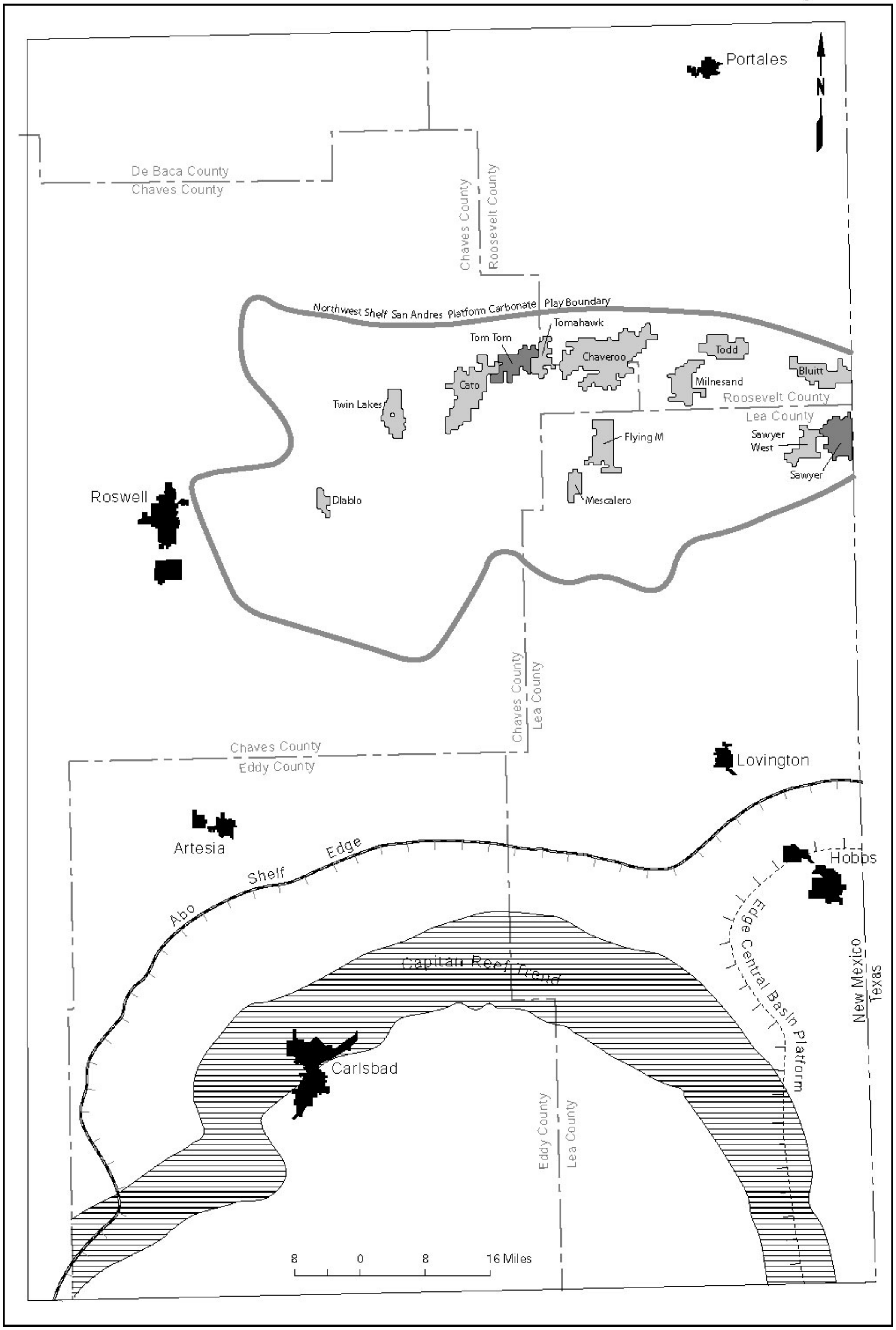

Figure 120-1. Distribution of reservoirs in the New Mexico part of the Northwest Shelf San Andres Platform Carbonate play with cumulative production more than 1 MMBO as of 2000.

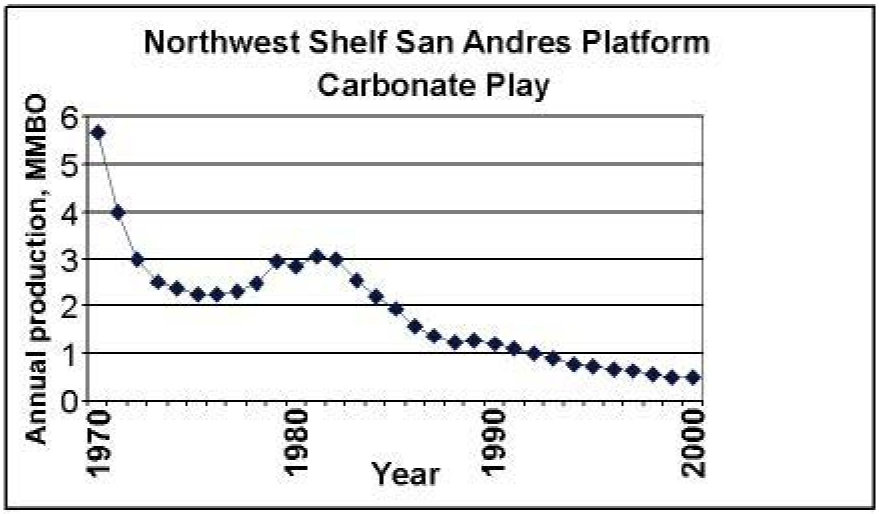

Figure 120-2. Annual production from 1970 to 2000 for the 13 reservoirs within the Northwest Shelf San Andres Platform Carbonate play that have produced more than 1 MMBO.

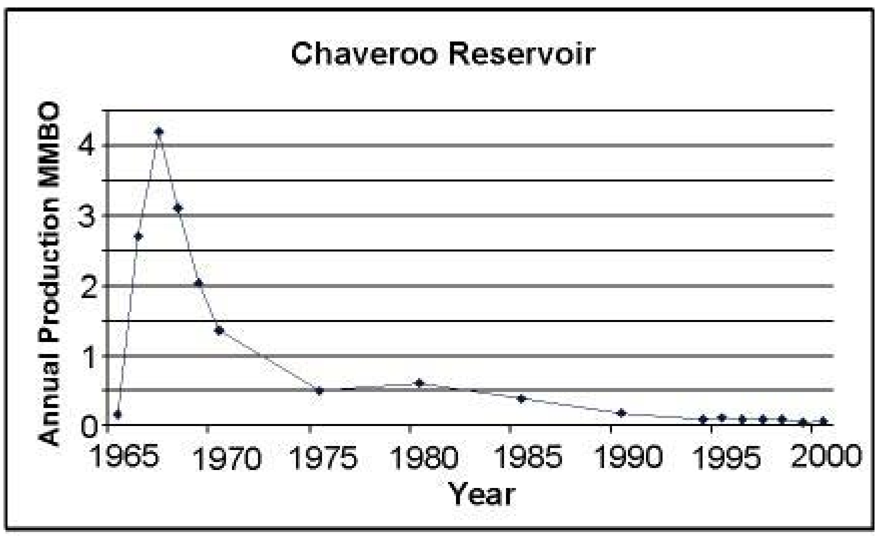

Figure 120-3. Annual oil production for the Chaveroo reservoir, discovered in 1965. The steep decline from this reservoir since 1968 is a major reason why the entire New Mexico part of the play declined soon after 1970. The decline in production within a few years of discovery is characteristic of the production history of many reservoirs in the play.

Play 118 - Bone Spring Basinal Sandstone and Carbonate Play

Reservoirs of the Bone Spring Basinal Sandstone and Carbonate play lie within the northern part of the Delaware Basin and stretch southward from the Abo shelf edge toward the New Mexico – Texas border (Fig. 118-1). There are 132 known, discovered reservoirs in this play, 16 of which have produced more than 1 MMBO (Table 118-1). Cumulative production from these 16 reservoirs was 71 MMBO as of 2000. The Bone Spring Formation is Leonardian (Permian) in age. Production from this play increased in the 1980's as several new reservoirs were discovered and subsequently declined during the middle and late 1990's as the newer reservoirs started to deplete (Fig. 119-2). During 2000 total production from the play began to increase (Fig. 118-2) as a result of additional drilling and increased production in the Shugart North reservoir.

Reservoirs were deposited in a basinal setting seaward of the Abo shelf edge (Figs. 118-3, 118-4; see *play 116, Abo Platform Carbonate play*). Production has been obtained from carbonate debris flows in the first, second and third Bone Spring carbonates as well as fine-grained sandstones in the first, second and third Bone Spring sandstones (Wiggins and Harris, 1985; Gawloski, 1987; Mazzullo and Reid, 1987; Saller et al., 1989; Montgomery, 1997; Downing and Mazzullo, 2000).

Carbonate debris flows form the primary Bone Spring reservoirs in the northernmost Delaware Basin and constitute the Bone Spring Carbonate subplay. These debris flows are located at the toe of slope of the Abo and Yeso shelf edge and were derived from carbonate detritus at the Abo and Yeso shelf margins. The reservoirs consist of dolomitized conglomerate breccias and dolomitized bioclast-peloid packstones (Montgomery, 1997). Porosity is mostly secondary. Vugular, moldic, intercrystalline, and intergranular pores are dominant. In the Mescalero Escarpe reservoir (Saller et al., 1989), open fractures in dolopackstones have enhanced permeability. Traps are stratigraphic or combination structural-stratigraphic; porous reservoirs are confined to channels and pinch out depositionally updip as they rise onto the submarine slope to the north.

Siliciclastic turbidites have widespread distribution in the first, second, and third Bone Spring sandstones. The Bone Spring sandstone reservoirs constitute the Bone Spring Sandstone subplay. These turbidites consist of fine-grained sandstones cemented by dolomite and authigenic clays (Gawloski, 1987; Saller et al., 1989). They were deposited in a channel and fan system at the base of slope and on the basin plain

(Montgomery, 1997; Pearson, 1999). Most reservoirs appear to be present in well-defined channels. The Bone Spring sandstones are the primary reservoirs in fields located more than 5 to 10 miles south of the shelf margin. Traps are stratigraphic or combination structural-stratigraphic; porous reservoirs are confined in channels and pinch out depositionally updip as they rise onto the submarine slope to the north. Recent drilling has extended the Bone Spring Sandstone subplay south into the Texas part of the Delaware Basin.

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Table 118-1. Reservoirs in the Bone Spring Basinal Sandstone and Carbonate play that had produced 1 MMBO as of the end of 2000. **Reservoir unit (NMOCD**) is the stratigraphic unit from which production is obtained, as designated by the New Mexico Oil Conservation Division. **O/G** indicates whether the reservoir is designated as an oil (O) reservoir or as a gas (G) reservoir. Cumulative production is through the end of 2000.

Reservoir Name	Reservoir Unit (NMOCD)	County	Discovery Year	Depth (feet)	O/G	2000 oil production (MMBO)	Cumulative production (MMBO)
Airstrip	Bone Spring	Lea	1979	9329	O	0.01	2.43
Airstrip North	Bone Spring	Lea	1986	9600	O	0.02	1.32
EK	Bone Spring	Lea	1975	9450	O	0.04	1.88
Lea	Bone Spring	Lea	1960	9480	O	0.03	3.34
Mescalero Escarpe	Bone Spring	Lea	1984	8660	O	0.22	8.42
Midway	Abo	Lea	1963	8850	O	0.01	2.88
Old Millman Ranch	Bone Spring	Eddy	1991	6140	O	0.06	1.21
Quail Ridge	Bone Spring	Lea	1962	9315	O	0.01	1.72
Querecho Plains	Upper Bone Spring	Lea	1959	8538	O	0.08	2.37
Red Hills	Bone Spring	Lea	1992	12200	O	0.53	5.63
Red Tank	Bone Spring	Lea	1992	8820	O	0.07	1.07
Scharb	Bone Spring	Lea	1962	10152	O	0.05	14.1
Shugart North	Bone Spring	Eddy	1986	7680	O	1.01	8.81
Tamano	Bone Spring	Eddy	1985	8100	O	0.03	2.73
Teas	Bone Spring	Lea	1963	9300	O	0.06	1.15
Young North	Bone Spring	Lea	1980	8416	O	0.25	11.64
TOTALS						**2.46**	**70.70**

Bone Spring Basinal Sandstone and Carbonate Play

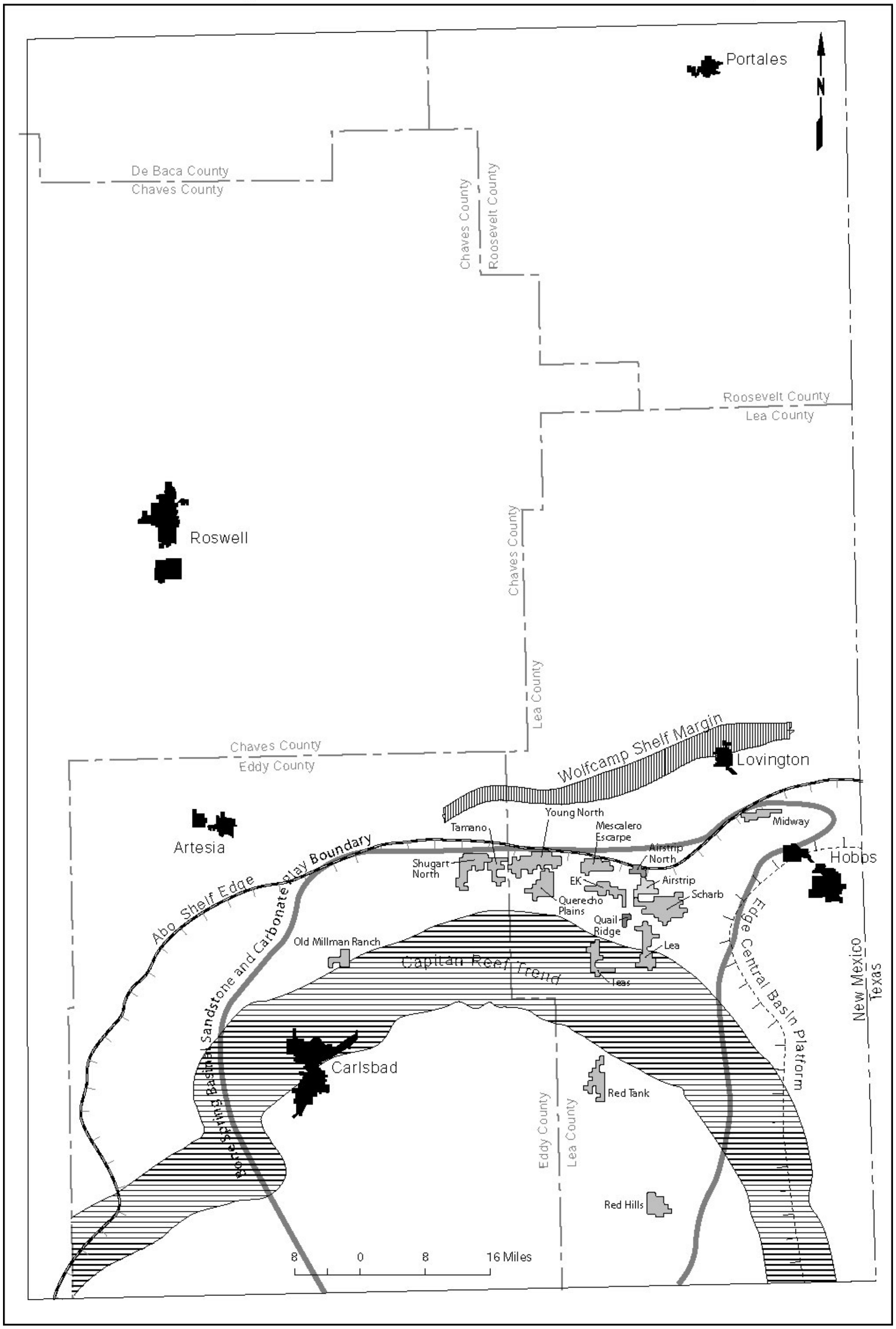

Figure 118-1. Location of reservoirs with more than 1 MMBO cumulative production in the Bone Spring Basinal Sandstone and Carbonate play.

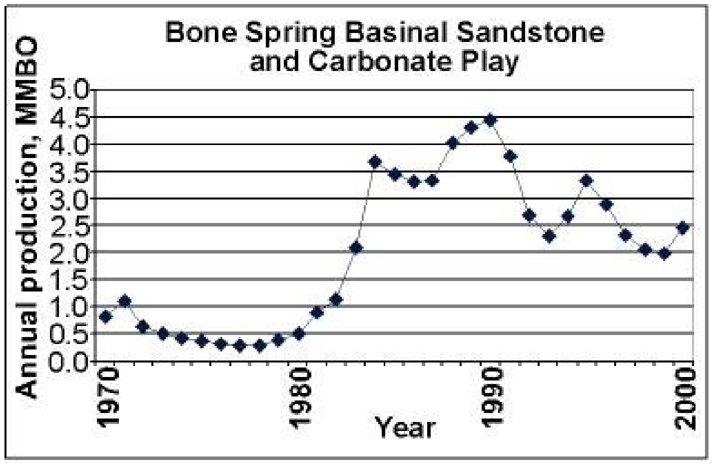

Figure 118-2. Historical annual production from 1970 to 2000 from reservoirs with more than 1 MMBO production in the Bone Spring Basinal Sandstone and Carbonate play.

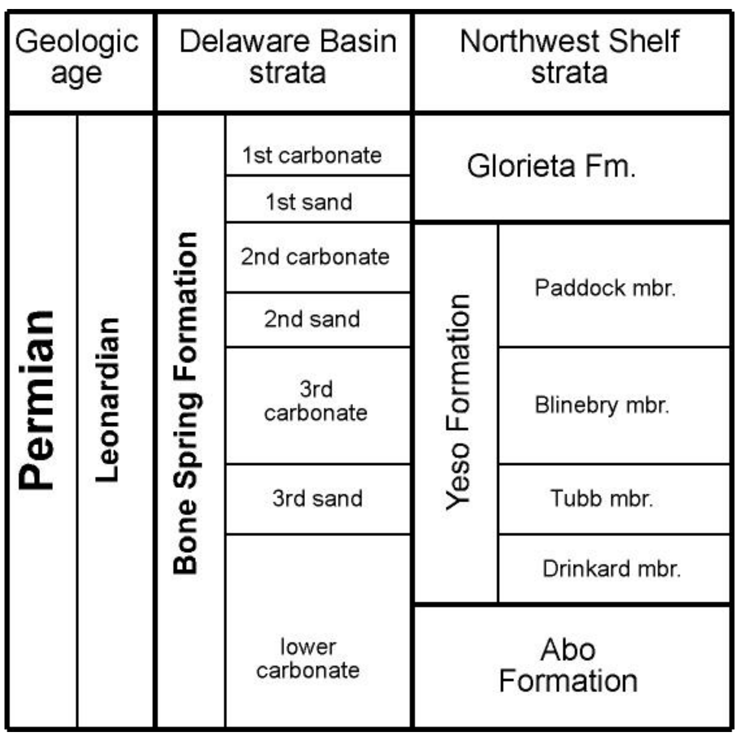

Figure 118-3. Stratigraphic chart showing relationship of Bone Spring basinal strata in the Delaware Basin to Lower Permian strata on the Northwest Shelf. Modified from Gawloski (1987), Saller et al. (1989) and Tyrrell (2002).

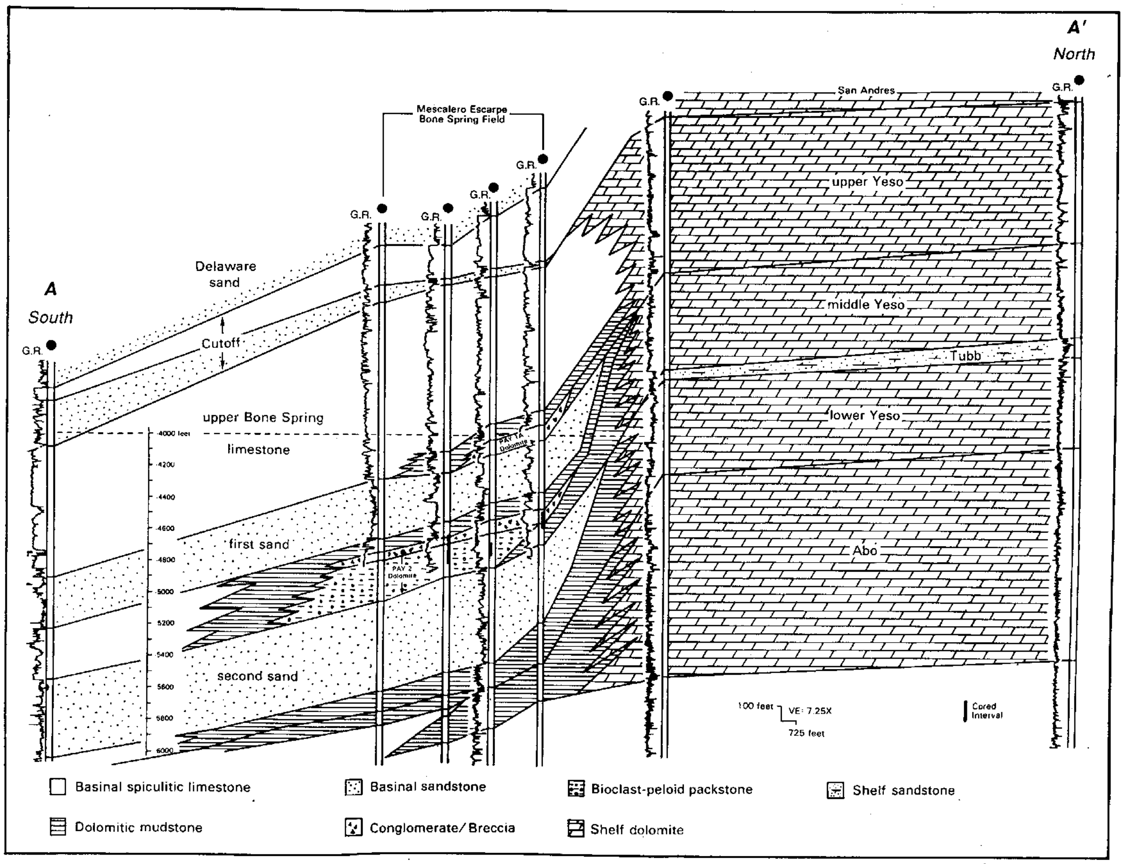

Figure 118-4. North-south cross section through Mescalero Escarpe reservoir showing southward depositional dip and transition from shelf facies of the Abo and Yeso Formations in the north to basinal carbonate and sandstone facies of the Bone Spring Formation in the south. From Saller et al. (1989). See Saller et al (1989) for location.

Play 117 - Leonard Restricted Platform Carbonate Play

Reservoirs of the Leonard Restricted Platform Carbonate play lie on the Central Basin Platform and along a curvilinear trend near the southern margin of the Northwest Shelf (Fig. 117-1 A-D). There are 102 known, discovered Leonard platform reservoirs in New Mexico. Most of these reservoirs are productive from platform dolostones and limestones but some are productive from sandstones. Thirty-four reservoirs in this play have produced more than 1 MMBO (Fig. 117-1 A-D; Table 117-1). Cumulative production from these 34 reservoirs was 431 MMBO as of 2000. Annual production from these 34 reservoirs was 6.19 MMBO during 2000. Although annual production from this play has shown a downward trend since 1970, there was a significant production spike during 1996 and 1997 (Fig. 117-2) as production increased in the Blinebry, Dollarhide, Vacuum and Warren reservoirs.

The Leonard Restricted Platform Carbonate play is productive from reservoirs in the Drinkard, Tubb, Blinebry, and Paddock members of the Yeso Formation (Permian: Leonardian) and reservoirs in the Glorieta Formation (Permian: Leonardian; Fig. 117-3). In the New Mexico part of the play, four subplays (Table 117-2) are recognized base upon division of productive reservoirs among the Glorieta Formation and the four members of the Yeso Formation. The four subplays are (descending): 1) Leonard upper Yeso subplay (Fig. 117-1A); 2) Leonard Blinebry subplay (Fig. 117-1B); 3) Leonard Tubb subplay (Fig. 117-1C); and 4) Leonard Drinkard subplay (Fig. 117-1D). Production from the four subplays is mostly from stacked reservoirs on the Central Basin Platform. On the Northwest Shelf, however, the lower reservoirs (Drinkard, Tubb, Blinebry) are productive from only the eastern part of the play trend. Production from the upper Yeso reservoirs (Paddock and Glorieta) stretches from the New Mexico-Texas border westward into central Eddy County (Fig. 117-1A). The upper Yeso subplay is the most productive of the four Leonard subplays in New Mexico (Table 117-2), as well as having the largest geographic extent (Figs. 117-1A through 117-1D). The stratigraphic distinction between the Paddock member of the Yeso Formation and the Glorieta Formation is imprecise; some reservoirs correlated traditionally as Glorieta are actually Paddock (e.g. the Vacuum Glorieta reservoir; Martin and Hickey, 2002).

Most reservoirs in the Leonard Restricted Platform Carbonate play are marine limestones and dolostones deposited on a restricted carbonate-dominated platform.

Carbonate reservoirs dominate the Drinkard, Blinebry, and Paddock sections. Fine-grained dolomitic sandstone reservoirs are dominant in some areas in the Tubb and Glorieta sections but dolostone reservoirs are dominant elsewhere in the Tubb and Glorieta. Percentage of sandstone increases westward within the Glorieta (Broadhead, 1993).

Drinkard reservoirs are productive from carbonates deposited in a variety of shelf and shelf-edge environments. On the Northwest Shelf, reservoir character in the Drinkard member is related to the location of the underlying Abo shelf-margin trend (Martin et al., 1999; see *play 116, Abo Platform Carbonate play* for a description of the Abo shelf-margin trend). In reservoirs located shoreward of the underlying Abo trend (e.g. Vacuum Drinkard), reservoir facies are formed by patch reefs and associated grainstones. Reservoirs located basinward of the underlying Abo trend (e.g. Knowles West) are formed by foreslope oolite shoals. In the Justis Tubb Drinkard reservoir on the Central Basin Platform, the best quality reservoir rocks are grain-dominated limestones; dolomitized grainstones are less porous and permeable (Hoffman, 2002).

Traps are generally formed by low-relief anticlines (Fig. 117-4). A single structure may act to trap oil and gas in multiple pay zones. Depths to productive reservoirs range from 2250 to 8200 ft. In some reservoirs, facies variations can create porosity pinchouts on anticlinal noses (Fig. 117-5) as well as unevenness in reservoir quality across a structure, resulting in a stratigraphic component to trapping and production and internal compartmentalization of the reservoirs. Depositional variation within Leonardian stratal units influences the distribution of reservoir facies across an oil accumulation; grainstones, which are primary productive facies in many reservoirs, are not evenly distributed across an oil field but instead are concentrated in oolitic barrier facies, at least in the Paddock member (Fig. 117-6).

Many of the Leonard carbonate reservoirs are densely fractured. Natural fractures do not occur in all strata within a reservoir but may, instead, be confined to only a few stratigraphic intervals (Martin and Hickey, 2002). Therefore, waterflooding of reservoirs in enhanced recovery operations has often resulted in premature water breakthrough in fractured zones and has left significant volumes of oil unflooded and unrecovered in the nonfractured zones. Methods for optimizing recovery via waterflooding include the drilling of lateral wells in unfractured intervals (Martin and Hickey, 2002). The lateral boreholes are used for both production and for water injection. In the Vacuum Glorieta

West unit of the Vacuum Glorieta reservoir, horizontal laterals drilled into porous but unfractured reservoir zones are expected to result in increased incremental production of 2.6 million bbls oil (Fig. 117-7; Martin and Hickey, 2002).

Anhydrite-filled fractures are characteristic of some Leonard carbonate reservoirs (Burnham, 1991). When present, it is possible that they will act to horizontally compartmentalize the reservoir and therefore result in less than optimum production from standard spacing and patterns of vertical wells.

In the Dollarhide Drinkard reservoir, high frequency sea level fluctuations combined with deposition on an uneven paleobathymetric surface resulted in a complex reservoir system composed of interbedded landward-stepping and seaward-stepping cycles; this architecture has given the reservoir a high degree of internal heterogeneity and compartmentalization (Johnson et al., 1997; Fitchen et al., 1995; Ruppel et al., 1995). Complex patterns of dolomitization controlled by depositional relations to intertidal and subtidal settings have added additional heterogeneity to the reservoir. Texaco applied a sinusoidal horizontal drilling technique to optimize production in the Dollarhide Drinkard reservoir (Johnson et al., 1997). This sinusoidal drilling resulted in a well that has been drilled laterally 2000 ft and has traversed 150 ft of vertical section in the reservoir. The reservoir was treated with HCl before completion. The result was substantially increased initial production rates, which increased from 8 bbls oil per day with original vertical completions to 70 bbls oil per day from the lateral sinusoidal leg. Presumably the horizontal sinusoidal well either tapped isolated reservoir compartments that were not productive with the vertical wells or penetrated low-permeability portions of the reservoir that were not in adequate communication with the vertical well bore.

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Table 117-1. Reservoirs in the Leonard Restricted Platform Carbonate play that had produced 1 MMBO as of the end of 2000. **Reservoir unit (NMOCD)** is the stratigraphic unit from which production is obtained, as designated by the New Mexico Oil Conservation Division. **O/G** indicates whether the reservoir is designated as an oil (O) reservoir or as a gas (G) reservoir. Cumulative production is through the end of 2000.

Reservoir Name	Reservoir Unit (NMOCD)	County	Discovery Year	Depth (feet)	O/G	2000 oil production (MMBO)	Cumulative production (MMBO)	Subplay
Atoka	Glorieta Yeso	Eddy	1983	2660	O	0.12	4.03	Upper Yeso
Fowler	Upper Yeso	Lea	1950	5705	O	0.03	4.92	Upper Yeso
Lovington	Paddock	Lea	1952	6150	O	0.16	17.57	Upper Yeso
Maljamar	Paddock	Eddy	1950	5300	O	0.03	1.30	Upper Yeso
Monument	Paddock	Lea	1948	5190	O	0.12	10.55	Upper Yeso
Paddock	Paddock	Lea	1945	5170	O	0.22	30.19	Upper Yeso
Paddock South	Paddock	Lea	1957	5100	O	0.01	2.82	Upper Yeso
Penasco Draw	San Andres Yeso	Eddy	1982	2250	O	0.02	2.28	Upper Yeso
Skaggs	Glorieta	Lea	1958	5250	O	0.01	1.90	Upper Yeso
Vacuum	Glorieta	Lea	1963	6100	O	1.13	73.52	Upper Yeso
Blinebry	Blinebry	Lea	1945	5600	O	0.73	41.17	Blinebry
Eunice North	Blinebry Tubb Drinkard	Lea	1944	5700	O	0.74	24.72	Blinebry
Hobbs	Upper Blinebry	Lea	1968	5870	O	0.06	6.40	Blinebry
Justis	Blinebry	Lea	1958	5350	O	0.10	9.68	Blinebry
Monument	Blinebry	Lea	1948	5660	O	0.07	10.13	Blinebry
Nadine West	Paddock Blinebry	Lea	1980	6008	O	0.16	3.48	Blinebry
Oil Center	Blinebry	Lea	1959	5907	O	0.05	8.24	Blinebry
Teague	Blinebry	Lea	1967	5400	O	0.37	6.37	Blinebry
Vacuum	Blinebry	Lea	1963	6600	O	0.03	2.32	Blinebry
Warren	Blinebry Tubb	Lea	1957	5900	O	0.21	5.41	Blinebry
Weir	Blinebry	Lea	1961	5700	O	0.03	1.79	Blinebry
Weir East	Blinebry	Lea	1962	5800	O	0.02	1.01	Blinebry
Justis	Blinebry Tubb Drinkard	Lea	1957	5720	O	0.32	30.21	Tubb
Monument	Tubb	Lea	1959	6400	O	0.15	5.11	Tubb
Tubb	Tubb	Lea	1946	6000	O	0.05	7.13	Tubb
Warren	Tubb	Lea	1957	6500	O	0.02	1.53	Tubb
Dollarhide	Tubb Drinkard	Lea	1951	6616	O	0.44	24.21	Drinkard
Drinkard	Drinkard	Lea	1944	6500	O	0.33	74.71	Drinkard
Hobbs	Drinkard	Lea	1952	6880	O	0.02	3.09	Drinkard
House	Drinkard	Lea	1949	6980	O	0.02	1.68	Drinkard
Justis	Tubb Drinkard	Lea	1957	5837	O	0.09	3.87	Drinkard
Knowles West	Drinkard	Lea	1975	8236	O	0.02	2.19	Drinkard
Skaggs	Drinkard	Lea	1953	6850	O	0.04	2.99	Drinkard
Vacuum	Drinkard	Lea	1962	7600	O	0.26	4.36	Drinkard
TOTALS						**6.19**	**430.88**	

* New reservoir (pool) created in 1992 to reflect historical commingling of the Blinebry, Tubb and Drinkard members in certain parts of what had been previously described as the Justis Blinebry and Justis Tubb Drinkard reservoirs. Data are for cumulative production since discovery of the Justis reservoirs in 1958.

Table 117-2. The four New Mexico subplays of the Leonard Restricted Platform Carbonate play. **MMBO**, million bbls oil.

Subplay	**Main productive stratigraphic units**	**Number reservoirs with cumulative production > 1 MMBO**	**Cumulative oil production from reservoirs with > 1 MMBO (MMBO)**
Upper Yeso	Glorieta Formation Paddock member of Yeso Formation	10	149
Blinebry	Blinebry member of Yeso Formation	12	121
Tubb	Tubb member of Yeso Formation	4	44
Drinkard	Drinkard member of Yeso Formation	8	117

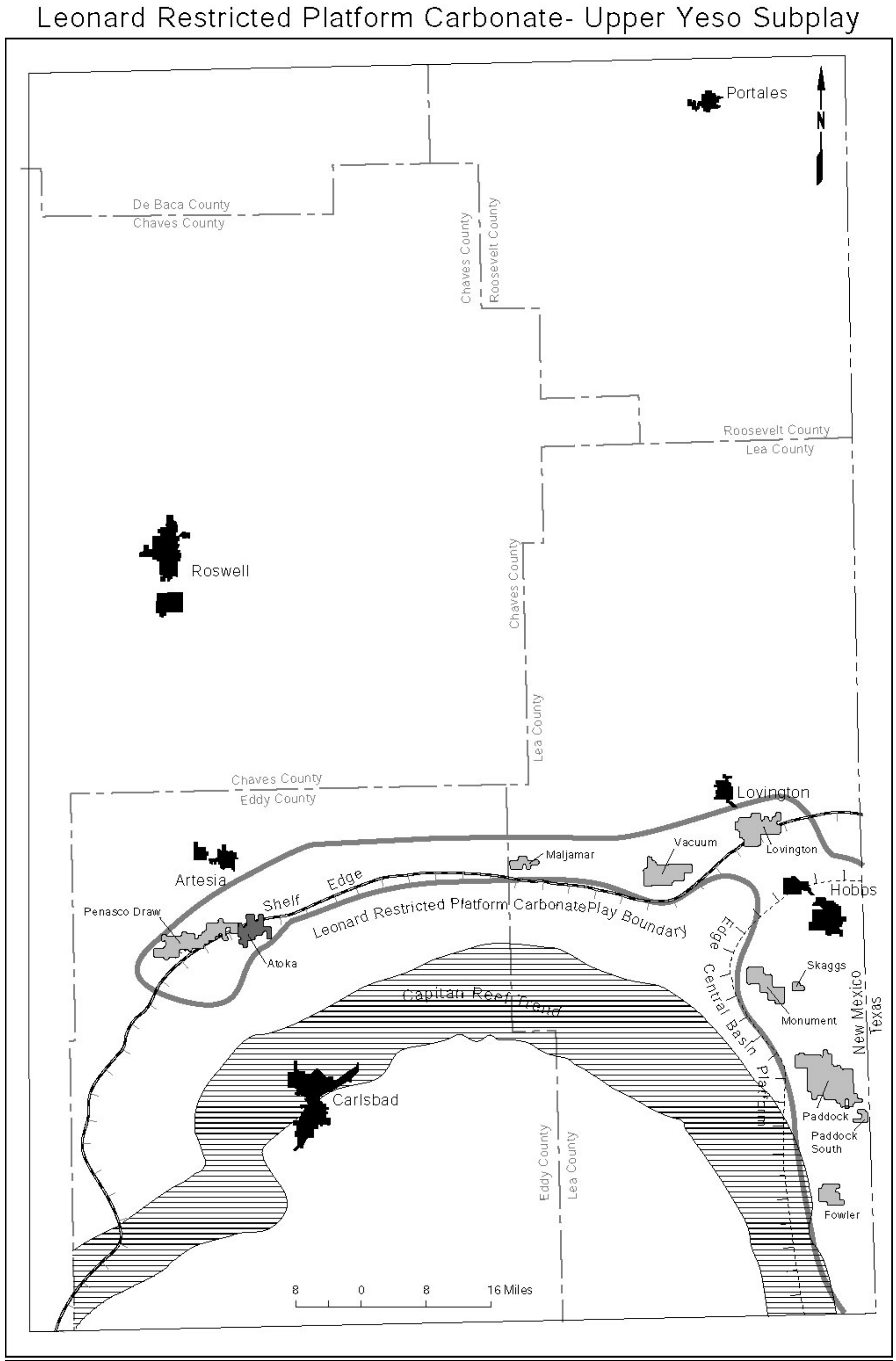

Figure 117-1 A. Location of reservoirs with more than 1 MMBO cumulative production in the Upper Yeso subplay of the Leonard Restricted Platform Carbonate play. Play outline shown is that of the entire Leonard Restricted Platform Carbonate play within New Mexico and not just the Upper Yeso subplay.

Leonard Restricted Platform Carbonate -Blinebry Subplay

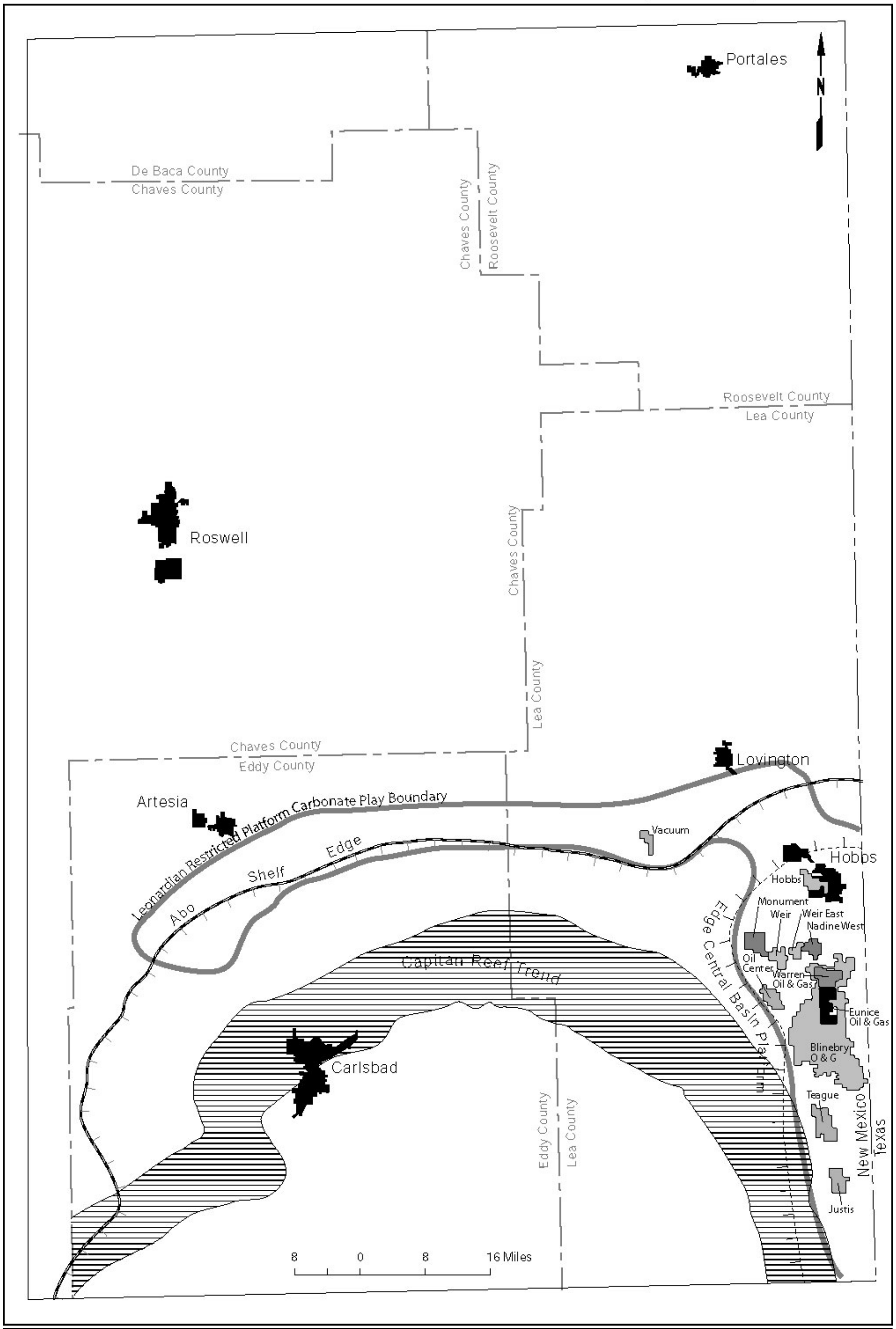

Figure 117-1 B. Location of reservoirs with more than 1 MMBO cumulative production in the Blinebry subplay of the Leonard Restricted Platform Carbonate play. Play outline shown is that of the entire Leonard Restricted Platform Carbonate play within New Mexico and not just the Blinebry subplay.

Leonard Restricted Platform Carbonate-Tubb Subplay

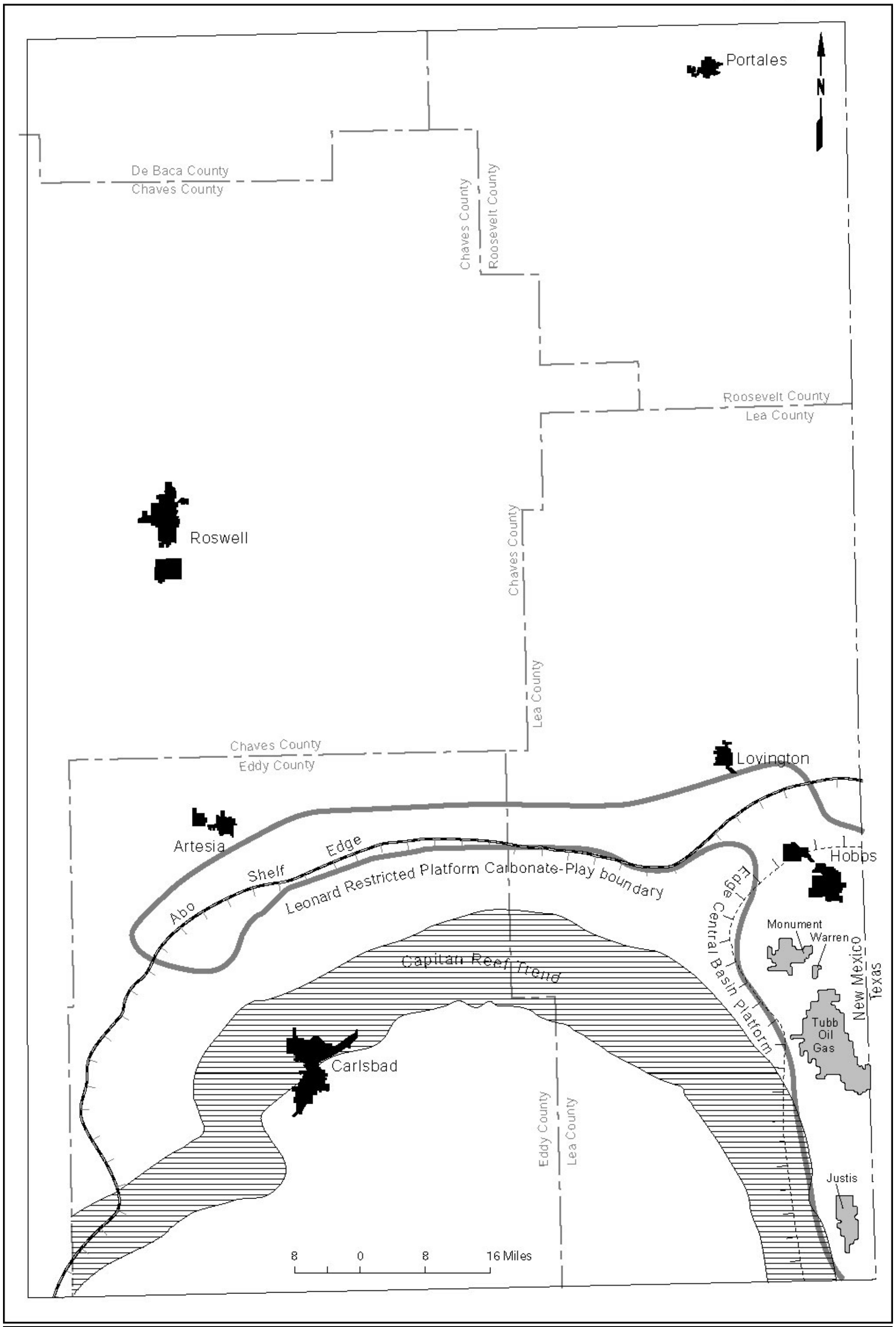

Figure 117-1 C. Location of reservoirs with more than 1 MMBO cumulative production in the Tubb subplay of the Leonard Restricted Platform Carbonate play. Play outline shown is that of the entire Leonard Restricted Platform Carbonate play within New Mexico and not just the Tubb subplay.

Leonard Restricted Platform Carbonate - Drinkard Subplay

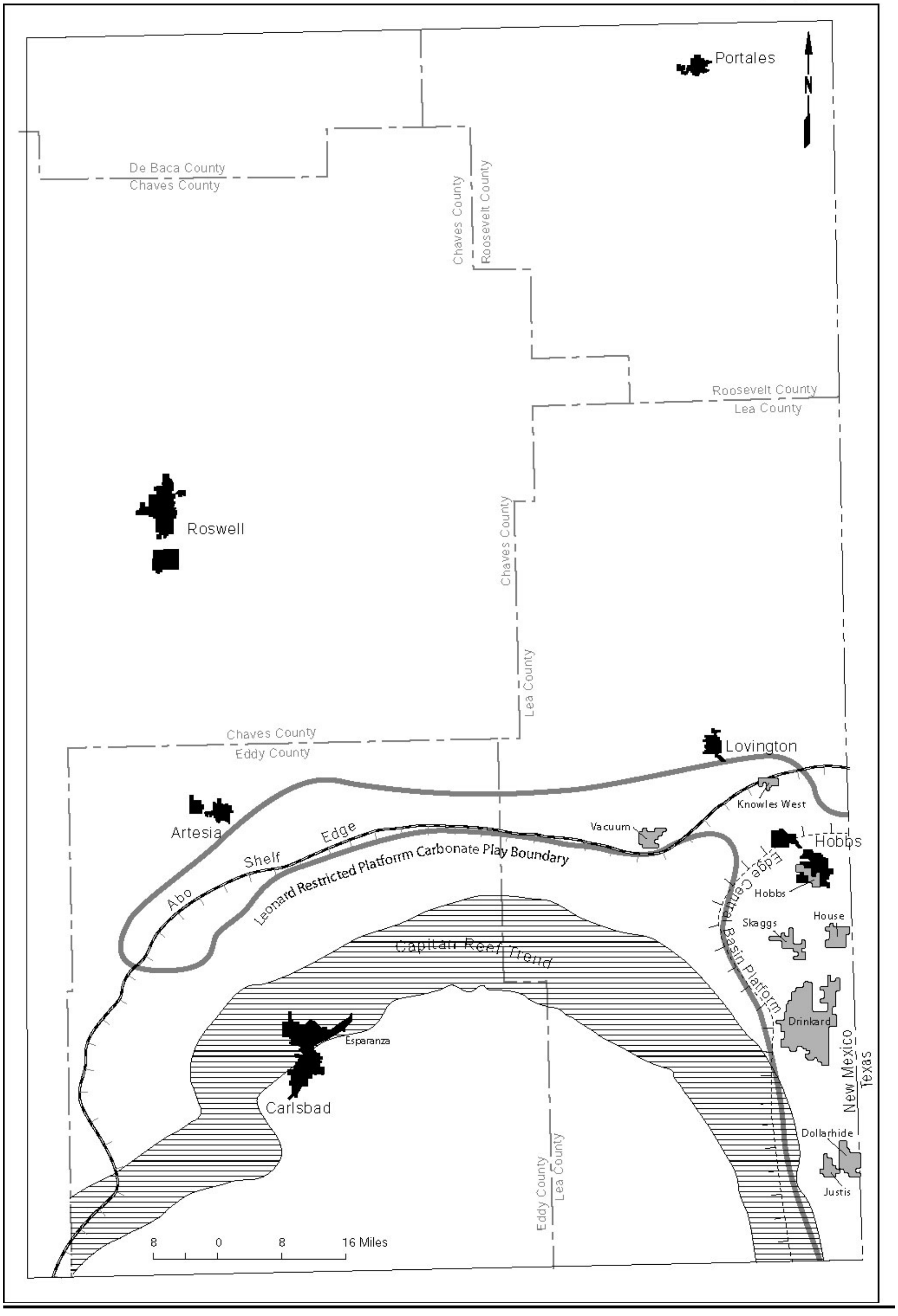

Figure 117-1 D. Location of reservoirs with more than 1 MMBO cumulative production in the Drinkard subplay of the Leonard Restricted Platform Carbonate play. Play outline shown is that of the entire Leonard Restricted Platform Carbonate play within New Mexico and not just the Drinkard subplay.

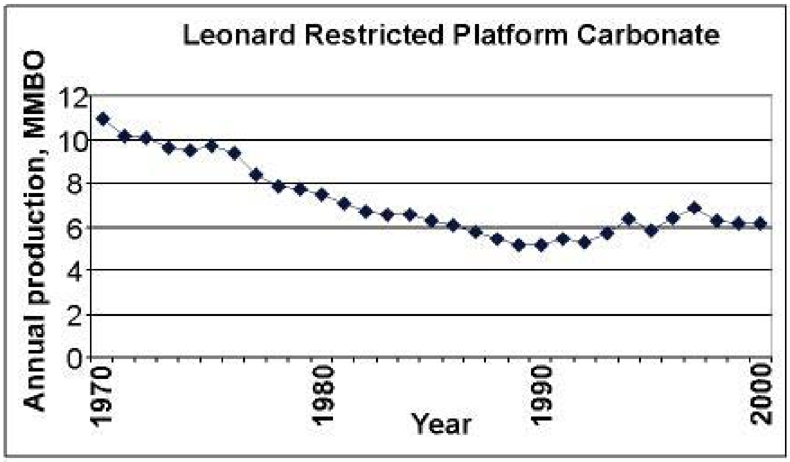

Figure 117-2. Historical annual production from 1970 to 2000 from reservoirs with more than 1 MMBO cumulative production in the Leonard Restricted Platform Carbonate play.

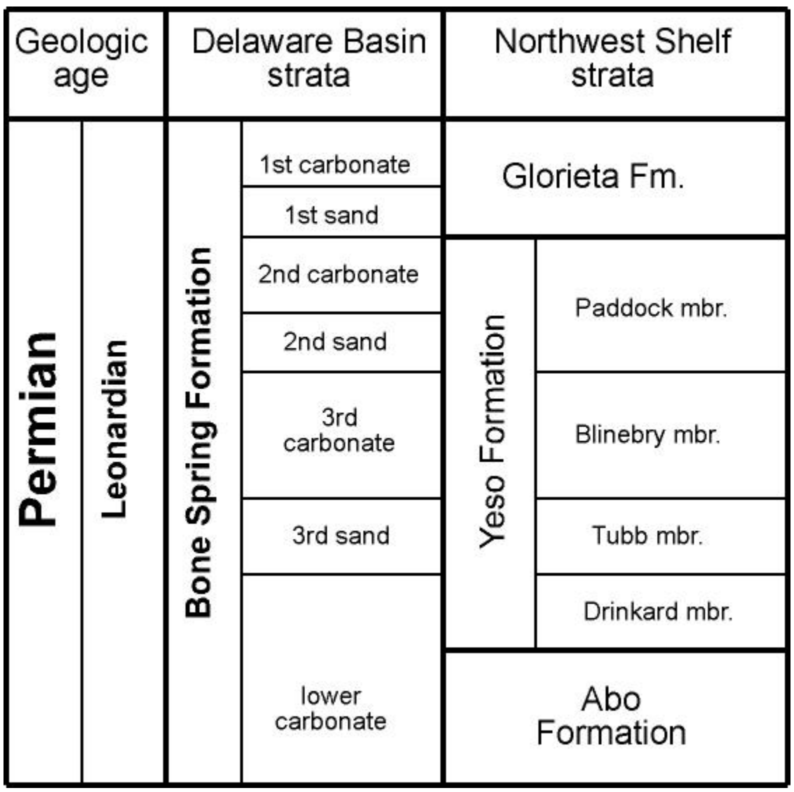

Figure 117-3. Stratigraphic chart showing correlation of Yeso strata on the Northwest Shelf with Lower Permian strata in the Delaware Basin. Modified from Gawloski (1987), Saller et al. (1989) and Tyrrell (2002).

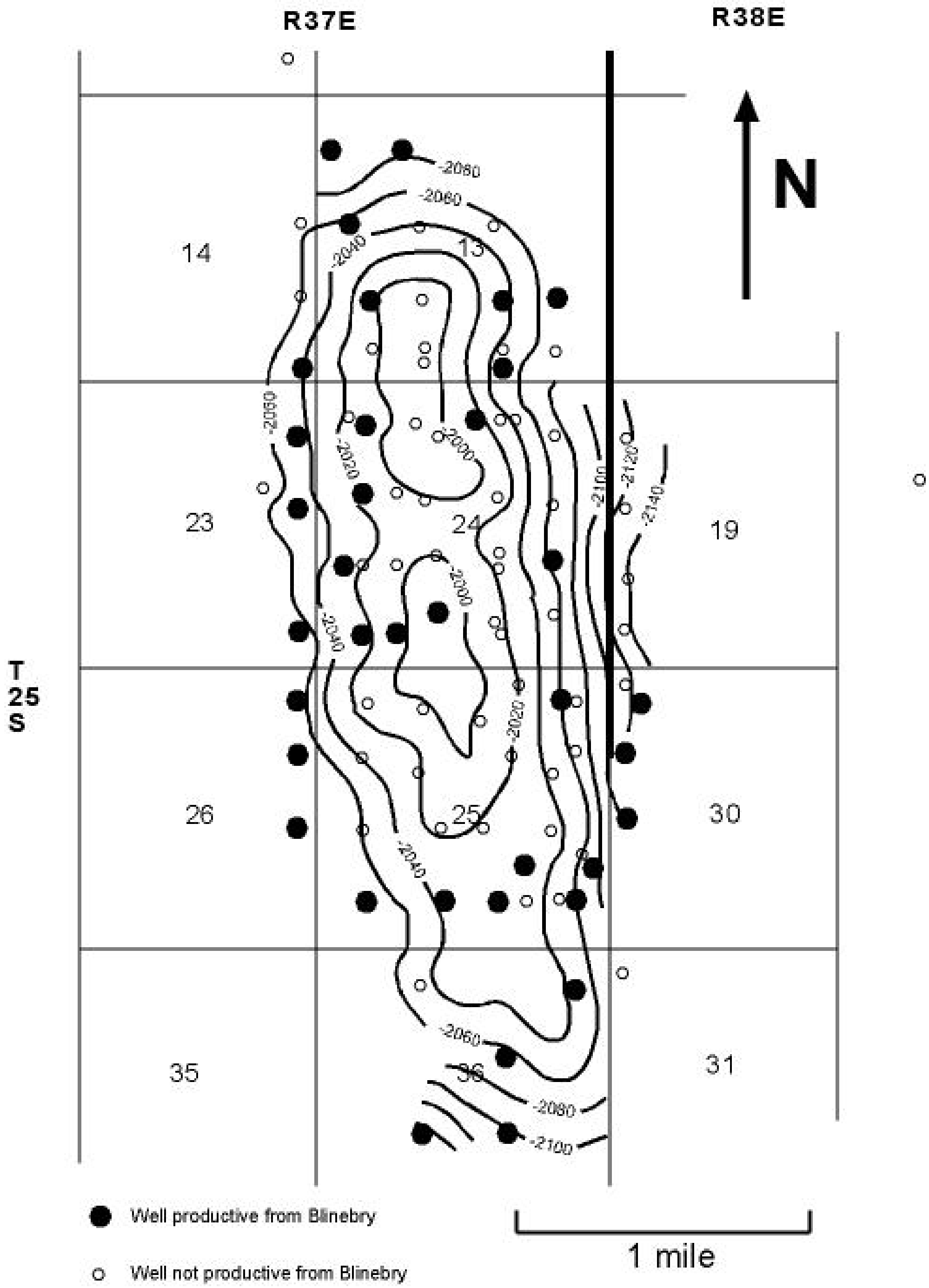

Figure 117-4. Structure contour map on top of Blinebry member of Yeso Formation, Justis Blinebry reservoir. Datum is sea level. Contour interval equals 20 ft. After Marshall and Foltz (1960).

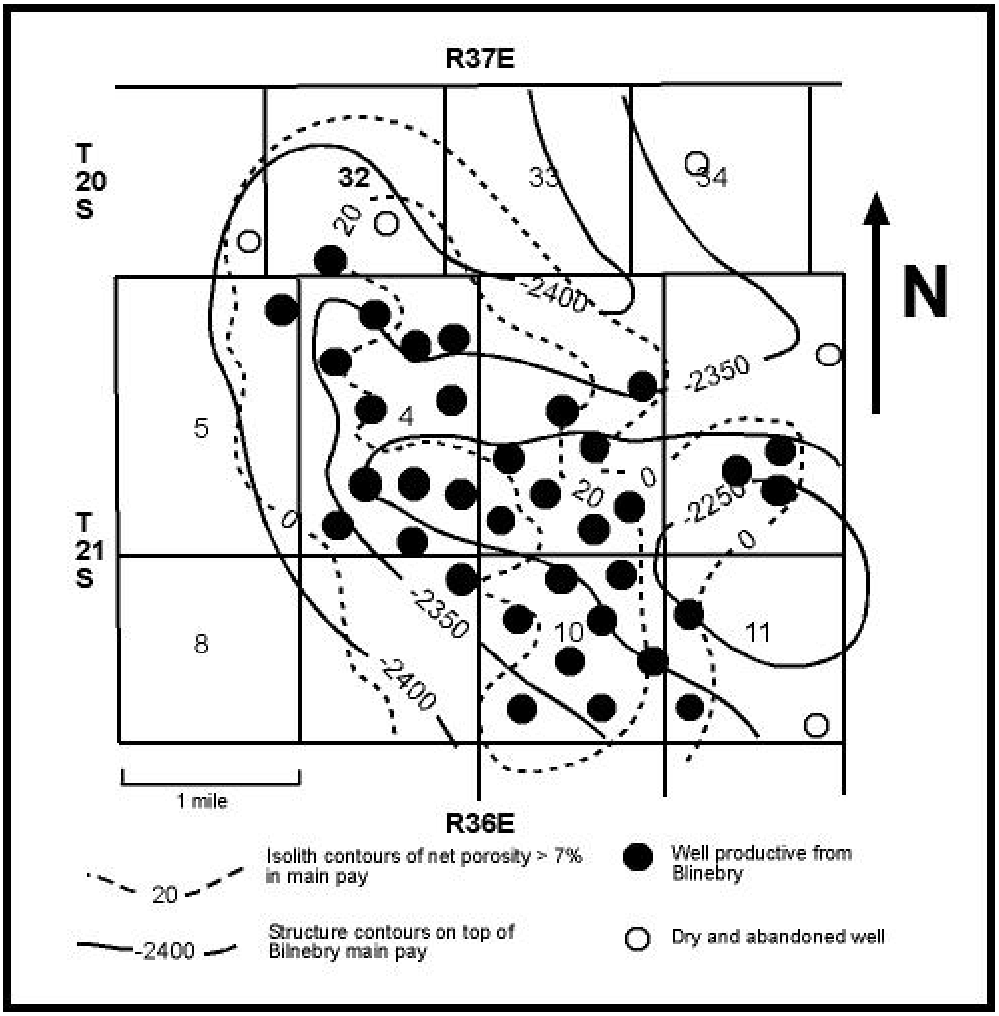

Figure 117-5. Structure contour map on top of the main Blinebry pay and isolith map of porosity greater than 7 percent, Oil Center Blinebry reservoir. Datum is sea level. After Kincheloe and David (1977).

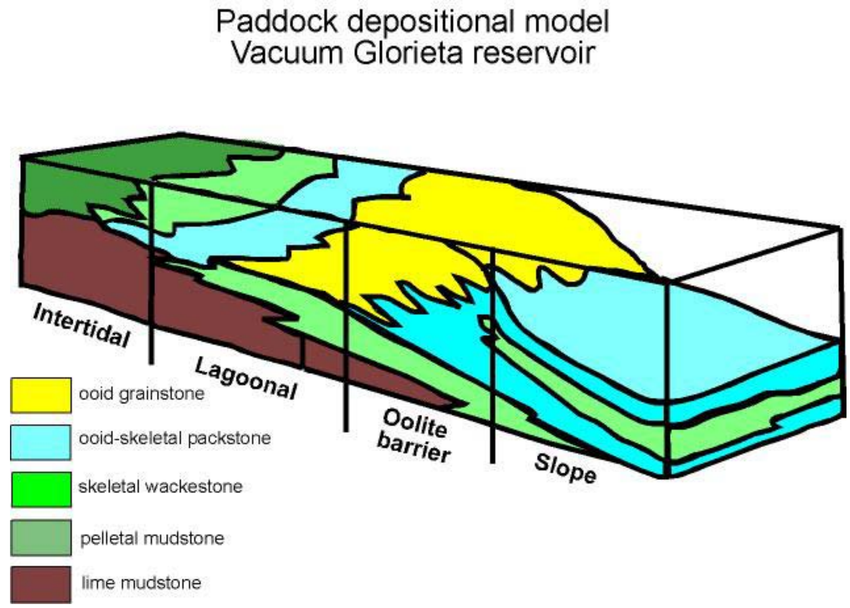

Figure 117-6. Block diagram of depositional environments in the Paddock member of the Yeso Formation, Vacuum Glorieta reservoir. After Burnham (1991).

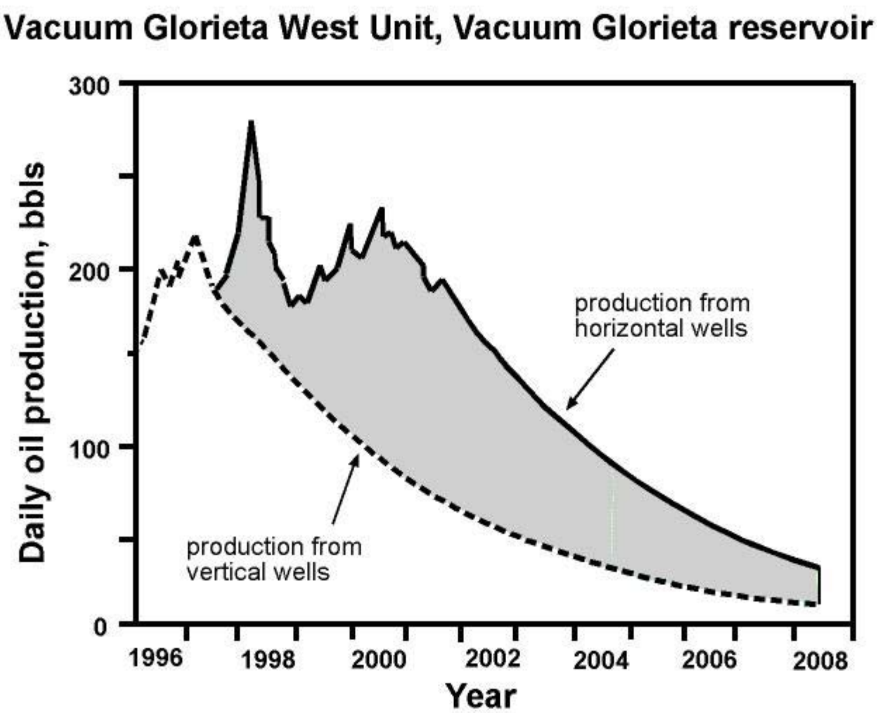

Figure 117-7. Daily oil production from the Vacuum Glorieta West Unit showing estimated incremental production that will be derived from the drilling of horizontal wells. From Martin and Hickey (2002).

Play 116 - Abo Platform Carbonate Play

Reservoirs of the Abo Platform Carbonate play lie along the southern margin of the Northwest Shelf and along the western margin of the Central Basin Platform (Fig. 116-1). Abo carbonate reservoirs are Leonardian (Permian) in age (Fig. 116-2). In New Mexico, the play is divided into two subplays, the Abo Platform Margin Carbonate subplay and the Abo Carbonate Shelf subplay. The Abo Platform Margin Carbonate subplay consists of reservoirs deposited at the shelf edge. The Abo Carbonate Shelf subplay consists of reservoirs that are found north of the shelf edge. There are 62 known, discovered reservoirs in the New Mexico part of the Abo Platform Carbonate play, 14 of which have produced more than 1 MMBO (Fig. 116-1; Table 116-1). Cumulative production from those 14 reservoirs was 455 MMBO as of 2000. During the 1970's, production in the play was dominated by the Empire Abo reservoir. As this important reservoir began to decline in the late 1970's, production from the play as a whole went into decline. Production from the play increased during the latter half of the 1990's (Fig. 116-3) as production in the Monument reservoir increased as a result of additional drilling. Annual production from the 14 reservoirs with more than 1 MMBO cumulative production was 3.68 MMBO during 2000.

Reservoirs in the Abo Platform Margin Carbonate subplay have been interpreted as classic fringing barrier reefs that grew at the shelf edge (LeMay, 1960), but more likely consist of a complex of a fringing reef and flanking carbonate sands. Runyan (1967) presented a map that indicated a narrow band of "reef detritus" on the basinward side of what he referred to as the "Abo reef"; this detritus forms the productive zone at the Double A reservoir. Although the exact depositional setting of the band of detrital material is not documented, structural position suggests it is detrital material that accumulated in deeper waters along the foreslope of the shelf margin.

Traps are largely stratigraphic and are located in porous shelf margin masses that are as long as 13 miles and as wide as 5 miles. The reservoir trend is localized along the pre-existing Bone Spring flexure (Snyder, 1962), which apparently formed a hingeline that marked the boundary between the Northwest Shelf and the Delaware Basin during the Early Permian. The reservoir trend is evident in younger, shallower strata by drape of the overlying sediments that forms the Artesia-Vacuum arch (Kelley, 1971).

Reservoirs in the Abo Platform Margin Carbonate subplay are white to light-gray, finely to coarsely crystalline dolostones (LeMay, 1960, 1972; Snyder, 1962). Pervasive dolomitization has obliterated depositional sedimentary structures and textures in the New Mexico reservoirs. Pay thickness exceeds 700 ft in parts of the Empire Abo reservoir but is less than 100 ft in most of the other reservoirs. Porosity is vugular, intercrystalline and fracture. Porosity and permeability are irregularly distributed and fluid communication within reservoirs is poor (LeMay, 1960, 1972). As a result, small gas pockets are present within structurally low areas of a reservoir. Depth to production ranges from 6000 to 9300 ft.

Traps in the shelf-margin reservoirs are predominantly stratigraphic (LeMay 1960, 1972). The vertical seal is formed by green siliciclastic shales and interbedded finely crystalline dolostones of the back reef facies that has prograded southward over the shelf-margin masses. East-west limits of the reservoirs are defined by gentle structural or morphologic plunge of the reservoir top under the oil-water contact or by occlusion of porosity by anhydrite cement on the shelf-ward side of the reservoir (LeMay 1960, 1972). The southern limits of the Abo shelf margin reservoirs are delineated by relatively sharp transition to nonporous, black argillaceous lime mudstones and fine-grained sandstones of the basinal Bone Spring Formation (Fig. 116-4). The dark-colored rocks of the Bone Spring are organic rich and are the probable source rocks for the oil in the shelf-edge carbonate reservoirs.

Reservoirs in the Abo Carbonate Shelf subplay are dolostones that were deposited on an evaporitic restricted marine shelf. Although poorly documented, traps appear to be formed by broad, low-relief anticlines. Porous zones appear to have relatively good continuity within defined reservoirs. Overall, however, porosity and permeability are unevenly distributed within Abo carbonates on the Northwest Shelf. Reservoirs are generally smaller and have smaller reserves in the Abo Carbonate Shelf subplay than reservoirs in the Abo Platform Margin Carbonate subplay. Only one reservoir in the Abo Carbonate Shelf subplay, Vacuum North, has produced more than 1 MMBO, although there are several other reservoirs that should produce 1 MMBO by the end of the next decade. Depth to production at Vacuum North is 8500 ft.

The primary drive mechanism for Abo carbonate reservoirs is primary gas-cap expansion supplemented by solution-gas drive. Best reservoir practices include perforating the pay zone at a sufficient depth below the gas-oil contact in order to prevent coning of the gas cap into the perforated interval, thereby conserving reservoir energy (Hueni and Schuessler, 1993). Unitization of the field may be implemented in order to initiate gas reinjection so that loss of reservoir energy, and therefore production rates, may be stabilized.

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Table 116-1. Reservoirs in the Abo Platform Carbonate play that had produced 1 MMBO as of the end of 2000. **Reservoir unit (NMOCD)** is the stratigraphic unit from which production is obtained, as designated by the New Mexico Oil Conservation Division. **O/G** indicates whether the reservoir is designated as an oil (O) reservoir or as a gas (G) reservoir. Cumulative production is through the end of 2000.

Reservoir Name	Reservoir Unit (NMOCD)	County	Discovery Year	Depth (feet)	O/G	2000 oil production (MMBO)	Cumulative production (MMBO)
Brunson South	Abo Drinkard	Lea	1974	6750	O	0.10	10.12
Buckeye	Abo	Lea	1965	8950	O	0.02	2.53
Corbin	Abo	Lea	1959	8410	O	0.07	15.68
Double A	Lower Abo	Lea	1960	9300	O	0.01	1.08
Double A South	Abo	Lea	1960	8900	O	0.02	1.97
Empire	Abo	Eddy	1957	6014	O	0.05	225.14
Jackson	Abo	Eddy	1961	6910	O	<0.01	1.05
Lovington	Abo	Lea	1951	8340	O	0.08	33.98
Maljamar	Abo	Lea	1959	8977	O	0.00	1.03
Monument	Abo	Lea	1948	7180	O	1.29	7.14
Monument North	Abo	Lea	1977	7300	O	0.22	1.20
Vacuum	Abo Reef	Lea	1960	8650	O	0.37	91.16
Vacuum North	Abo	Lea	1963	8500	O	1.30	52.98
Wantz	Abo	Lea	1950	6560	O	0.13	9.87
TOTALS						**3.68**	**454.94**

Abo Platform Carbonate Play

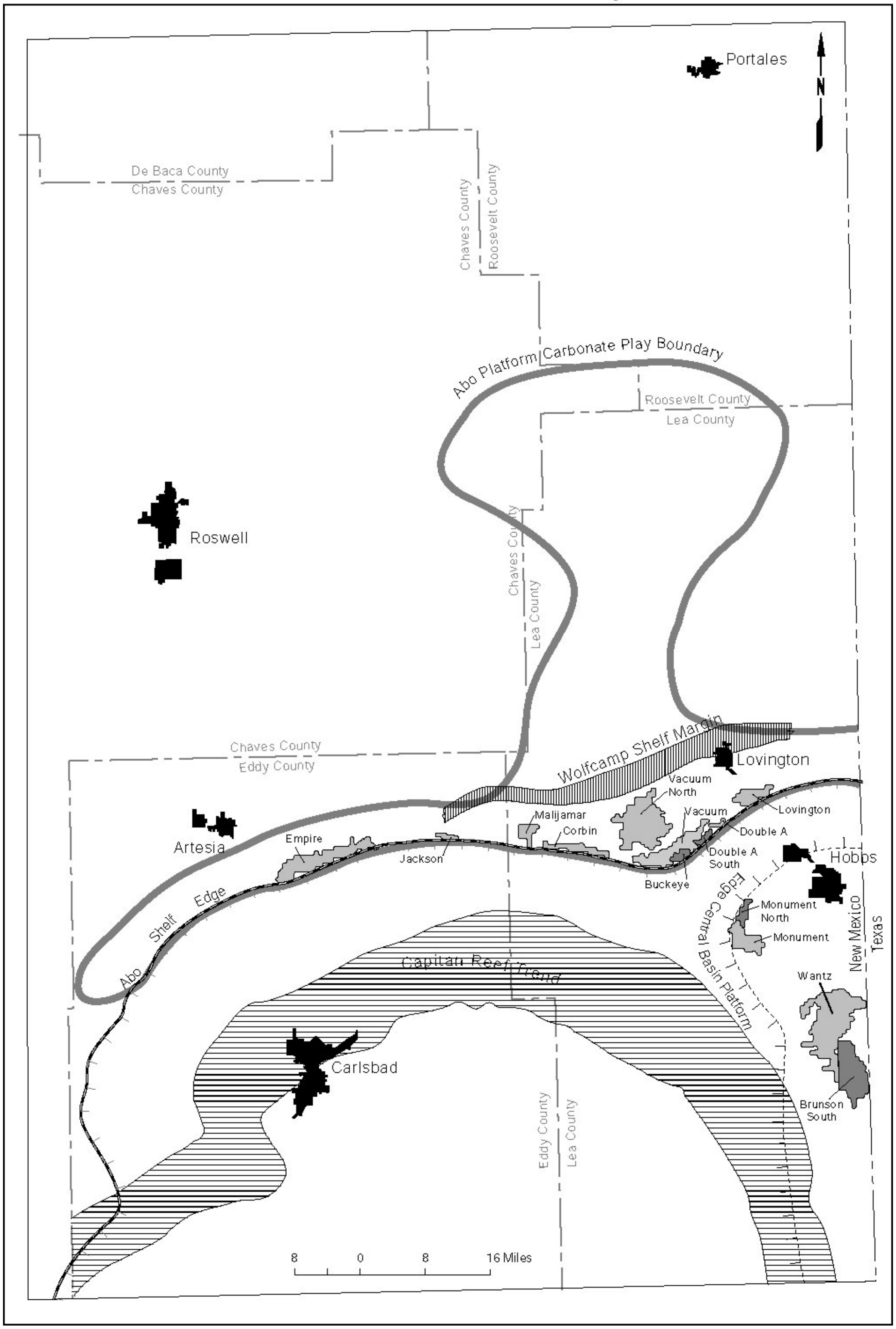

Figure 116-1. Location of reservoirs with more than 1 MMBO cumulative production in the New Mexico part of the Abo Platform Carbonate play.

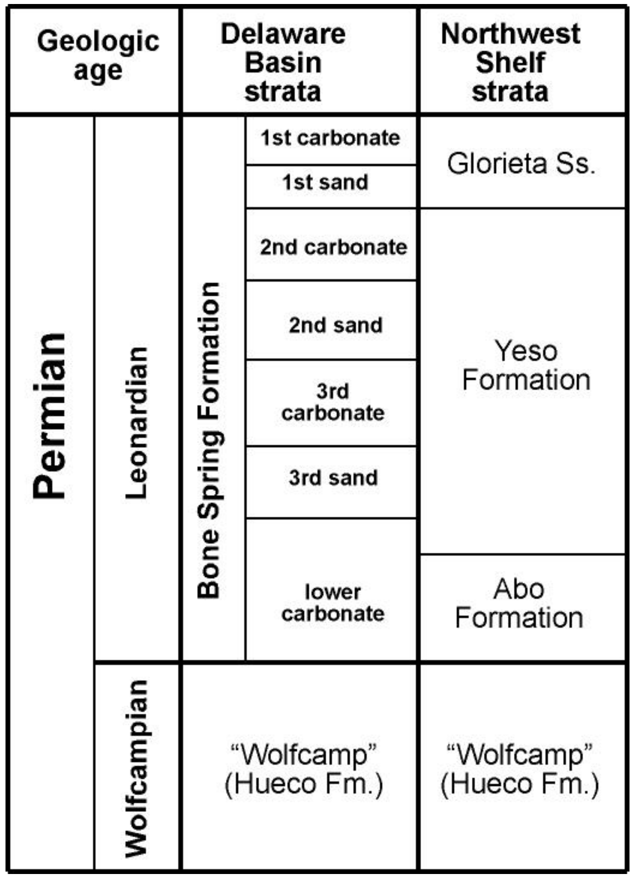

Figure 116-2. Stratigraphic chart showing relationship of Abo carbonate strata on the Northwest Shelf to equivalent basinal strata of the Delaware Basin. Modified from Gawloski (1987), Saller et al., (1989), and Tyrrell (2002).

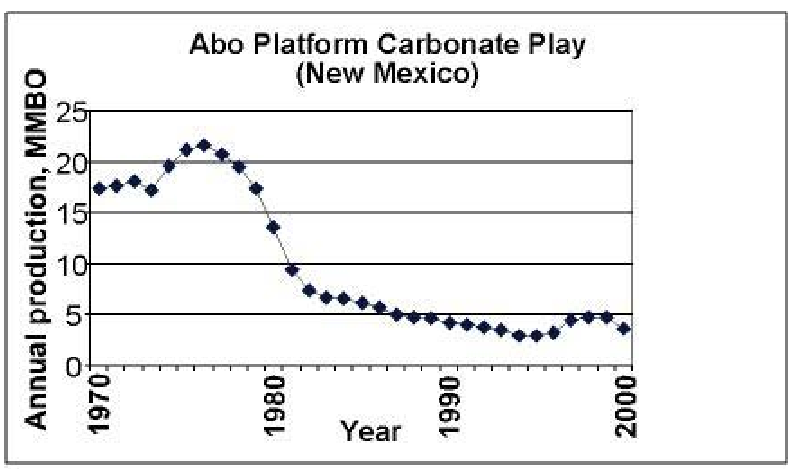

Figure 116-3. Historical annual production from 1970 to 2000 from reservoirs with more than 1 MMBO cumulative production in the Abo Platform Carbonate play.

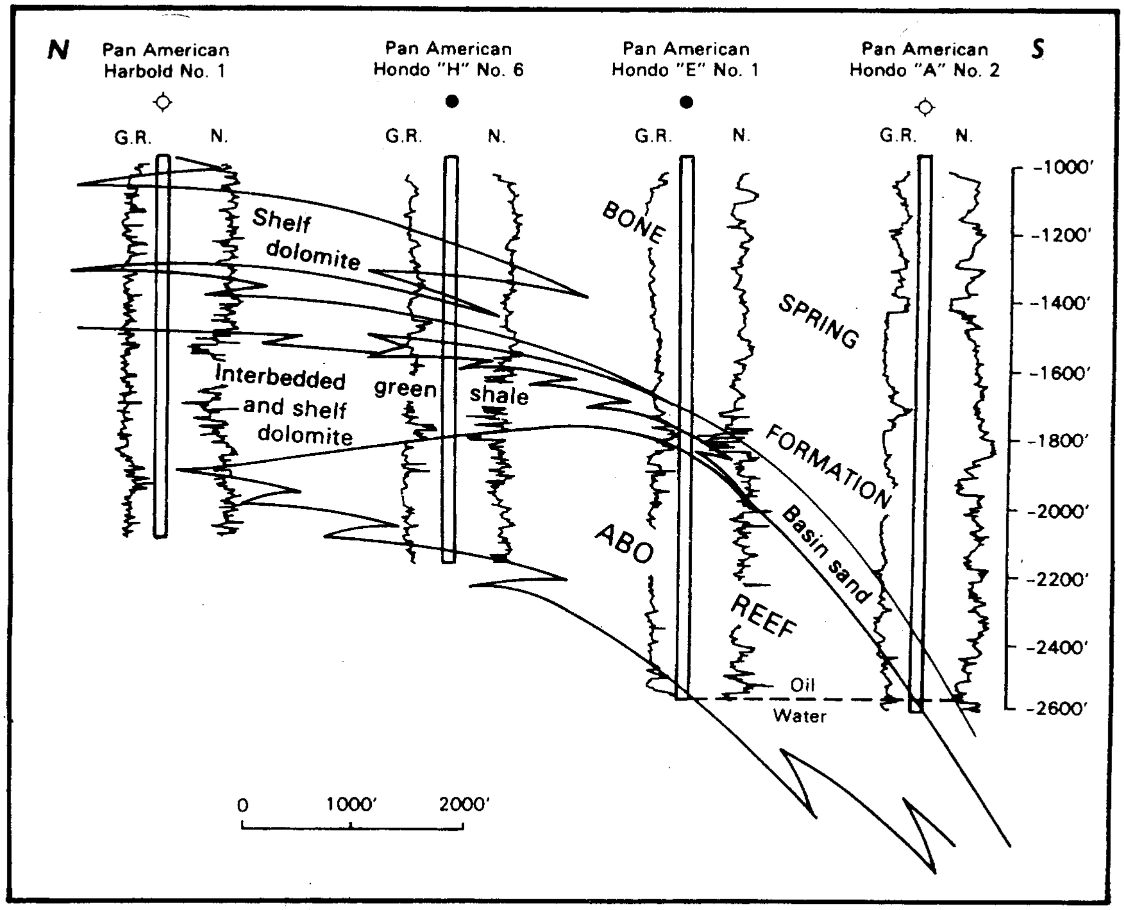

Figure 116-4. North-south structural cross section through Empire Abo reservoir showing relationship of porous Abo reef (shelf margin) facies to Abo backreef facies and basinal Bone Spring Formation. Vertical scale is in feet below sea level. From LeMay (1960). See LeMay (1960) for location of cross section.

Play 115 - Wolfcamp/Leonard Slope and Basinal Carbonate Play

Wolfcamp reservoirs in New Mexico are divided into two major plays: those with reservoirs deposited on the Northwest Shelf and the margin of the Northwest Shelf (the *Wolfcamp Platform Carbonate play*), and those deposited south of the shelf margin within the Delaware Basin (*Wolfcamp/Leonard Slope and Basinal Carbonate play*; Fig. 115-1). This play description discusses the reservoirs deposited south of the shelf margin. Nine New Mexico reservoirs in this play have produced more than 1 MMBO (Table 115-1). Cumulative production from these nine reservoirs was 32 MMBO as of 2000. Eight of the nine reservoirs produce from Wolfcampian-age basinal carbonates with cumulative production of 23.9 MMBO. One reservoir, Wantz, is productive from clastics of the Granite Wash subplay. The Wantz Granite Wash reservoir produced 7.8 MMBO as of 2000. Although the New Mexico reservoirs are Wolfcampian in age, similar reservoirs in the Texas part of the Permian Basin are in Lower Leonardian strata as well as in Wolfcampian strata; therefore the play name encompasses Leonardian strata as well as Wolfcampian strata.

Between 1970 and 2000, production from this play rose from 430 thousand bbls oil per year during 1970 to a peak of more than 1.4 MMBO per year during 1992 and has since declined to approximately 640 thousand bbls per year (Fig. 115-2). Since 1970, there have been three substantial peaks in production: 1) from 1974 to 1977; 2) in 1983; and 3) from 1991 to 1992. The 1974 to 1977 peak resulted from maximum development of the Wantz Granite Wash reservoir in the Granite Wash subplay. The 1983 peak was a result of full development of the Scharb reservoir following discovery in 1980. The 1991 to 1992 peak was a result of redevelopment and additional drilling in the Corbin South reservoir.

Reservoirs in this play are located basinward of the Wolfcampian shelf margin. Where this margin has been mapped in detail, it extends approximately from the southern part of T16S R31E to the southern part of T15S R36E (Malek-Aslani, 1970) and is also present to the west in the northernmost part of T18S R27-28E (Loucks et al., 1985). The Wolfcamp shelf margin appears to be roughly coincident with the overlying, younger Abo shelf margin but in some places may be seaward of it or landward of it by as much as one mile. Production is largely derived from limestones in the lower Wolfcamp although limestones in the middle to upper Wolfcamp are productive in some reservoirs.

Most productive strata appear to be carbonate debris flows derived from the shelf margin (see Loucks et al., 1985) or possibly the slope. Traps are largely stratigraphic, with reservoirs encased in dark-gray to black, kerogen-rich basinal shales which act as both the seal and the source rock. The eight reservoirs in the New Mexico part of this play that are productive from carbonates occur at depths from 9160 to 13,500 ft.

Two lower Wolfcampian New Mexico reservoirs (Vacuum North, Shoe Bar North) were placed in this play because they lie immediately south of the shelf edge as mapped by Malek-Aslani (1970). The lithology and depositional setting of these reservoirs is not well known, so it is conceivable that they are actually platform margin reservoirs deposited during temporally limited progradation of the shelf margin. However, their position in terms of recognized paleobathymetry indicates they should be included in the Wolfcamp/Leonard Slope and Basinal Carbonate play rather than in the Wolfcamp Platform Carbonate play. Further south, the Scharb reservoir is formed by allocthonous debris flow carbonates deposited on the Wolfcamp paleoslope (Mazzullo and Arrant, 1988). Burton Flat North is productive from carbonates in a shale-rich part of the Wolfcamp. The Wolfcamp at Johnson Ranch is comprised of interbedded brown limestone and brown shale and is interpreted as a basinal facies on the basis of this gross lithologic description as well as its distant location from the shelf margin.

Two Wolfcamp reservoirs in New Mexico, Vacuum and Corbin, have been assigned to the Wolfcamp/Leonard Slope and Basinal Carbonate play based on their location south of the Wolfcamp shelf margin as mapped by Malek-Aslani (1970, 1985; Figs. 114-1, 115-1). The mapped shelf margin is based on lower Wolfcamp facies. Vacuum is productive from both the upper and lower parts of the Wolfcamp and Corbin South is productive from the upper and middle parts of the Wolfcamp. The lower and middle Wolfcamp in this area are comprised of interbedded dark shales and limestones and on this basis appear to be basinal facies. The upper Wolfcamp, however, is comprised dominantly of light-colored carbonates. At the Vacuum reservoir, the upper Wolfcamp has a mound shaped appearance and crosswell seismic tomography indicates the productive interval has internal clinoformal bedding (Martin et al., 2002). On the basis of overall shape and internal bedding surfaces, Martin et al. (2002) suggested that the upper Wolfcamp reservoir may be an isolated algal mound deposited on the Wolfcamp shelf. If this is the case, then the upper parts of the Vacuum reservoir belong in the *Wolfcamp Carbonate Shelf play* and the shelf edge prograded southward at least 10 to 12 miles during Wolfcamp time from an initial location the Kemnitz reservoir (fig. 114-1) to a position south of the Vacuum reservoir (fig. 115-1). If the upper part of the Vacuum reservoir is a shelf deposit, then general location and general lithologic composition suggest that the upper part of the Corbin South reservoir was also deposited on the Wolfcamp shelf, and not in the basin. Alternatively, the southward prograding clinoforms seen via crosswell seismic tomography in the Vacuum reservoir may be indicative of southward prograding slope deposits.

Granite Wash subplay

Reservoirs in the Granite Wash subplay are productive from laterally discontinuous Wolfcampian-age conglomerates and "granite wash" arkosic sandstones deposited on the flanks of structural highs of Early Permian age and in paleotopographic lows on top of structural highs of Early Permian age (Bowsher and Abendshein, 1988; Speer, 1993). The sandstones are encased in shales that seal the sandstone and conglomerate reservoirs. Examination of drill cuttings and logs indicates that a portion of the reservoir resides in fractured Precambrian granite that underlies the granite wash (A.L. Bowsher, cited in Speer, 1993). Low-displacement high-angle faults, acting in concert with the lenticular geometry of the reservoir sands and conglomerates, compartmentalize reservoirs. Compartmentalization has perhaps prevented optimal development with standard vertical wells drilled on 40-acre spacing. Average depth to the Wantz reservoir is 7200 ft.

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Table 115-1. Reservoirs in the Wolfcamp/Leonard Slope and Basinal Carbonate play that had produced 1 MMBO as of the end of 2000. **Reservoir unit (NMOCD**) is the stratigraphic unit from which production is obtained, as designated by the New Mexico Oil Conservation Division. **O/G** indicates whether the reservoir is designated as an oil (O) reservoir or as a gas (G) reservoir. Cumulative production is through the end of 2000.

Reservoir Name	**Reservoir Unit (NMOCD)**	**County**	**Discovery Year**	***Depth* (feet)**	**O/G**	**2000 oil production (MMBO)**	**Cumulative production (MMBO)**
Baish	Wolfcamp	Lea	1962	9800	O	0.03	1.07
Burton Flat North	Wolfcamp	Eddy	1975	9160	G	0.05	3.33
Corbin South	Wolfcamp	Lea	1967	11000	O	0.13	6.61
Johnson Ranch	Wolfcamp	Lea	1985	13500	G	0.29	1.38
Scharb	Wolfcamp	Lea	1980	10519	O	0.02	1.20
Shoe Bar North	Wolfcamp	Lea	1973	10456	O	0.02	1.71
Vacuum	Wolfcamp	Lea	1962	9950	O	0.08	6.66
Vacuum North	Lower Wolfcamp	Lea	1967	10690	O	0.00	1.95
Wantz*	Granite Wash	Lea	1963	7270	O	0.08	7.78
TOTALS						**0.69**	**31.69**

* The Wantz Granite Wash reservoir is productive from clastics of the Granite wash subplay and not carbonates of the Wolfcamp/Leonard Slope and Basinal Carbonate play.

Wolfcamp/Leonard Slope and Basinal Carbonate Play

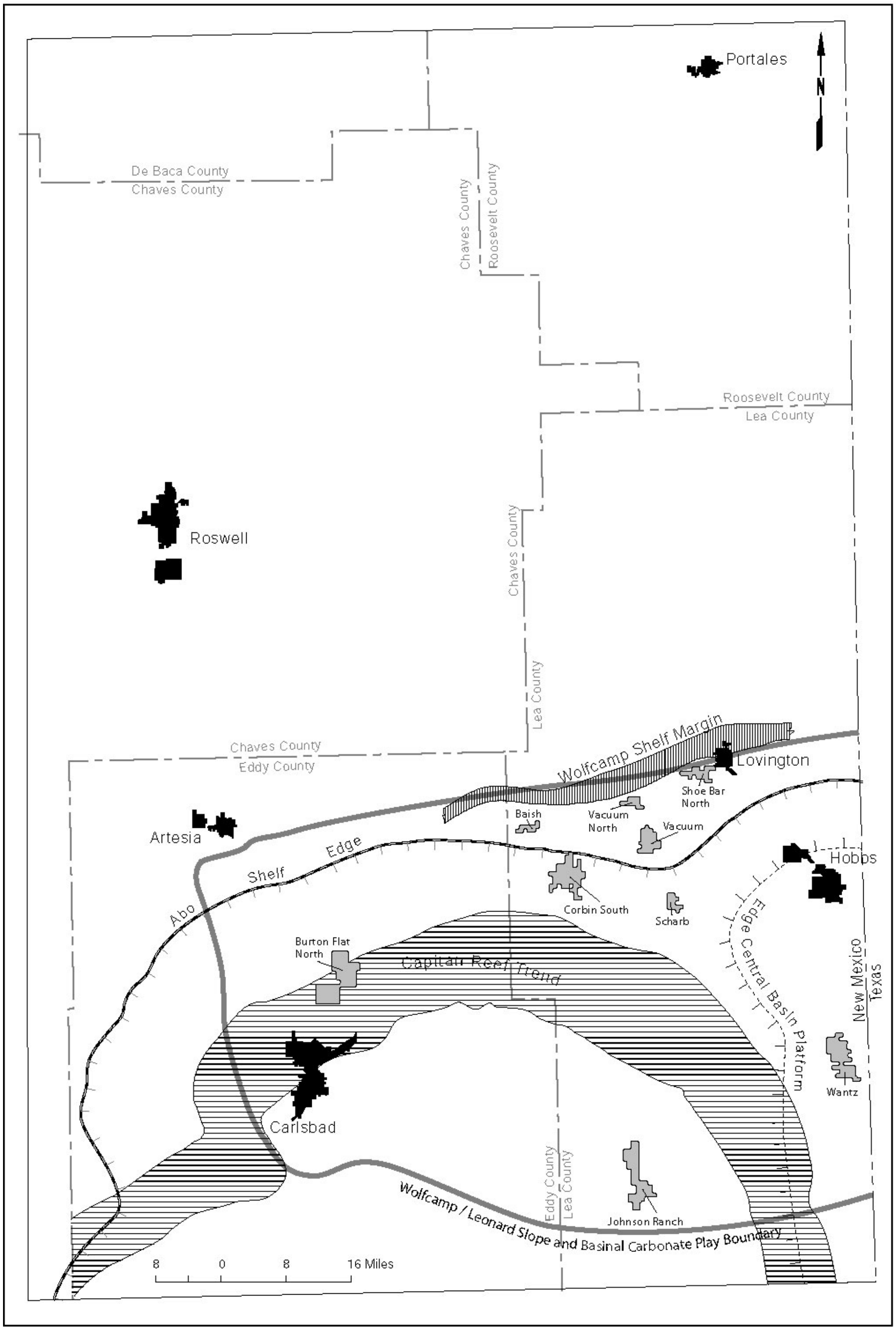

Figure 115-1. Location of reservoirs with more than 1 MMBO cumulative production in the New Mexico part of the Wolfcamp/Leonard Slope and Basinal Carbonate play.

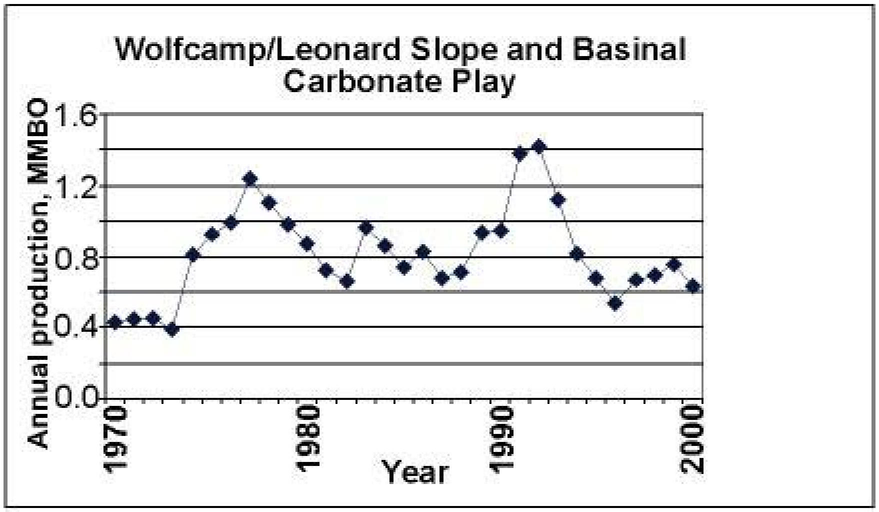

Figure 115-2. Annual production from 1970 to 2000 for the nine reservoirs within the Wolfcamp/Leonard Slope and Basinal Carbonate play that have produced more than 1 MMBO.

Play 114 - Wolfcamp Platform Carbonate Play

Wolfcamp reservoirs in New Mexico are divided into two major plays: those with reservoirs deposited on the shelf and shelf margin of the northern Delaware Basin (the *Wolfcamp Platform Carbonate play*; Fig. 114-1), and those deposited basinward of the shelf margin (*play 115, Wolfcamp/Leonard Slope and Basinal Carbonate*). The Wolfcamp Platform Carbonate play includes those Wolfcampian age carbonate reservoirs located on the shelf margin and the shelf to the north. The Wolfcamp Platform Carbonate play has sixteen New Mexico reservoirs with cumulative production of at least 1 MMBO as of 2000. Total cumulative production from these 16 reservoirs is 116.29 MMBO. Production from this play has declined from 2 MMBO per year in 1970 to 570 thousand bbls per year in 2000 (Fig. 114-2). Depths to reservoirs range from 7580 to 10,750 ft. Although similar in age and depositional setting to reservoirs in the *Northwest Shelf Upper Pennsylvanian Carbonate play* (play 110), the reservoir strata in the Wolfcamp Platform Carbonate play are slightly younger and have traditionally been grouped into a separate play.

Reservoirs in this play are located on or shelfward (northward) of the east-west trending Wolfcampian shelf margin, the central portion of which extends approximately from southern T16S R31E to southern T15S R36E (Fig. 114-1; see Malek-Aslani, 1970). Although some reservoirs are found well north of the shelf margin, most are clustered on or near the shelf margin. Production is largely derived from lower Wolfcamp units. Shelf margin reservoirs are interpreted to lie within a barrier reef complex, with lithologies consisting of reefal (hydrozoan boundstones), backreef (skeletal grainstones), and forereef (talus slope) facies (Malek-Aslani, 1970). The northern shelf area reservoirs are composed of shallow marine limestone facies, with most accumulations found in phylloid-algal bioherms developed on pre-existing paleobathymetric highs or as grainstones capping and flanking the bioherms (Malek-Aslani, 1985; Cys and Mazzullo, 1985; Cys, 1986).

Traps on the shelf are largely stratigraphic, with porosity pinchouts formed by porous biohermal and grainstone facies that grade laterally into lower porosity non-biohermal facies. On the shelf margin, traps are combinations of structural high areas and stratigraphic pinchouts (porous reefal facies laterally juxtaposed with lower porosity non-reef strata). The structural high areas generally trend north-south and are believed to be bounded by low-relief faults of probable Wolfcampian age. Because of the relationship of Wolfcamp reservoirs to positive structural elements that have a tectonic origin, it is common to find Wolfcamp reservoirs stacked atop structurally controlled reservoirs in older, deeper strata.

Two Wolfcamp reservoirs in New Mexico, Vacuum and Corbin South, have been assigned to the *Wolfcamp/Leonard Slope and Basinal Carbonate play* (play 115) based on their location south of the Wolfcamp shelf margin as mapped by Malek-Aslani (1970, 1985; Figs. 114-1, 115-1). The mapped shelf margin is based on lower Wolfcamp facies. Vacuum is productive from both the upper and lower parts of the Wolfcamp and Corbin South is productive from the upper and middle parts of the Wolfcamp. The lower and middle Wolfcamp in this area are comprised of interbedded dark shales and limestones and are basinal facies. The upper Wolfcamp, however, is comprised dominantly of light-colored carbonates. At the Vacuum reservoir, the upper Wolfcamp has a mound-shaped appearance and crosswell seismic tomography indicates the productive interval has internal clinoformal bedding (Martin et al., 2002). On the basis of overall shape and internal bedding surfaces, Martin et al. (2002) suggested that the upper Wolfcamp reservoir may be an isolated algal mound deposited on the Wolfcamp shelf. If this is the case, then the upper parts of the Vacuum and Corbin South reservoirs are in the *Wolfcamp Carbonate Shelf play* (114) and the shelf edge prograded southward at least 10 to 12 miles during Wolfcamp time from the Kemnitz reservoir (Fig. 114-1) to a position south of the Vacuum reservoir (Fig. 115-1). If the upper part of the Vacuum reservoir is a shelf deposit, then general location and general lithologic composition suggest that the upper part of the Corbin South reservoir was also deposited on the Wolfcamp shelf, and not in the basin. Alternatively, the southward prograding clinoforms seen via crosswell seismic tomography in the Vacuum reservoir may be indicative of southward prograding slope deposits.

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Table 114-1. Reservoirs in the Wolfcamp Platform Carbonate play that had produced 1 MMBO as of the end of 2000. **Reservoir unit (NMOCD)** is the stratigraphic unit from which production is obtained, as designated by the New Mexico Oil Conservation Division. **O/G** indicates whether the reservoir is designated as an oil (O) reservoir or as a gas (G) reservoir. Cumulative production is through the end of 2000.

Reservoir Name	**Reservoir Unit (NMOCD)**	**County**	**Discovery Year**	**Depth (feet)**	**O/G**	**2000 oil production (MMBO)**	**Cumulative production (MMBO)**
Anderson Ranch	Wolfcamp	Lea	1953	9760	O	0.02	4.24
Anderson Ranch North	Wolfcamp	Lea	1960	9823	O	0.03	6.65
Bronco	Wolfcamp	Lea	1953	9600	O	<0.01	2.09
Caudill	Permo Penn	Lea	1956	10285	O	0.01	1.98
Denton	Wolfcamp	Lea	1950	9240	O	0.24	41.76
Gladiola	Wolfcamp	Lea	1950	9578	O	0.01	4.14
Henshaw	Wolfcamp	Eddy	1960	8822	O	0.01	3.40
Kemnitz	Lower Wolfcamp	Lea	1956	10742	O	0.02	16.61
Kemnitz West	Wolfcamp	Lea	1963	10678	O	<0.01	1.03
King	Wolfcamp	Lea	1951	9300	O	0.02	1.37
Lane	Wolfcamp	Lea	1955	9700	O	0.00	1.03
Morton	Wolfcamp	Lea	1964	10310	O	0.01	2.61
Morton East	Wolfcamp	Lea	1970	10506	O	0.02	1.78
Todd	Wolfcamp	Roosevelt	1971	7580	O	0.03	1.12
Townsend	Permo-Upper Penn	Lea	1952	10400	O	0.12	24.10
Tulk	Wolfcamp	Lea	1951	9700	O	0.02	2.43
TOTALS						**0.57**	**116.32**

Wolfcamp Platform Carbonate Play

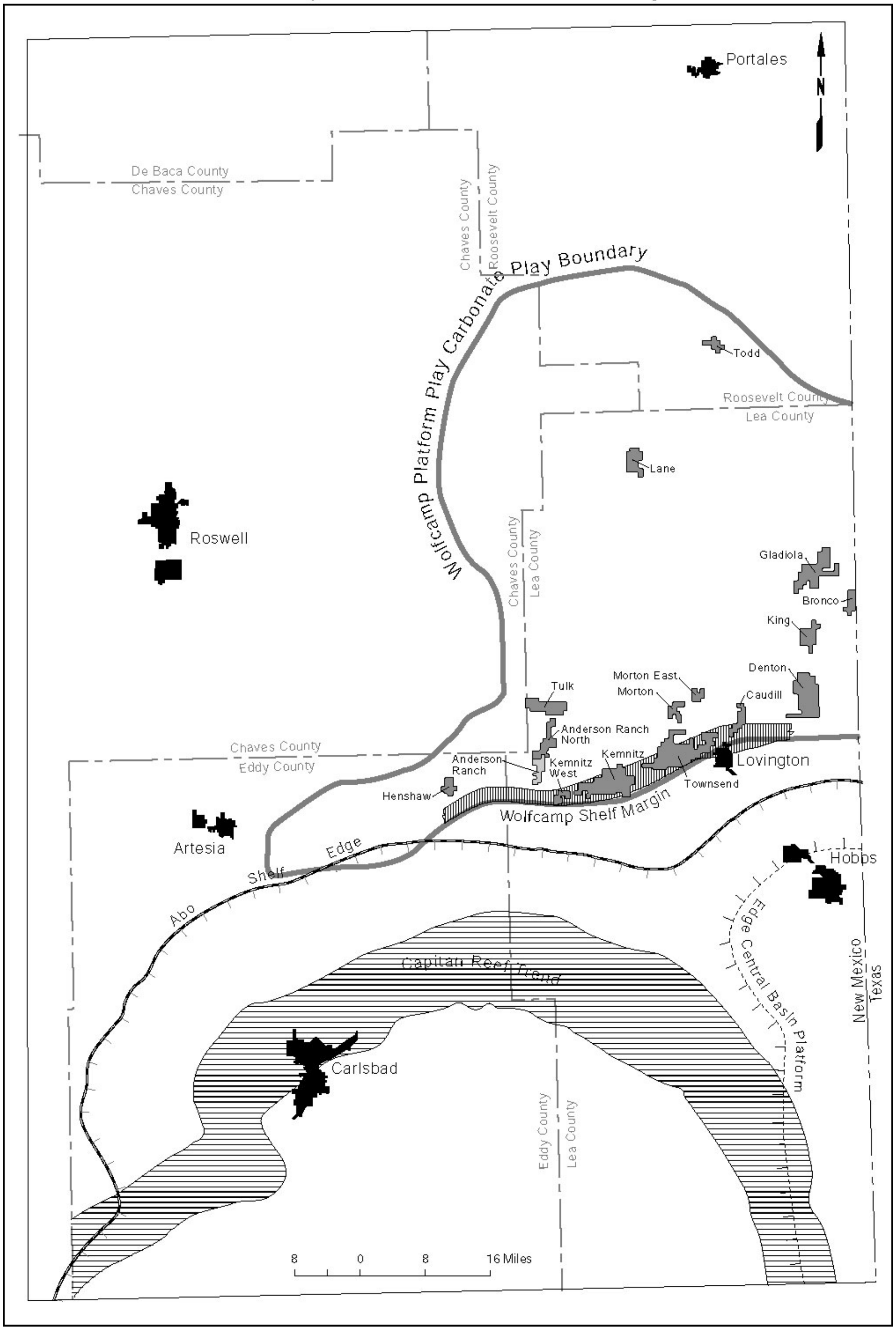

Figure 114-1. Location of reservoirs with more than 1 MMBO cumulative production in the New Mexico part of the Wolfcamp Platform Carbonate play. Trend of Wolfcamp shelf margin from Malek-Aslani (1970).

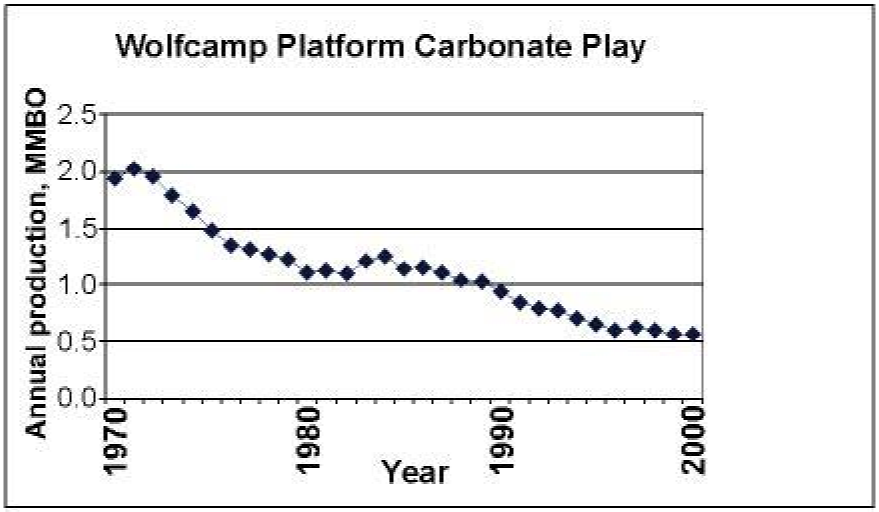

Figure 114-2. Annual production from 1970 to 2000 for the 16 reservoirs within the Wolfcamp Platform Carbonate play that have produced more than 1 MMBO.

Play 110 - Northwest Shelf Upper Pennsylvanian Carbonate Play

Reservoirs of the Northwest Shelf Upper Pennsylvanian Carbonate play lie on the Northwest Shelf of the Permian Basin. The trend of reservoirs extends from the shelf edge near Carlsbad in Eddy County onto the shelf interior in Roosevelt and Chaves Counties (Fig. 110-1). There are 197 known, discovered reservoirs in this play, 34 of which have produced more than 1 MMBO (Table 110-1). Cumulative production from these 34 reservoirs was 354 MMBO as of 2000. During the 1990's, annual production from this play peaked at 11.2 MMBO during 1996 and has since declined by 56 percent to 4.9 MMBO per year (Fig. 110-2), largely as a result of production decline in the Dagger Draw North and Dagger Draw South reservoirs. The production increase during the early 1990's is a result of new oil brought online with renewed development of the Dagger Draw reservoir.

Reservoirs are carbonates of Canyon (Upper Pennsylvanian: Missourian) age, the Cisco and Bough D zones (Upper Pennsylvanian: Virgilian) age, and the Bough B and C zones of earliest Wolfcampian (Permian) age (Fig. 110-3). The Bough A, B and C zones have been traditionally considered by the industry and regulatory entities as Virgilian in age but fusulinid biostratigraphy indicates they are of lowermost Wolfcampian age (Cys and Mazzullo, 1985; Cys, 1986). More recent work based on correlation with conodonts has suggested that the Bough intervals may perhaps be of latest Virgilian age after all (see Wahlman, 2001). Whatever their correct age assignment, the Bough B and C zones form major reservoirs on the Northwest Shelf from Saunders northward to Allison although the underlying Bough D zone of definite Upper Pennsylvanian age also contributes significant production in many of the reservoirs along this trend. The stratigraphic relationship of reservoirs in the Northwest Shelf part of this play to the reservoirs in the Wolfcamp Platform carbonate play (play no. 114) is not well established but available data indicate that the reservoirs assigned to the Wolfcamp Platform carbonate play are younger than those assigned to this play with Wolfcamp Platform Carbonate play reservoirs productive from the Bough A and younger zones.

Traps in the Northwest Shelf Upper Pennsylvanian carbonate play are primarily stratigraphic and are formed by phylloid algal mounds and associated grainstones and packstones (Cys, 1986; Speer, 1993; Cox et al., 1998; Mazzullo, 1998). Reservoirs on the Northwest Shelf are limestones. On shelf areas, wide and well-bedded phylloid algal banks grew across shallow water paleobathymetric highs (Wahlman, 2001). The boundaries of many of the reservoirs on the Northwest Shelf are regulatory in nature and much of the oil has accumulated in essentially continuous stratigraphic traps that cross reservoir boundaries that are regulatory rather than geologic in nature. Reservoirs in the southwestern part of the play (e.g. Dagger Draw North, Dagger Draw South) are Missourian to Virgilian in age, older than on the Northwest Shelf, and have generally been dolomitized. On the shelf edge, traps are formed primarily by massive phylloid algal mound complexes that grew along paleobathymetric breaks (Cox et al., 1998; Wahlman, 2001). Productive porosity is mostly intercrystalline, intergranular, and vugular; the porosity system is dominated by vugular porosity. Depth to production varies from 7400 ft to 11,500 ft.

At Dagger Draw North and Dagger Draw South, production is obtained from a dolomitized fairway of shelf-edge algal mounds and intermound grainstones and packstones (Cox et al., 1998; Fig. 110-4). Impermeable, thinly bedded limestones lay shelfward and act as a seal on the shelf side of the algal mound trend. Impermeable basinal black shales, that also act as source rocks for the algal mound complex, lie basinward.

Upper Pennsylvanian carbonate reservoirs on the Northwest Shelf have typically been discovered by drilling small, seismically defined anticlines. Initial development has generally been concentrated on the crests of the anticlines and, in most of the larger fields, generally has not extended into off structure areas (Broadhead, 1999; Fig. 110-5). However, in many cases, the anticlinal structures have little, if anything, to do with oil entrapment. Subsequent drilling in many reservoirs proceeded in discrete phases, each with a corresponding increase in production (Fig. 110-6). The stratigraphic nature of entrapment was often not recognized until large portions of the reservoir were drilled out many years after initial discovery. Recognition of the stratigraphic nature of these reservoirs early in development is necessary if the reservoir is to be developed efficiently and completely in the years immediately following discovery.

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Table 110-1. Reservoirs in the Northwest Shelf Upper Pennsylvanian Carbonate play that had produced 1 MMBO as of the end of 2000. **Reservoir unit (NMOCD)** is the stratigraphic unit from which production is obtained, as designated by the New Mexico Oil Conservation Division. **O/G** indicates whether the reservoir is designated as an oil (O) reservoir or as a gas (G) reservoir. Cumulative production is through the end of 2000.

Reservoir Name	Reservoir Unit (NMOCD)	County	Discovery Year	Depth (feet)	O/G	2000 oil production (MMBO)	Cumulative production (MMBO)
Allison	Pennsylvanian	Lea	1954	9673	O	0.03	23.83
Anderson Ranch North	Cisco Canyon	Lea	1984	11498	O	0.01	1.32
Bagley	Pennsylvanian	Lea	1949	9190	O	<0.01	4.34
Bagley North	Permo Penn	Lea	1957	10000	O	0.14	52.95
Bar-U	Pennsylvanian	Lea	1963	9100	O	0.04	1.36
Baum	Upper Pennsylvanian	Lea	1955	9940	O	0.03	15.22
Bough	Permo Penn	Lea	1949	9617	O	0	6.33
Cerca	Upper Pennsylvanian	Lea	1968	10397	O	0	1.98
Crossroads	Pennsylvanian	Lea	1949	9750	O	0	2.17
Dagger Draw North	Upper Penn	Eddy	1964	7550	O	1.81	48.91
Dagger Draw South	Upper Penn	Eddy	1971	7506	O	0.42	16.21
Dean	Permo Penn	Lea	1955	10700	O	0.02	6.17
Flying M South	Bough	Lea	1965	9020	O	0	1.21
High Plains	Permo Penn	Lea	1963	10400	O	0.01	1.06
Hightower East	Upper Pennsylvanian	Lea	1959	10218	O	0.01	1.05
Inbe	Permo Penn	Lea	1962	9658	O	0.01	16.44
Indian Basin	Upper Pennsylvanian	Eddy	1963	7370		1.91	13.27
Jenkins	Cisco	Lea	1963	9750	O	0	2.10
Lazy J	Pennsylvanian	Lea	1952	9600	O	0.03	7.63
Leamex	Pennsylvanian	Lea	1956	11340	O	<0.01	1.37
Milnesand	Pennsylvanian	Roosevelt	1956	9202	O	0	1.00
Nonombre	Upper Pennsylvanian	Lea	1965	10345	O	0	1.08
Prairie South	Cisco	Roosevelt	1960	9651	O	0	2.91
Ranger Lake	Pennsylvanian	Lea	1956	10300	O	0.01	5.08
Saunders	Permo-Upper Penn	Lea	1950	9800	O	0.13	38.92
Saunders East	Permo Penn	Lea	1962	10363	O	<0.01	2.72
Shoe Bar	Pennsylvanian	Lea	1954	10440	O	0	1.06
Tobac	Pennsylvanian	Chaves	1964	9058	O	0.01	9.23
Travis	Upper Pennsylvanian	Eddy	1977	9825	O	0.10	1.99
Tres Papalotes	Pennsylvanian	Lea	1970	10400	O	0.02	1.94
Tres Papalotes West	Pennsylvanian	Lea	1972	10400	O	0	1.24
Tulk	Pennsylvanian	Lea	1965	9856	O	0.01	1.81
Vacuum	Upper Pennsylvanian	Lea	1964	10000	O	0.08	6.61
Vada	Pennsylvanian	Roosevelt & Lea	1956	9800	O	0.03	53.34
TOTALS						**4.87**	**353.85**

Northwest Shelf Upper Pennsylvanian Carbonate Play

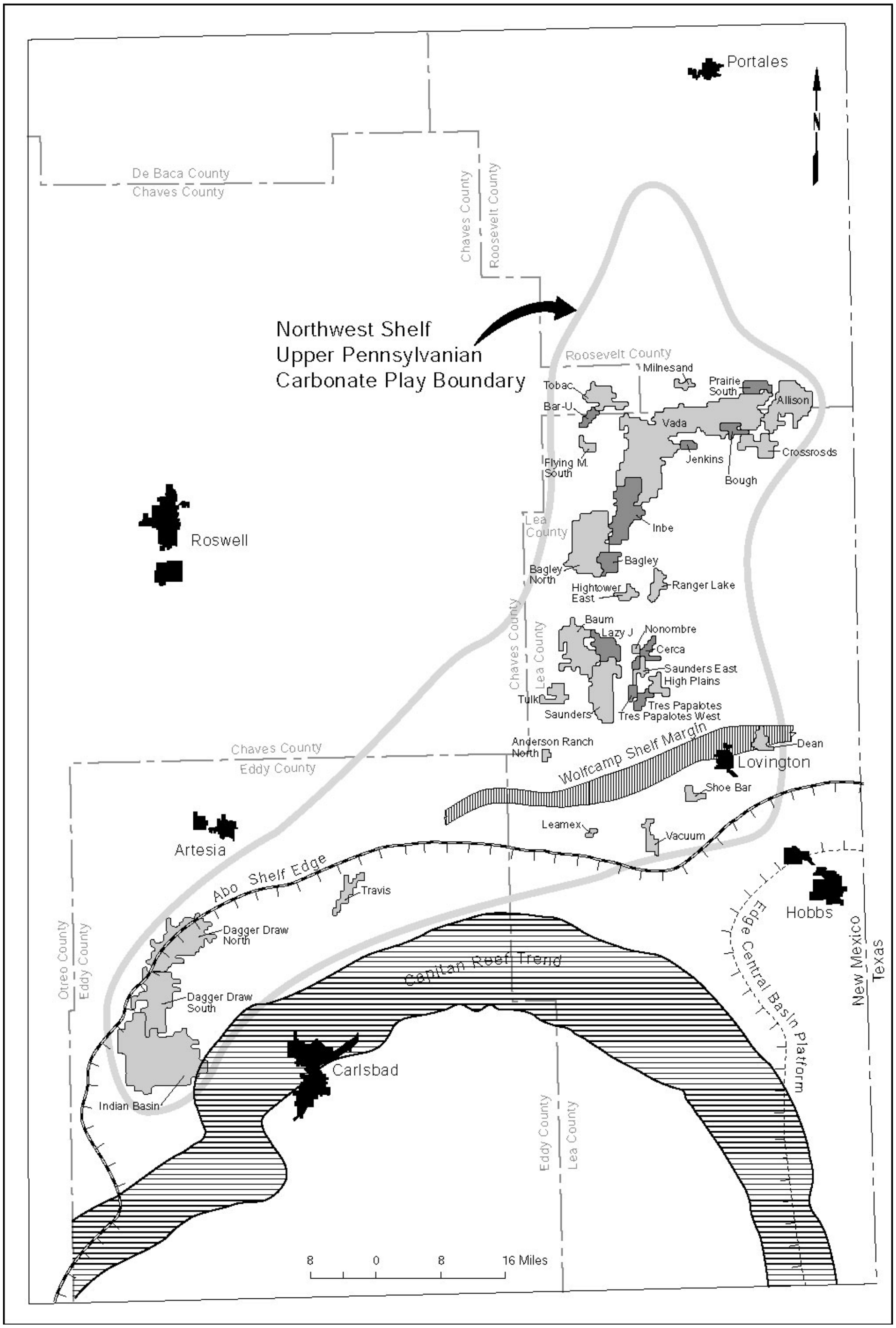

Figure 110-1. Location of reservoirs with more than 1 MMBO cumulative production in the Northwest Shelf Upper Pennsylvanian Carbonate play.

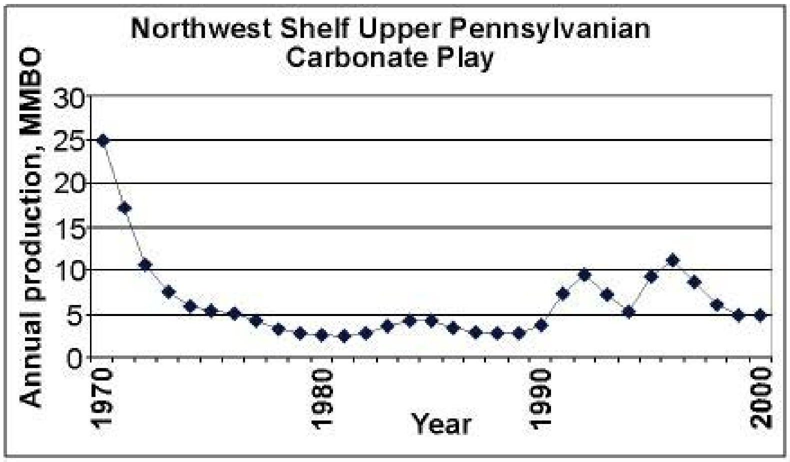

Figure 110-2. Historical annual production from 1970 to 2000 from reservoirs with more than 1 MMBO cumulative production in the Northwest Shelf Upper Pennsylvanian Carbonate play.

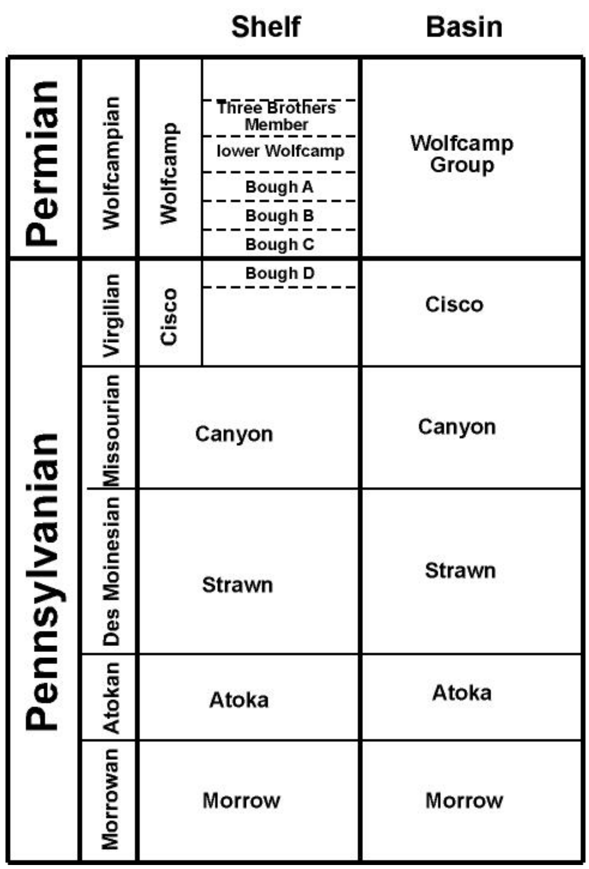

Figure 110-3. Stratigraphic column of Upper Pennsylvanian and Lower Permian strata, southeast New Mexico.

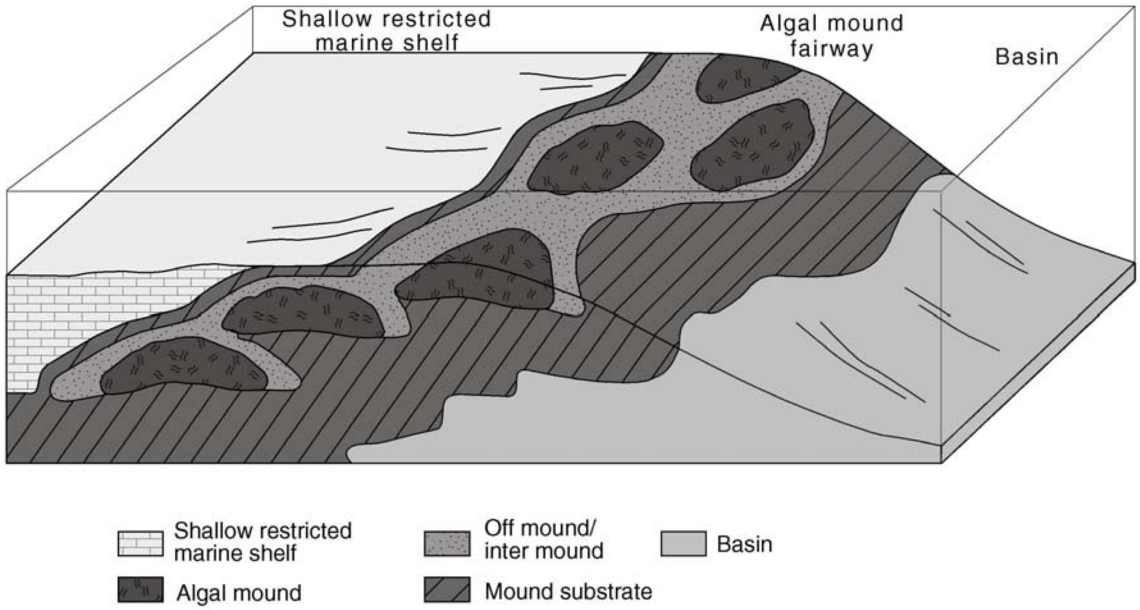

Figure 110-4. Depositional model for Upper Pennsylvanian algal mound complex, Dagger Draw South reservoir. After Cox et al. (1998).

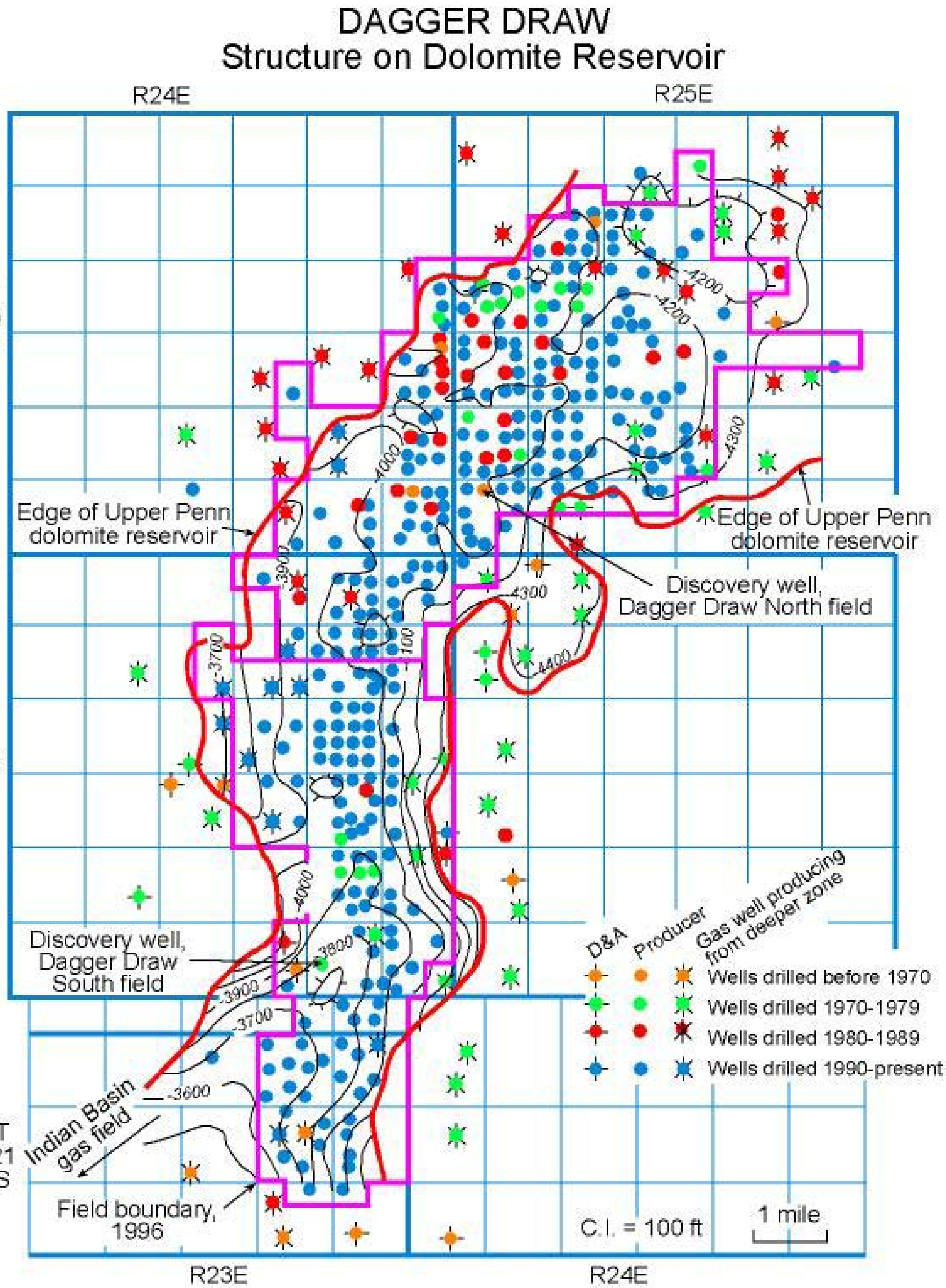

Figure 110-5. Structure contour map on top of Upper Pennsylvanian dolostone reservoir, South Dagger Draw and North Dagger Draw reservoirs and time periods during which wells were drilled. After Broadhead (1999). Contours from Reddy (1995).

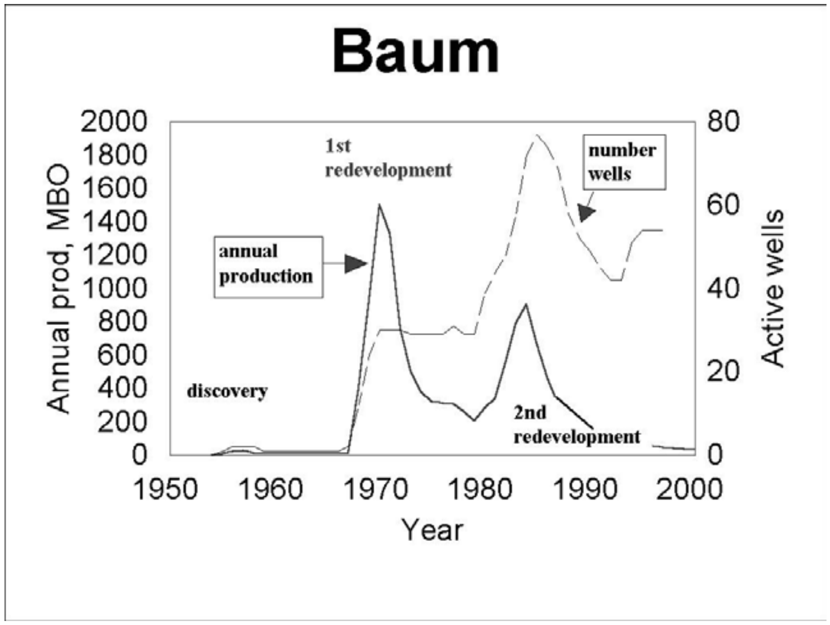

Figure 110-6. Historical annual oil production and number of productive wells active in any given year, Baum Upper Pennsylvanian reservoir. After Broadhead (1999).

Play 109 - Northwest Shelf Strawn Patch Reef Play

Reservoirs of the Northwest Shelf Strawn Patch Reef play lie on the Northwest Shelf of the Permian Basin and are also present within the Delaware Basin. Most reservoirs are located within a triangular trend formed roughly by the cities of Lovington, Carlsbad, and Artesia (Fig. 109-1). Oil productive reservoirs are found mainly in the eastern two-thirds of this triangular trend; gas reservoirs are found in the western part of the trend as well as outside of the main trends. The play boundary terminates on the west in the transition zone between oil and gas production; the gas fields of the western part of the play are not shown in Figure 109-1. There are 104 known, discovered Strawn reservoirs in the play, 13 of which have produced more than 1 MMBO (Fig. 109-1, Table 109-1). Cumulative production from these 13 reservoirs was 70 MMBO as of 2000. Annual production from these 13 reservoirs was 1.54 MMBO during 2000. Production from this play has seen an overall decrease during the 1990's as production from existing reservoirs has matured (Fig. 109-2).

Reservoirs are patch reefs of Strawn (Des Moinesian: Middle Pennsylvanian) age. The patch reefs grew on a south-dipping carbonate ramp that was present before the western Permian Basin segmented into the Northwest Shelf and the Delaware Basin. Reservoirs are principally bioherms composed of phylloid algal, coralgal, and foraminiferal lime wackestones and packstones (Harris, 1990). Bioherm growth was localized on pre-existing structures that had bathymetric expression (Thornton and Gaston, 1967; Harris, 1990). Seals are interbedded marine mudstones. The larger Strawn reservoirs are internally complex and exhibit intricate porosity variations (Fig. 109-3).

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Table 109-1. Reservoirs in the Northwest Shelf Strawn Patch Reef play that had produced 1 MMBO as of the end of 2000. **Reservoir unit (NMOCD**) is the stratigraphic unit from which production is obtained, as designated by the New Mexico Oil Conservation Division. **O/G** indicates whether the reservoir is designated as an oil (O) reservoir or as a gas (G) reservoir. Cumulative production is through the end of 2000.

Reservoir Name	**Reservoir Unit (NMOCD)**	**County**	**Discovery Year**	**Depth (feet)**	**O/G**	**2000 oil production (MMBO)**	**Cumulative production (MMBO)**
Big Eddy	Strawn	Eddy	1966	11333	O	0	1.40
Burton Flat East	Strawn	Eddy	1976	10600	G	0.07	2.99
Casey	Strawn	Lea	1975	11326	O	0.02	3.41
Cass	Pennsylvanian	Lea	1944	7700	O	0	2.89
Golden Lane	Strawn	Eddy	1969	11098	G	0.02	1.45
Humble City	Strawn	Eddy	1972	11429	O	0.02	1.301
Humble City South	Strawn	Lea	1982	11520	O	0.02	3.44
Lovington Northeast	Pennsylvanian	Lea	1952	11256	O	0.474	17.40
Lovington West	Strawn	Lea	1985	11594	O	0.48	5.16
Lusk	Strawn	Lea & Eddy	1960	11168	O	0.04	20.68
Reeves	Pennsylvanian	Lea	1956	10950	O	0.01	1.29
Shipp	Strawn	Lea	1985	11138	O	0.04	7.62
Shoe Bar North	Strawn	Lea	1973	11275	O	0.34	1.30
TOTALS						**1.54**	**70.34**

Northwest Shelf Strawn Patch Reef Play

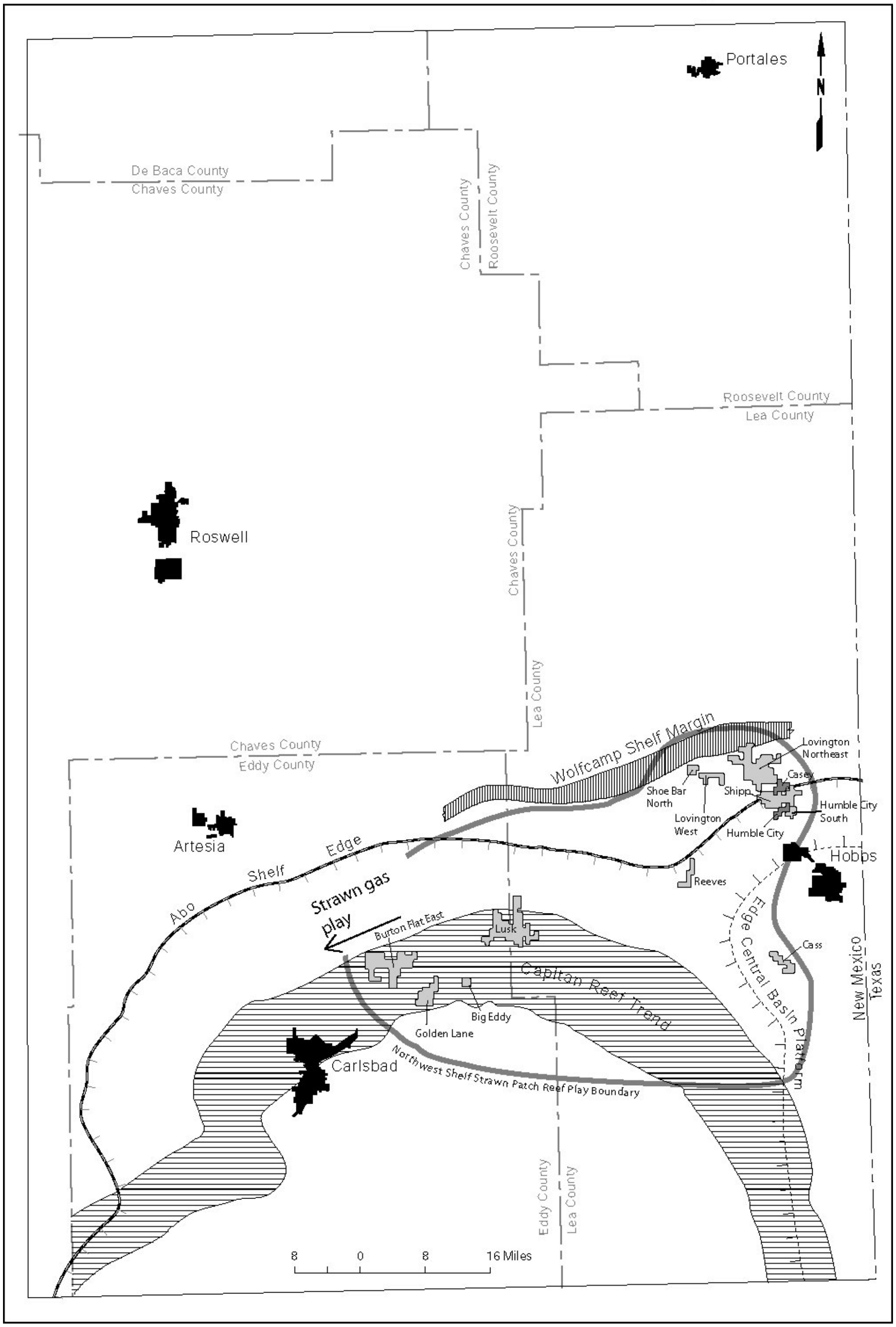

Figure 109-1. Location of reservoirs with more than 1 MMBO cumulative production in the Northwest Shelf Strawn Patch Reef play.

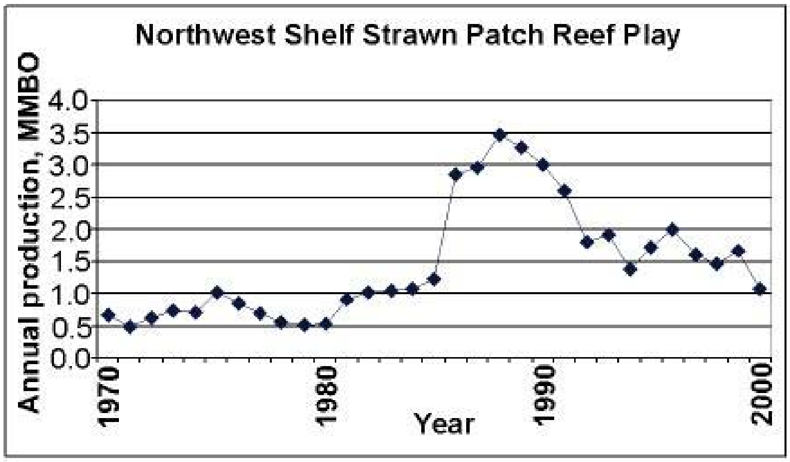

Figure 109-2. Historical annual production from 1970 to 2000 from reservoirs with more than 1 MMBO cumulative production in the Northwest Shelf Strawn Patch Reef play.

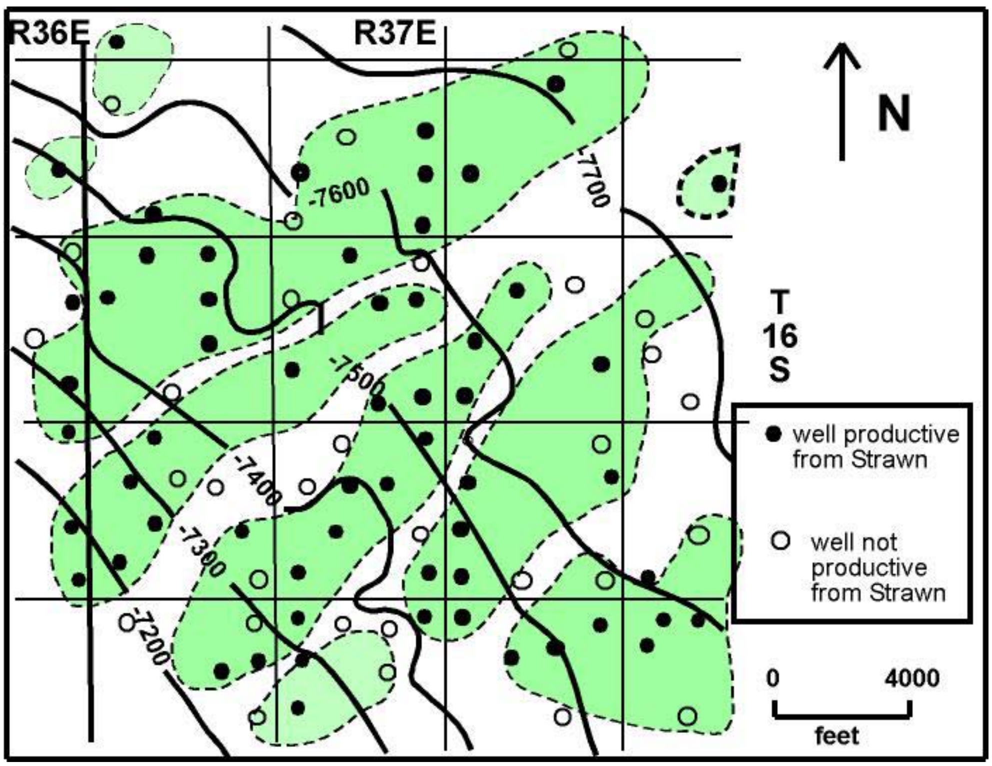

Figure 109-3. Map of Strawn structure and porosity at the Lovington Northeast reservoir. Shown is structure of the Strawn limestone. Contour interval is 50 ft. Shaded areas are where the Strawn has porosity greater than or equal to 4 percent. Modified by Speer (1993) from Caughey (1988).

Play 106 – Devonian Thirtyone Deepwater Chert

The Devonian Thirtyone Deepwater Chert play is a large oil play with 44 reservoirs that have produced 1 MMBO (Dutton and others, 2004). Only one reservoir, the Dollarhide Devonian, is present in New Mexico (Fig. 106-1; Table 106-1). The remainder and by far largest part of the play is in Texas. The Dollarhide reservoir was discovered in 1952 and had produced a cumulative 9.17 MMBO by the end of 2000. Modern annual production peaked at 504 thousand bbls oil in 1973 and has since declined to 70 thousand bbls oil per year in 2000 (Fig. 106-2). Depth to production at the Dollarhide reservoir is 8170 ft. The play is limited so southern Lea County by the distribution of the Thirtyone Formation, which is truncated by erosion under the pre-Woodford unconformity to the north and west of the Dollarhide reservoir (Ruppel and Barnaby, 2001).

Reservoirs at the Dollarhide reservoir of Lea County New Mexico and adjacent Andrews County, Texas consist of an upper dolostone and a lower chert within the Thirtyone Formation (Lower Devonian; Keener, 1957; Saller et al., 2001). The New Mexico part of the reservoir is productive primarily from the dolostone in the upper part of the Thirtyone Formation, which consists of coarsely crystalline cherty dolostone and thin interbeds of white chert (Sharp, 1956). The trap at Dollarhide is formed by an anticline bounded by high-angle faults (Keener, 1957).

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Table 106-1. Reservoirs in the Devonian Thirtyone Deepwater Chert play that had produced 1 MMBO as of the end of 2000. **Reservoir unit (NMOCD**) is the stratigraphic unit from which production is obtained, as designated by the New Mexico Oil Conservation Division. **O/G** indicates whether the reservoir is designated as an oil (O) reservoir or as a gas (G) reservoir. Cumulative production is through the end of 2000.

FIELD NAME	RESERVOIR UNIT (NMOCD)	COUNTY	DISCOVERY YEAR	DEPTH (feet)	O/G	2000 oil production (MMBO)	Cumulative production (MMBO)
Dollarhide	Devonian	Lea	1952	8170	O	0.07	9.18

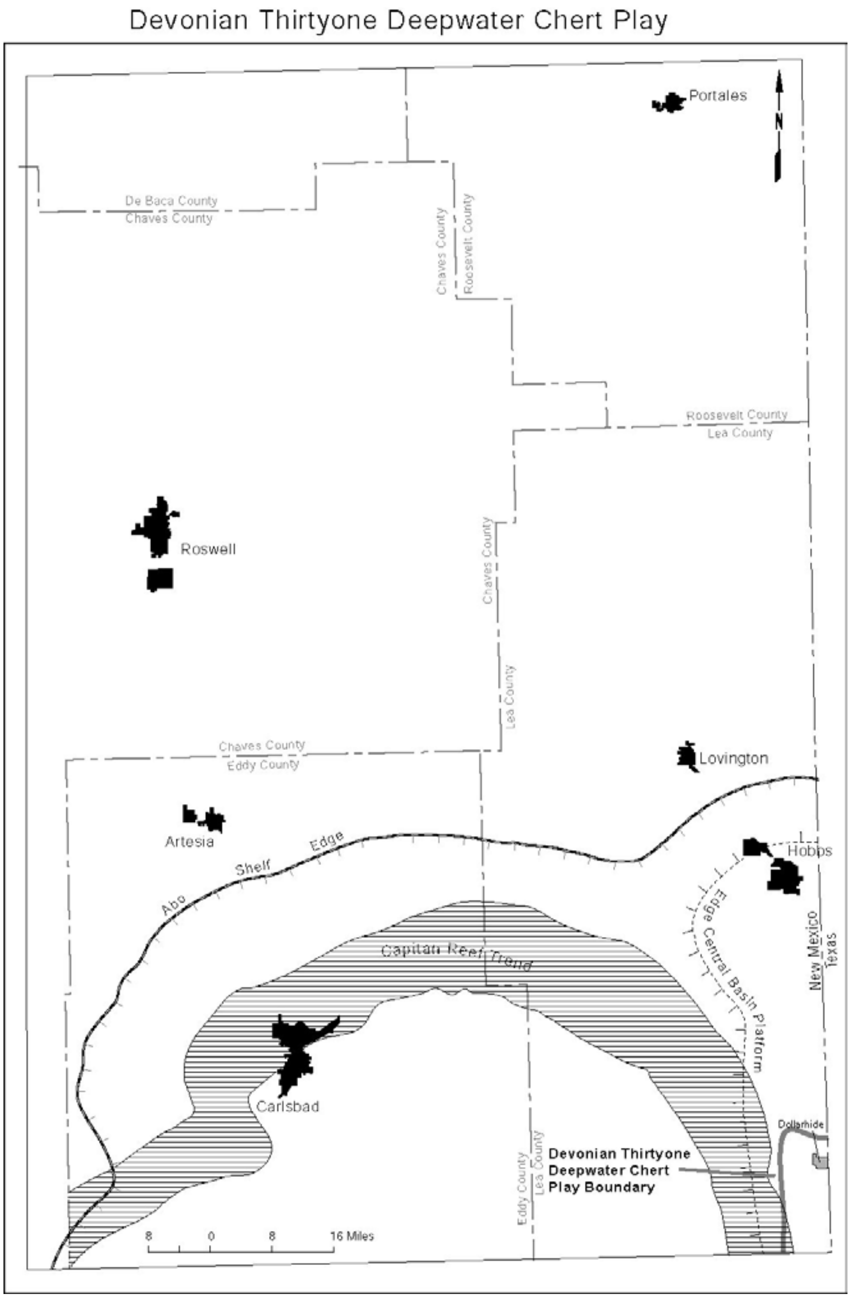

Figure 116-1. Location of reservoirs with more than 1 MMBO cumulative production in the New Mexico part of the Abo Platform Carbonate play.

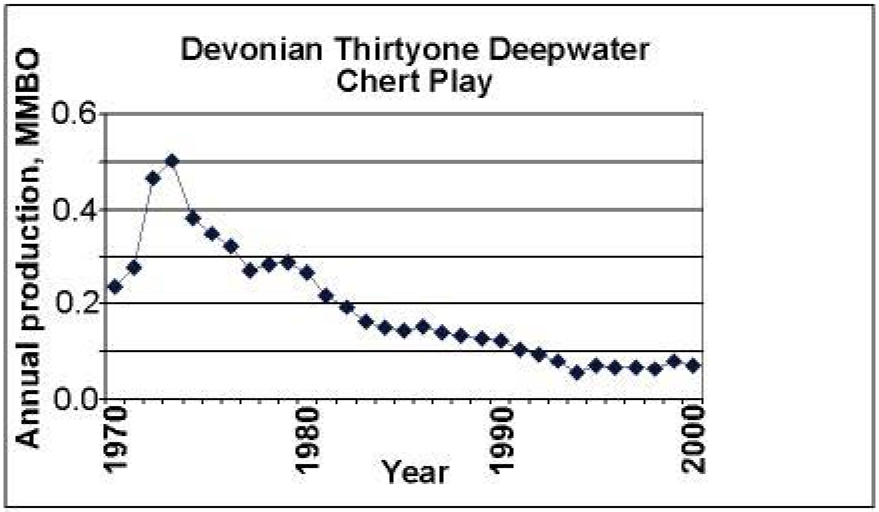

Figure 106-2. Historical annual production from 1970 to 2000 from the single reservoir with more than 1 MMBO cumulative production in the New Mexico part of the Devonian Thirtyone Deepwater Chert play.

Play 105 - Wristen Buildups and Platform Carbonate Play

Production obtained from the Wristen Group (Silurian) in New Mexico has in the past been allocated to stratal units described as “Devonian”, “Silurian”, or “Siluro-Devonian”. Recent biostratigraphy (Barrick et al., 1993; Barrick, 1995) and regional stratigraphic analysis (Ruppel and Holtz, 1994) indicate that Devonian strata do not extend north of the southernmost part of Lea County. In southeastern New Mexico, almost all of the dolomitic carbonates present in southeast New Mexico above the Fusselman Formation and below the Woodford Shale belong to the Wristen Group (Silurian). Devonian carbonates are limited to the southern part of Lea County. Thirty-six New Mexico reservoirs with more than 1 MMBO cumulative production as of 2000 produce either solely or dominantly from the Wristen. Cumulative production from these 36 reservoirs was 369 MMBO as of 2000 (Table 105-1).

The play is mature, with most large reservoirs discovered from the late 1940’s though 1960 (Table 105-1). Many of these older reservoirs were in decline prior to 1980; annual oil production from the larger reservoirs in this play saw a steep drop during the 1970’s (Fig. 105-2). In general, production from individual reservoirs in this play peaks within a few years of discovery and subsequently undergoes a sharp decline (Fig. 105-3).

Silurian strata in New Mexico and West Texas were deposited within the Tobosa Basin and on the Tobosa Shelf; the shelf margin was located approximately 10 miles north of the Texas-New Mexico state line and aligned in an east-west direction (Ruppel and Holtz, 1994; Fig. 105-4). South (basinward) of the shelf margin in west Texas and southeasternmost New Mexico, the Silurian Wristen Group is divided into a lower, gray, nodular limestone mudstone to wackestone unit (Wink Formation of Hills and Hoenig, 1979) and an upper shaley to argillaceous lime mudstone and wackestone unit (Frame Formation of Hills and Hoenig, 1979). North (shelfward) of the shelf margin, the contact between the Wink and Frame Formations is indistinct and the entire Wristen Group is composed of shallow water strata assigned to the Fasken Formation. The Fasken is comprised of mixed limestone and dolostone with mudstone to grainstone and boundstone textures; local, relatively small patch reefs are dominated by wackestones (Ruppel and Holtz, 1994). Buildups of coral, stromatoporoid, pelmatazoan, bryozoan boundstones and rudstones with oolitic grainstone caps are present along the shelf margin (Ruppel and Holtz, 1994).

The Wristen thickens in a westerly direction across west Texas and into southeastern Lea County, New Mexico (Fig. 105-4). Maximum Wristen thickness is at least 1400 ft in western Andrews County, Texas and southeastern Lea County, New Mexico (Fig. 105-4). Further west, the Wristen thins as it is erosionally truncated under the pre-Woodford unconformity. It has a meandering zero-thickness line trending generally northeast-southwest from approximately T16S R24E north of Artesia to T8S R36E in southern Roosevelt County.

Porosity in Wristen reservoir facies is dolomitic as well as moldic, vugular, karstic (including collapse breccia) and intercrystalline, and is typically associated with subaerial exposure at the tops of upward-shallowing cycles (Entzminger and Loucks, 1992; Ruppel and Holtz, 1994). The shelf margin buildups and grainstones contain significant primary intergranular porosity. Where it is present, the overlying Woodford Shale acts as both source and seal. Traps are dominantly structural.

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Table 105-1. Reservoirs in the Wristen Buildups and Platform Carbonate play that had produced 1 MMBO as of the end of 2000. **Reservoir unit (NMOCD**) is the stratigraphic unit from which production is obtained, as designated by the New Mexico Oil Conservation Division. **O/G** indicates whether the reservoir is designated as an oil (O) reservoir or as a gas (G) reservoir. Cumulative production is through the end of 2000.

Reservoir Name	Reservoir Unit (NMOCD)	County	Discovery Year	Depth (feet)	O/G	2000 oil production (MMBO)	Cumulative production (MMBO)
Anderson Ranch	Devonian	Lea	1953	13374	O	0.01	8.73
Bagley	Siluro-Devonian	Lea	1949	10950	O	0.12	28.46
Bronco	Siluro-Devonian	Lea	1955	11700	O	0.05	16.05
Bronco West	Devonian	Lea	1965	12170	O	0.01	1.42
Caudill	Devonian	Lea	1954	13585	O	0.02	5.71
Crossroads	Siluro-Devonian	Lea	1948	12115	O	0.06	43.44
Crossroads East	Devonian	Lea	1956	12173	O	0.05	2.54
Crossroads South	Devonian	Lea	1954	12250	O	0.03	3.27
Crossroads West	Devonian	Lea	1959	12000	O	0.00	2.06
Dean	Devonian	Lea	1955	13600	O	0.00	3.03
Denton	Devonian	Lea	1949	12200	O	0.27	101.23
Denton South	Devonian	Lea	1955	13110	O	0.00	3.75
Echols	Devonian	Lea	1951	11500	O	0.00	4.62
Echols North	Devonian	Lea	1952	12057	O	0.02	1.42
Fowler	Devonian	Lea	1955	7587	O	0.01	1.33
Garrett West	Devonian	Lea	1970	12850	O	0.01	3.12
Gladiola	Devonian	Lea	1950	11859	O	0.04	52.84
Gladiola Southwest	Devonian	Lea	1960	12304	O	0.01	4.44
King	Devonian	Lea	1956	12439	O	0.01	6.24
Knowles	Devonian	Lea	1949	12570	O	0.02	4.94
Knowles South	Devonian	Lea	1954	12140	O	0.10	9.71
Langley	Devonian	Lea	1979	12150	G	0.00	1.37
Lea	Devonian	Lea	1960	14400	O	0.02	7.80
Little Lucky Lake	Devonian	Chaves	1958	11050	O	0.01	1.83
Lovington	Devonian	Lea	1969	11570	O	0.01	1.74
McCormack South	Silurian	Lea	1967	7100	O	0.06	1.02
Medicine Rock	Devonian	Lea	1961	12630	O	0.00	1.64
Mescalero	Devonian	Lea	1952	9850	O	0.02	5.83
Moore	Devonian	Lea	1952	10100	O	0.01	22.22
Ranger Lake West	Devonian	Lea	1966	12850	G	0.01	1.19
Shoe Bar	Devonian	Lea	1953	12480	O	0.00	1.08
Shoe Bar East	Devonian	Lea	1968	13013	O	0.01	1.94
Shugart	Siluro-Devonian	Eddy	1957	12362	G	0.00	1.11
Teague Northwest	Devonian	Lea	1992	7450	O	0.05	1.00
Vacuum Mid	Devonian	Lea	1963	11644	O	0.01	1.77
Vacuum South	Devonian	Lea	1958	11546	O	0.02	8.93
TOTALS						**1.08**	**368.82**

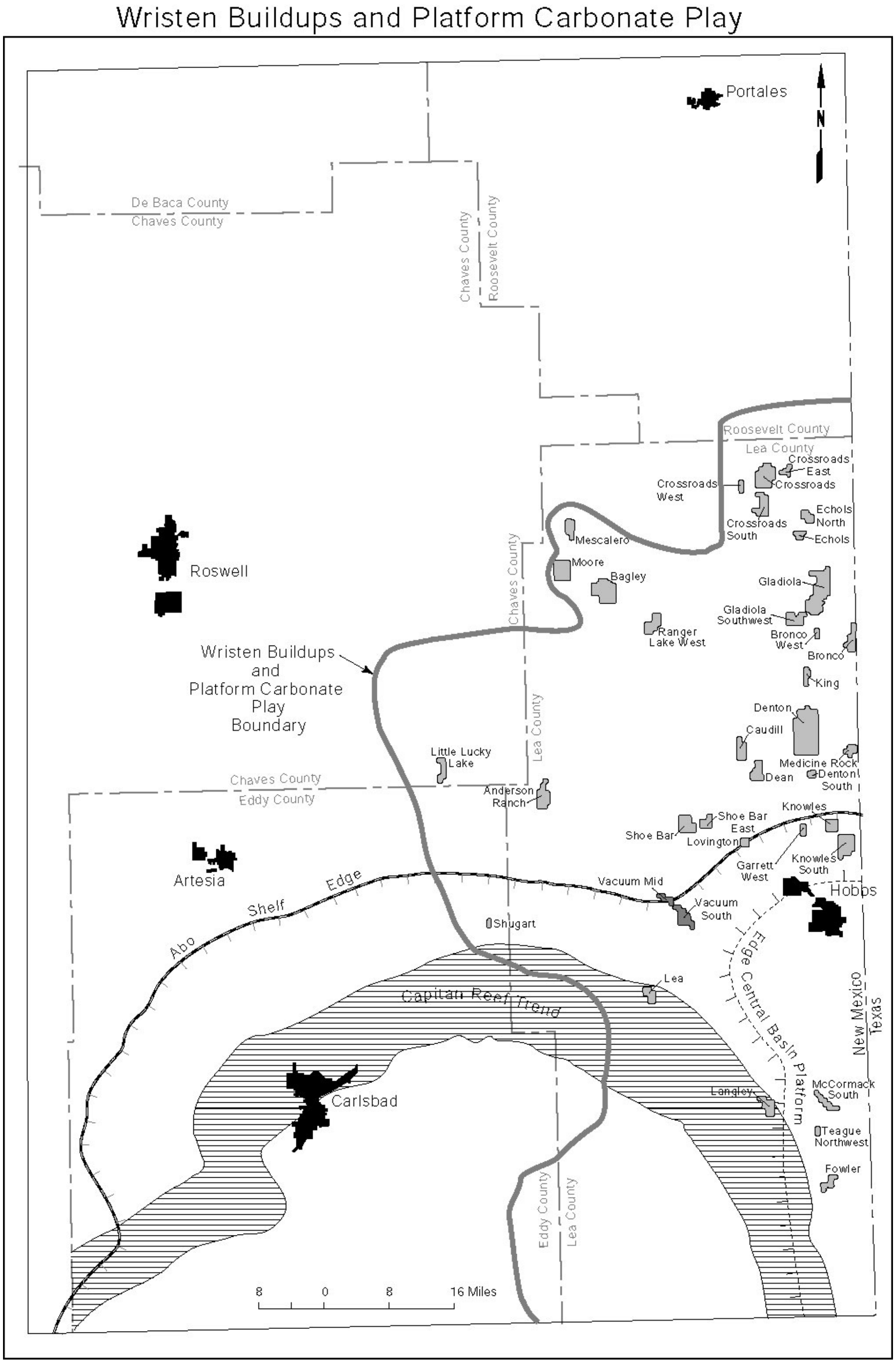

Figure 105-1. Location of reservoirs with more than 1 MMBO cumulative production in the New Mexico part of the Wristen Buildups and Platform Carbonate play.

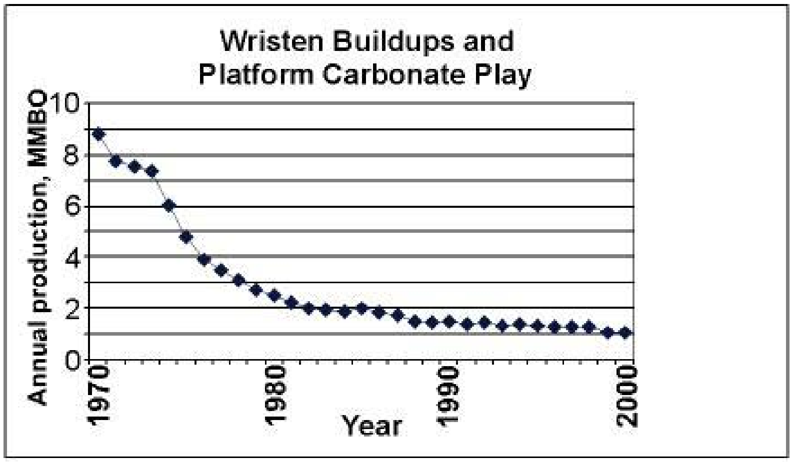

Figure 105-2. Annual production from 1970 to 2000 for the 36 reservoirs within the Wristen Buildups and Platform Carbonate play that have produced more than 1 MMBO.

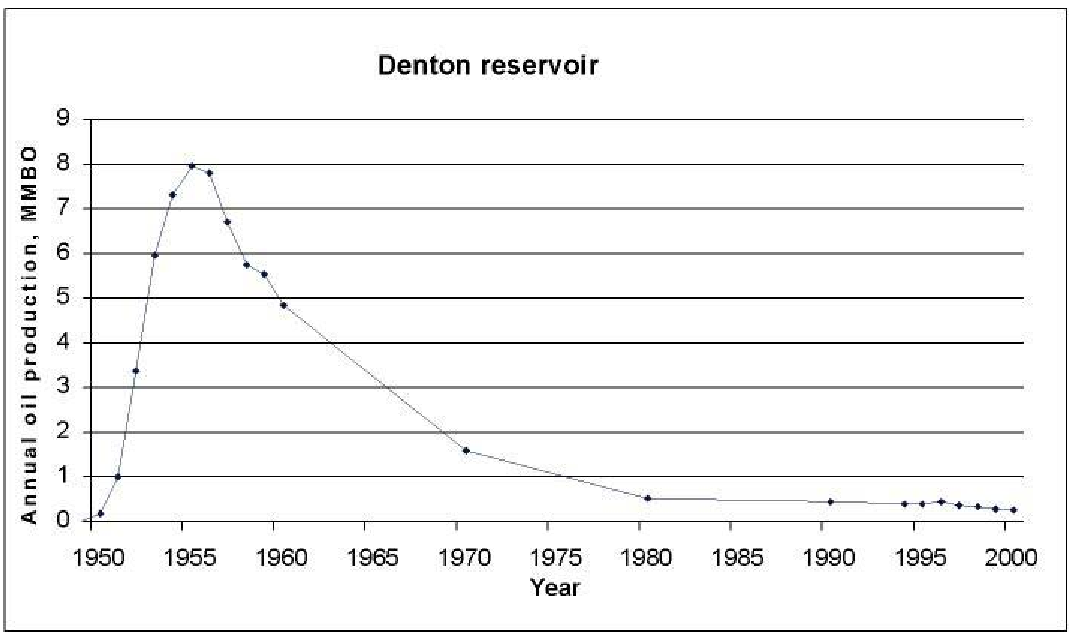

Figure 105-3. Annual production for the Denton reservoir, Lea County, New Mexico. The Denton reservoir is the most productive reservoir in the New Mexico part of the Wristen play, with 101.2 MMBO cumulative production as of 2000.

Wristen Group distribution and approximate isopach

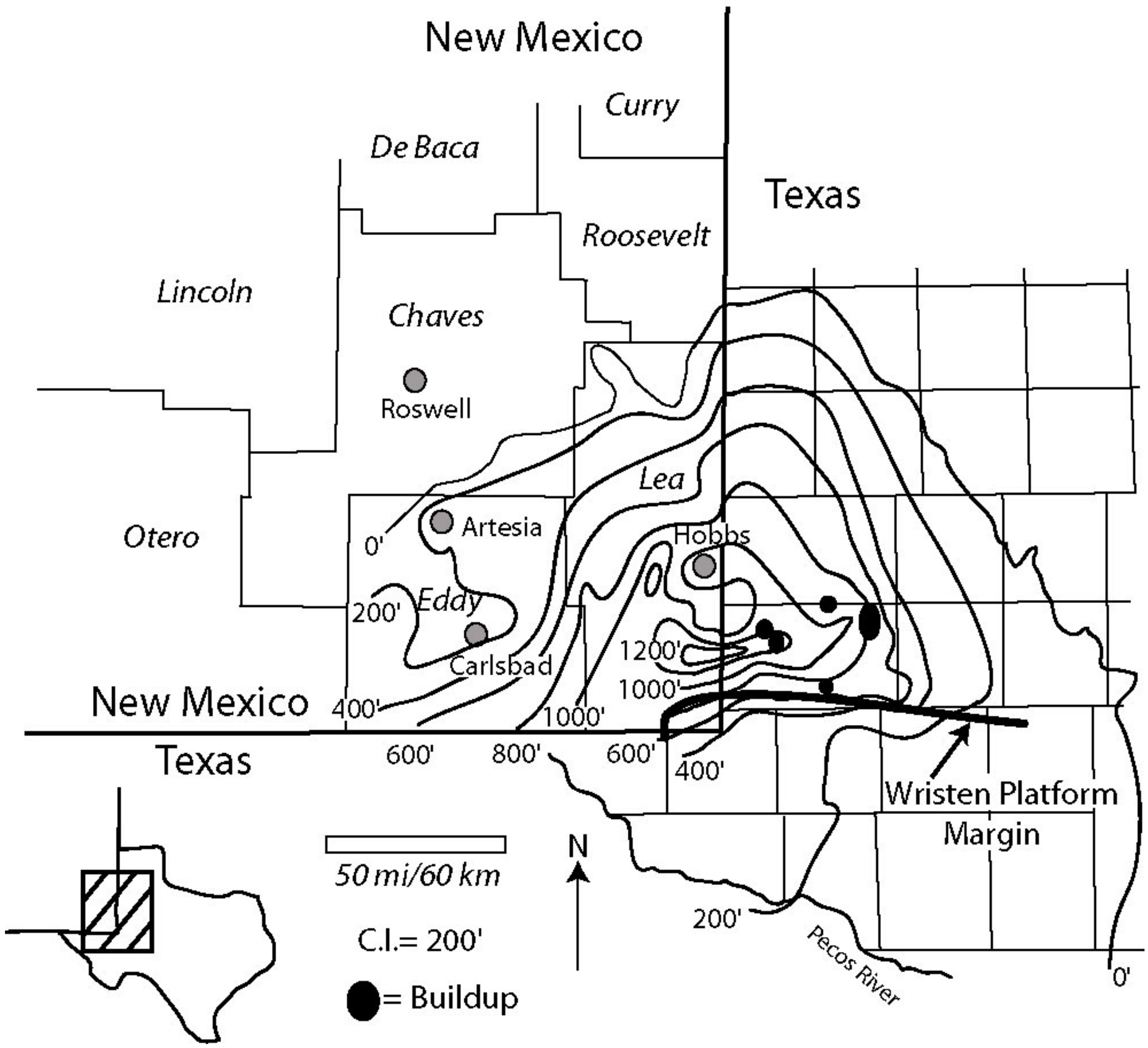

Figure 105-4. Isopach map of the Wristen Group in New Mexico and West Texas. Recent biostratigraphic work (Barrick et al., 1993; Barrick, 1995) and regional stratigraphy (Ruppel and Holtz, 1994; Baldonado and Broadhead, 2002 and unpublished) allow the New Mexico portion of the Wristen isopach to be added to the existing Texas portion (Ruppel and Holtz, 1994).

Play 104 - Fusselman Shallow Platform Carbonate Play

The northwestern end of the Fusselman Shallow Platform Carbonate play extends into southeastern new Mexico from neighboring areas of west Texas (Fig. 104-1). By far the largest part of the play occurs in west Texas (Dutton et al, 2004). Sixty-two million bbls oil have been produced in this play from 11 New Mexico reservoirs that have cumulative production more than 1 MMBO (Table 104-1). This includes ten Fusselman reservoirs with cumulative production of 57.2 MMBO. One Montoya (Ordovician) reservoir (Justis Montoya) with cumulative production of 4.8 MMBO was included in this play description because it is the sole Montoya reservoir with 1 MMBO cumulative production in New Mexico. A play was not made for the Montoya in this project.

In New Mexico production occurs over a wide area from the Northwest Shelf to the Central Basin Platform (Fig. 104-1). Productive depths range from 5900 to 12,809 feet in the Fusselman and 6200 to 6900 feet in the Montoya (Speer, 1993). Production from the 11 reservoirs in New Mexico has declined from 1.5 MMBO per year in 1970 bbls to 245 thousand bbls per year in 2000 (Fig. 104-2).

The Fusselman Formation (Upper Ordovician to Silurian) is a cherty dolostone (New Mexico and northern West Texas) to limestone (southern West Texas) deposited on a broad carbonate platform of shallow to open marine depths within the Tobosa shelf and basin. In New Mexico the formation is largely of shallow water origin, dolomitized, and often brecciated. Differentiation of the Fusselman from the bounding Montoya Formation and Wristen Group is difficult in New Mexico due to the similar dolostone content of each. On the Northwest Shelf the Fusselman is beveled by the pre-Woodford unconformity along a northeast-southwest trend in Roosevelt and Chaves Counties, with thickness varying from over 600 feet in southeast Lea County to zero east of Roswell, with a meandering zero line from approximately T12S R25E to T4S R28E. The formation is also eroded locally across highs on the Central Basin Platform and on the Northwest Shelf.

Porosity and permeability is developed within the coarsely crystalline dolomite matrix, with economic flow rates usually accompanied by fracture, vug, and karstic (collapse breccia) enhancement. Outcrops in the Franklin Mountains contain three unconformity-bounded sequences, with the uppermost surface heavily karsted (LeMone, 1996), while four major sea level falls are documented in Oklahoma and the subsurface of West Texas (Johnson, 1987, Ruppel and Holtz, 1994). Traps occur most commonly as fault-bounded anticlines of late Paleozoic age with lower Paleozoic strata truncated beneath upper Paleozoic strata.The Woodford Shale acts as a source rock and, where it directly overlies the Fusselman, as a seal.

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Table 104-1. Reservoirs in the Fusselman Shallow Platform Carbonate play that had produced 1 MMBO as of the end of 2000. **Reservoir unit (NMOCD)** is the stratigraphic unit from which production is obtained, as designated by the New Mexico Oil Conservation Division. **O/G** indicates whether the reservoir is designated as an oil (O) reservoir or as a gas (G) reservoir. Cumulative production is through the end of 2000.

Reservoir Name	**Reservoir Unit (NMOCD)**	County	**Discovery Year**	***Depth* (feet)**	O/G	**2000 oil production (MMBO)**	**Cumulative production (MMBO)**
Bough	Devonian	Lea	1965	11920	O	0.01	3.80
Brunson	Fusselman	Lea	1980	7200	O	0.00	1.16
Caprock East	Devonian	Lea	1951	10450	O	0.06	23.61
Chisum	Devonian	Chaves	1950	6490	O	0.03	1.22
Dollarhide	Fusselman	Lea	1952	8710	O	0.01	6.62
Four Lakes	Devonian	Lea	1956	12809	G	0.00	1.87
Justis	Fusselman	Lea	1958	6600	O	0.04	10.99
Justis	Montoya	Lea	1958	6886	O	0.01	4.77
Justis North	Fusselman	Lea	1961	7050	O	0.01	3.36
McCormack	Silurian	Lea	1947	7145	O	0.01	1.22
Peterson South	Fusselman	Roosevelt	1978	7800	O	0.07	3.39
TOTALS						**0.25**	**62.01**

Fusselman Shallow Platform Carbonate Play

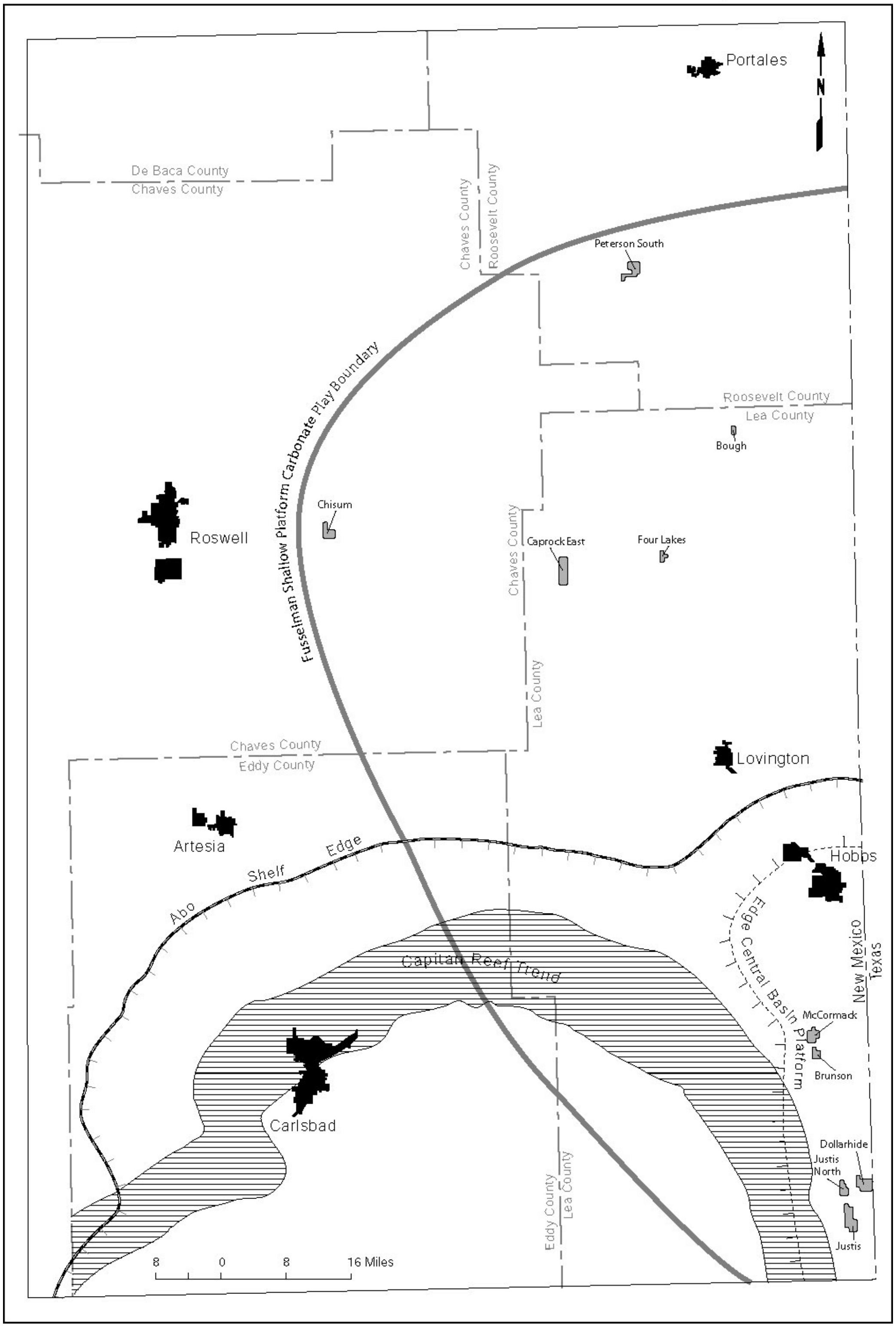

Figure 104-1. Location of reservoirs with more than 1 MMBO cumulative production in the New Mexico part of the Fusselman Shallow Platform Carbonate play.

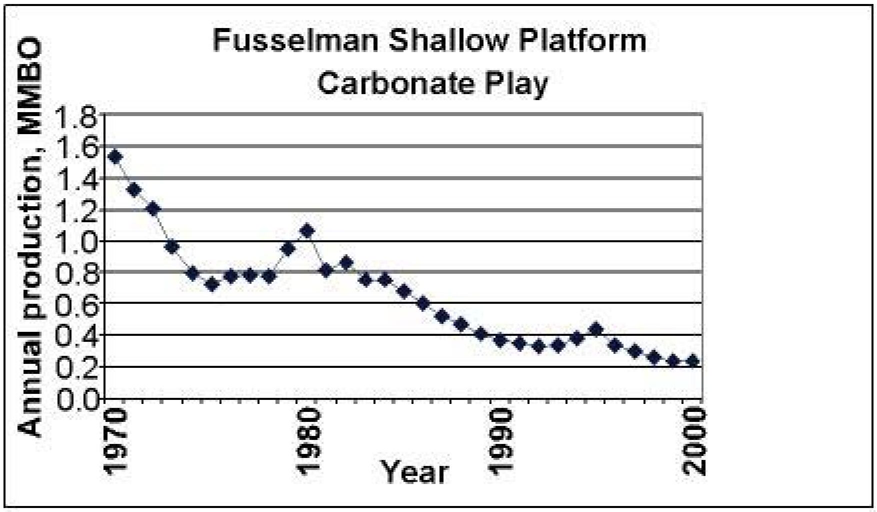

Figure 104-2. Annual production from 1970 to 2000 for the 11 reservoirs within the Fusselman Shallow Platform Carbonate play that have produced more than 1 MMBO.

Play 103 - Simpson Cratonic Sandstone Play

The northwestern part of the Simpson Cratonic Sandstone play extends into Lea County, New Mexico (Fig. 103-1) from west Texas where most of the play is located (Dutton et al., 2004). Production is obtained from sandstones in the Simpson Group (Middle Ordovician). Three reservoirs in the New Mexico part of the play have produced more than 1 MMBO. Cumulative production from these three reservoirs was 22 MMBO as of 2000 (Table 103-1). Depth to production ranges from 7500 to 9600 feet (Speer, 1993). Production has generally increased since 1994 (Fig. 103-2) because of reestablishment of production from Simpson sandstones in the Teague McKee reservoir during 1993. Teague, discovered in 1948, was nonproductive by 1983 as all wells in the reservoir were either abandoned or recompleted to other reservoir zones; new wells drilled during 1993 were completed in the Simpson and production was reestablished within the McKee sandstone of the Simpson Group.

The Simpson Group was deposited within the broad, gently downwarped Tobosa Basin of west Texas and southeast New Mexico. In New Mexico, the Simpson attains a maximum thickness of approximately 1000 ft in southeastern Lea County and thins north and west to a pinchout in central Lea County and southeastern Eddy County (Wright, 1979). The Simpson is comprised of five formations (ascending; Fig. 103-3): Joins Formation, Oil Creek Formation, McLish Formation, Tulip Creek Formation, and Bromide Formation.

The Joins and Bromide Formations are largely nonproductive. The Joins Formation is composed of limestone, dolostone, and minor shale. The Bromide Formation is composed of limestone and minor sandstone and green shale.

Productive Simpson reservoirs are found within the Oil Creek, McLish, and Tulip Creek Formations. These three stratigraphic units are composed mostly of green shales. Productive reservoirs are blanket sandstones found at the base of each of these three units: the Connell sandstone, the Waddell sandstone, and the McKee sandstone (Fig. 103-2; Wright, 1979). The productive sandstones are friable, rounded, fine- to coarse-grained coalesced shoreline deposits. Sandstones comprise approximately 5 percent of the total thickness of the Simpson Group. Simpson sandstones range in thickness from 20 ft to 100 ft in Lea County (Wright, 1979).

Traps for Simpson reservoirs are structural and combination structural-stratigraphic. In New Mexico, they are found on the Central Basin Platform (Fig. 103-1). Structural traps are mostly anticlinal although high-angle faults on the flanks of the anticlines may form part of the trapping mechanism as at the Teague McKee reservoir (Sharp, 1956). Combination traps, such as the one that forms the Hare Simpson reservoir (Symposium Committee, 1956), are found where the Simpson is truncated underneath a major regional unconformity along the flanks of anticlines. That unconformity, at the base of Pennsylvanian and Permian strata, was formed during major late Paleozoic uplift that formed the Central Basin Platform and the smaller structures associated with Simpson traps.

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Table 103-1. Reservoirs in the Simpson Cratonic Sandstone play that had produced 1 MMBO as of the end of 2000. **Reservoir unit (NMOCD**) is the stratigraphic unit from which production is obtained, as designated by the New Mexico Oil Conservation Division. **O/G** indicates whether the reservoir is designated as an oil (O) reservoir or as a gas (G) reservoir. Cumulative production is through the end of 2000.

Reservoir Name	**Reservoir Unit (NMOCD)**	**County**	**Discovery Year**	**Depth (feet)**	**O/G**	**2000 oil production (MMBO)**	**Cumulative production (MMBO)**
Hare	Simpson	Lea	1947	7550	O	0.04	17.19
Justis	McKee	Lea	1957	7700	O	0	1.31
Teague	Simpson	Lea	1948	9340	O	0.22	3.47
TOTALS						**0.25**	**21.98**

Simpson Cratonic Sandstone Play

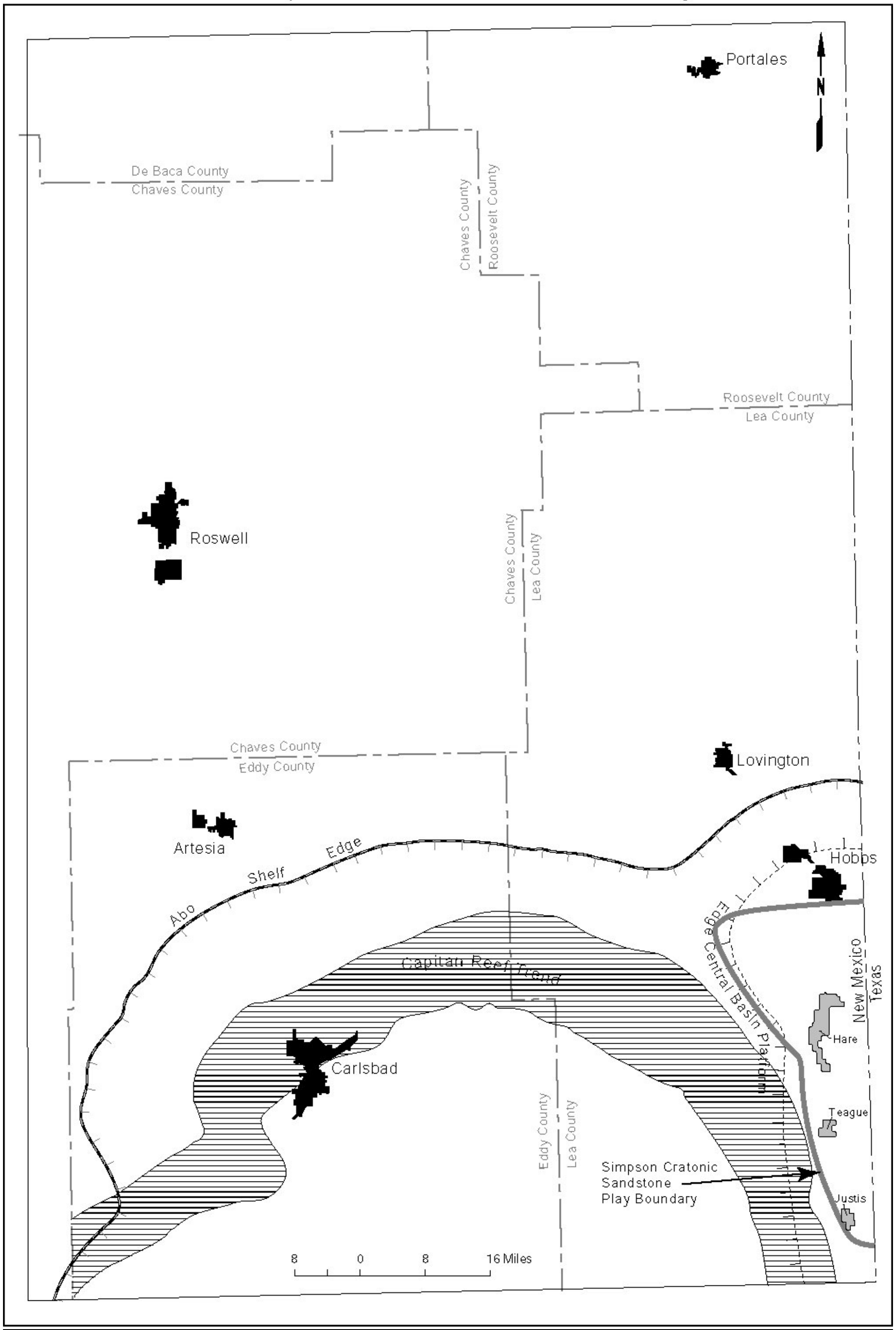

Figure 103-1. Location of reservoirs with more than 1 MMBO cumulative production in the New Mexico part of the Simpson Cratonic Sandstone play.

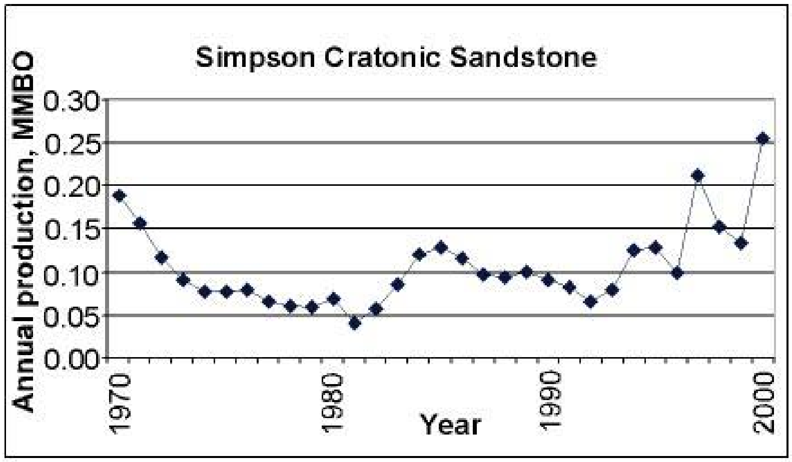

Figure 103-2. Annual production from 1970 to 2000 for the 3 reservoirs within the Simpson Cratonic Sandstone play that have produced more than 1 MMBO.

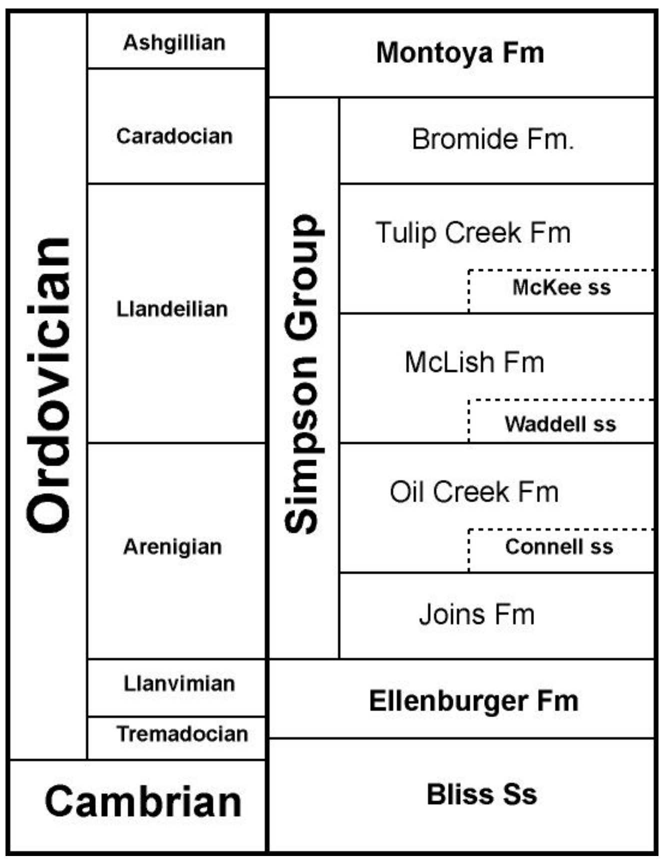

Figure 103-2. Stratigraphic chart of the Simpson Group, indicating the principal productive stratigraphic units: the Connell, Waddell, and McKee sandstones.

Play 102 - Ellenburger Karst-Modified Restricted Ramp Carbonate Play

The Ellenburger Karst-Modified Restricted Ramp Carbonate play in New Mexico covers the Central Basin Platform in Lea County, New Mexico (Fig. 102-1). Most of the play is located in west Texas (Dutton et al., 2004). Seven reservoirs in New Mexico have produced more than 1 MMBO from the Ellenburger Formation (Lower Ordovician). These seven reservoirs had produced 64.3 MMBO through 2000 (Table 102-1). Productive depths range from 8060 to 12,100 ft (Table 102-1); the Ellenburger is productive in New Mexico from depths at least as great as 15,000 feet (Speer, 1993). Between 1970 and 2000 annual production from the seven reservoirs in the play has steadily declined from 1.3 MMBO to 95 thousand bbls; total annual production during 2000 was less than 10 percent of what it was during 1970 (Fig. 102-2). The increase in production during the early 1990's was due to the discovery of the Teague North reservoir during 1988 and the subsequent development of that reservoir.

In New Mexico, the Ellenburger Formation is comprised of dolostones deposited on a restricted inner platform; extensive subaerial diagenesis was associated with changes in relative sea level (Clemons, 1989; Kerans and Lucia, 1989; Goldhammer et al., 1993). Although dolomitized, the Langley reservoir of Lea County contains identifiable intertidal to supratidal facies successions that include alternations of: laminated mudstone/wackestone, peloid/ooid grainstone, peloid-algal mat boundstone, and intraclast and pebble breccia (Verseput, 1989). The Langley reservoir is not shown in Table 102-1 or Figure 102-1 because it had produced less than 1 MMBO as of 2000.

Ellenburger porosity types include intercrystalline matrix, vugs, karst dissolution pores, and fractures (Mazullo, 1989). The most significant porosity type is associated with karst dissolution and collapse breccia (see Loucks, 1999). In addition, isolated porosity zones are present in deeper water muddy carbonate facies that underwent late burial dolomitization, resulting in coarse-grained textures (Kerans and Lucia, 1989). In the Langley reservoir, maximum intergranular porosity of 5% porosity and permeability of 0.5 md (millidarcies) are present in peloid-algal mat boundstone and peloid/ooid grainstone facies (Verseput, 1989). Non-fabric selective fractures and solution collapse breccia also occur and enhance both porosity (up to 8%) and permeability (up to 50 md).

In the Stateline reservoir, the Ellenburger is composed completely of fabric destructive dolostone (Amthor and Friedman, 1989). Impermeable upper Ellenburger strata are underlain by lower units interpreted as cave-roof facies that contain abundant stylolites, fractures, molds, vugs, and dissolution cavities with maximum porosity of 15 percent (Amthor and Friedman, 1989).

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Table 102-1. Reservoirs in the Ellenburger Karst-Modified Restricted Ramp Carbonate play that had produced 1 MMBO as of the end of 2000. **Reservoir unit (NMOCD**) is the stratigraphic unit from which production is obtained, as designated by the New Mexico Oil Conservation Division. **O/G** indicates whether the reservoir is designated as an oil (O) reservoir or as a gas (G) reservoir. Cumulative production is through the end of 2000.

Reservoir Name	Reservoir Unit (NMOCD)	County	Discovery Year	Depth (feet)	O/G	2000 oil production (MMBO)	Cumulative production (MMBO)
Brunson	Ellenburger	Lea	1945	8059	O	0.01	27.65
Dollarhide	Ellenburger	Lea	1951	10135	O	0.01	3.51
Fowler	Ellenburger	Lea	1949	9505	O	0.07	17.01
Justis	Ellenburger	Lea	1957	8115	O	0.01	7.66
Stateline	Ellenburger	Lea	1965	12100	O	0	4.19
Teague	Ellenburger	Lea	1950	9700	O	0	2.49
Teague North	Ellenburger	Lea	1988	10200	O	0	1.77
TOTALS						**0.10**	**64.29**

Ellenburger Karst-Modified Restricted Ramp Carbonate Play

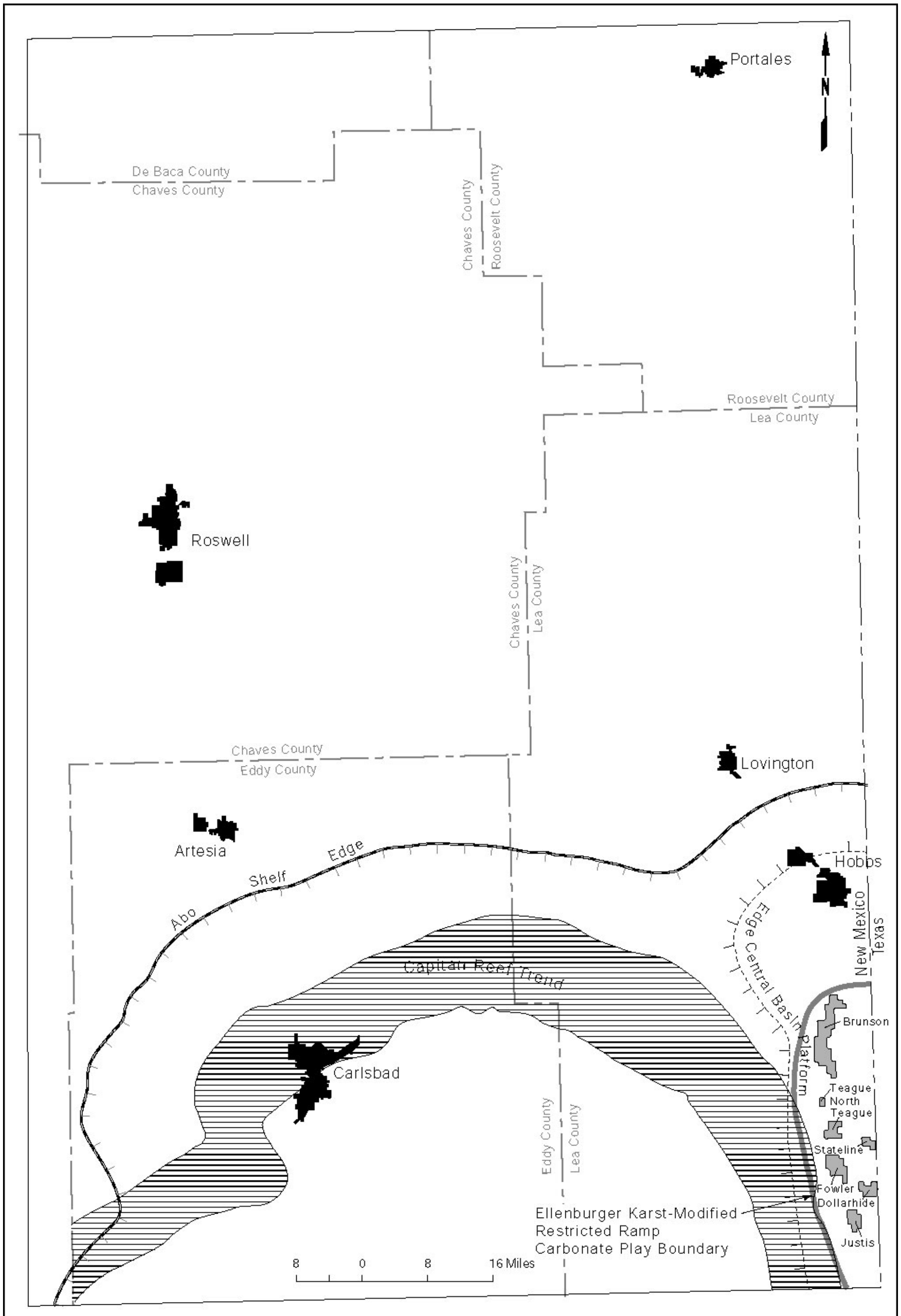

Figure 102-1. Location of reservoirs with more than 1 MMBO cumulative production in the New Mexico part of the Ellenburger Karst-Modified Restricted Ramp Carbonate play.

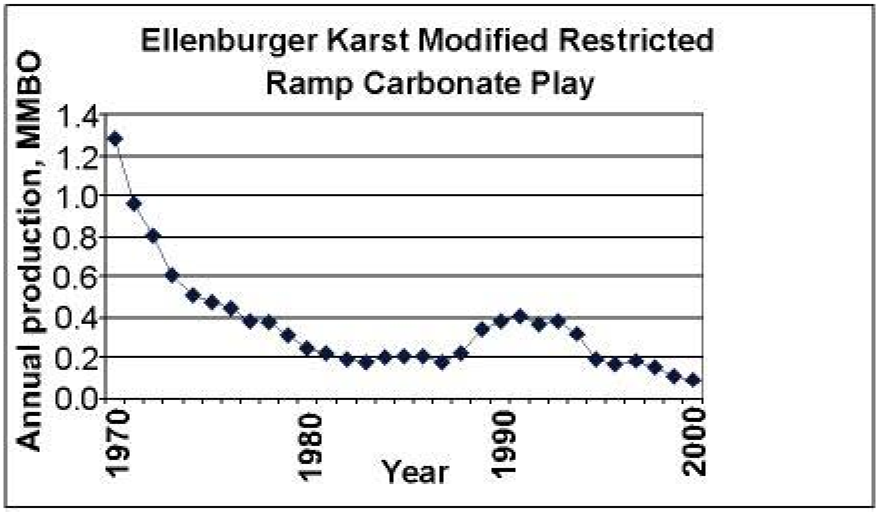

Figure 102-2. Annual production from 1970 to 2000 for the 7 reservoirs within the Ellenburger Karst-Modified Restricted Ramp Carbonate play that have produced more than 1 MMBO.

APPENDIX OF PLAY MAPS IN PDF FORMAT

This appendix contains play maps in *Portable Document Format* (pdf) for all of the oil plays in the New Mexico part of the Permian basin except for Play 106 – Devonian Thirtyone Deepwater Chert play. These maps show locations of reservoirs, play boundaries, and major geologic elements (Abo shelf edge, Wolfcamp shelf margin, Capitan reef trend and edge of Central Basin Platform) superimposed on a township-range grid. Major roads and cities are also shown.