DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Review of the Geology of the Marathon Fold Belt Province, Southwest Texas, as a basis for Assessment of undiscovered hydrocarbon resources

by

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Open-File Report 87-450T

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

Denver, Colorado

1988

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INTRODUCTION

The purpose of this report is to review the geology and petroleum potential of the Marathon fold belt province. This province is located in southwestern Texas in Brewster, Pecos, Terrell and Val Verde Counties. For assessment purposes,the term province, as used in this report, refers to a geographic area that contains one or more geologic features; often, but not always, a sedimentary basin.

Limited production exists in the province at the Pinon gas field in southern Pecos County. Future discoveries in this province are not expected to be great.

The method used for assessment is play analysis. A play is defined as a group of prospects and/or discovered fields[or accumulations] having common characteristics such as source rock, trapping mechanism, structural history,etc,[which]may contain gas and/or oil (Procter and others, 1982). Present estimates of undiscovered hydrocarbons are limited to accumulations with expected ultimate recovery volumes greater than 1 million barrels of oil (MMBO) or 6 billion cubic feet of gas (BCFG). Production and geologic data were collected from the literature and from magnetically stored information such as Petroleum Data System (PDS) where available.

Computer generated drilling density maps were made from PDS data to aid in visualization of producing trends and promising show trends. These maps supplemented geological data and aided in play definition in more thoroughly explored areas by showing locations of dry holes and shows from tested wells.

GEOLOGIC SETTING

General

The Marathon fold belt province is located in southwestern Texas in Brewster, Pecos, Terrell and Val Verde Counties (Fig. 1) and covers an area of about 8000 square miles (20,500 square km). This structurally complex area has been the site of large scale subsidence, thick sedimentary accumulations and intense

Manuscript approved for publication June 10, 1988

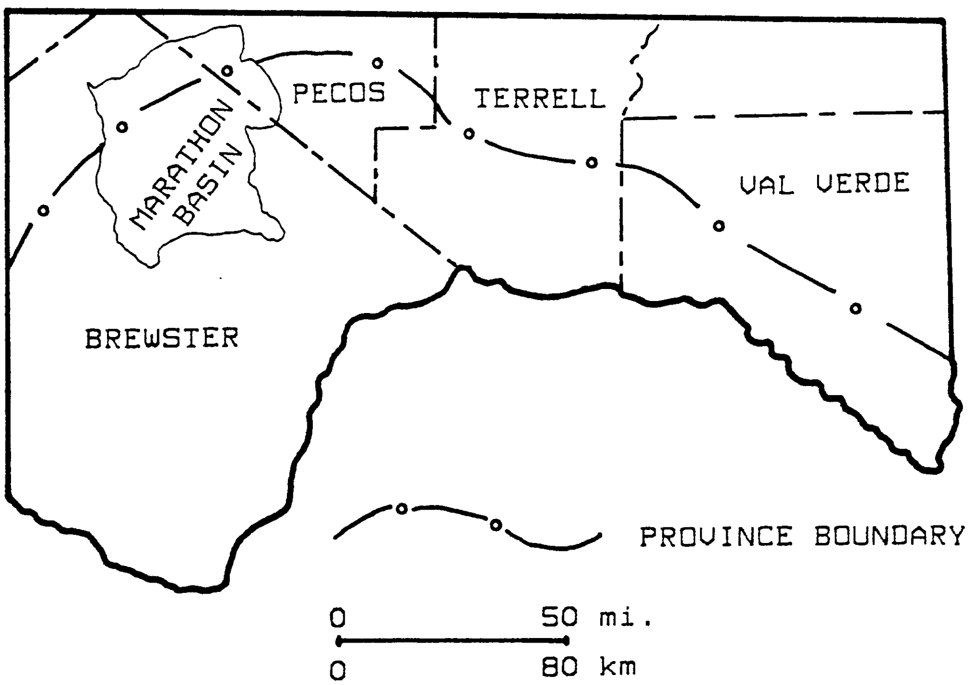

Figure 1. Location of the Marathon fold belt province.

folding and faulting associated with thrusting (King, 1937).

Much of what is known about the area was interpreted by King (1937) from exposures present in the Marathon basin, a topographic basin located on the Marathon Uplift (Fig. 1). The Marathon basin is about 30 miles (48 km) wide and 40 miles (65 km) long.

The Marathon fold belt province lies within two major geographic provinces; the western part is in the Mexican Highlands Province and the central part is in the Great Plains Province (King, 1937). The Marathon fold belt province contains rocks that range in age from Cambrian to Recent (King, 1937; Maxwell, 1968).

Structural

The Llanoria geosyncline is the major structural feature in this province (Fig. 2). Well data indicate that this feature is an extension of the Ouachita geosyncline which is known from exposures in Oklahoma and Arkansas (Flawn and others, 1961).

The Llanoria geosyncline began forming in Cambrian time, experienced a starved basin stage until Devonian time, then underwent a filling stage, primarily during the Pennsylvanian Period. Maximum sedimentary thickness in the geosyncline is not known, but it is in excess of 20,688 feet (6,269 m) (King, 1980).

The northern boundary of the geosyncline in this province is near the center of the Marathon basin (Fig. 3). The position of the southern boundary is less certain, but may be indicated by exposed schist, found underlying Cretaceous rocks about 80 miles (129 km) south of the town of Marathon (Hall, 1956). Suggestions of the original width of the geosyncline of up to 400 miles (640 km) are found in Morgan (1952).

Several episodes of tectonic disturbance have been inferred from boulder beds and other structural features in exposed rocks (Flawn and others, 1961; King, 1937; King, 1980). King (1937) described overturned folds, thrust faults, transverse flaws, tear faults, crumpled and squeezed shale beds, fractural cherts and novaculites and shattered, jointed and slickensided sandstones and limestones from the Marathon basin. Indurated sandstones and shales that approach slates southeast of the Marathon basin are also noted (King, 1937). Recent drilling data suggest that the structural complexity seen at the surface also occurs at depth (King, 1980). Many faults and folds occur at a spacing of tenths of a mile (King, 1937).

Flawn and others (1961) mapped the approximate boundaries of the frontal and interior zones of the geosyncline in the Marathon fold belt province (Fig. 3). They defined the frontal zone on the basis of rocks which displayed no metamorphic to weak metamorphic effects and the interior zone on the basis of rocks which displayed weak to low grade metamorphic effects and a high degree of shearing. The preceeding descriptions of

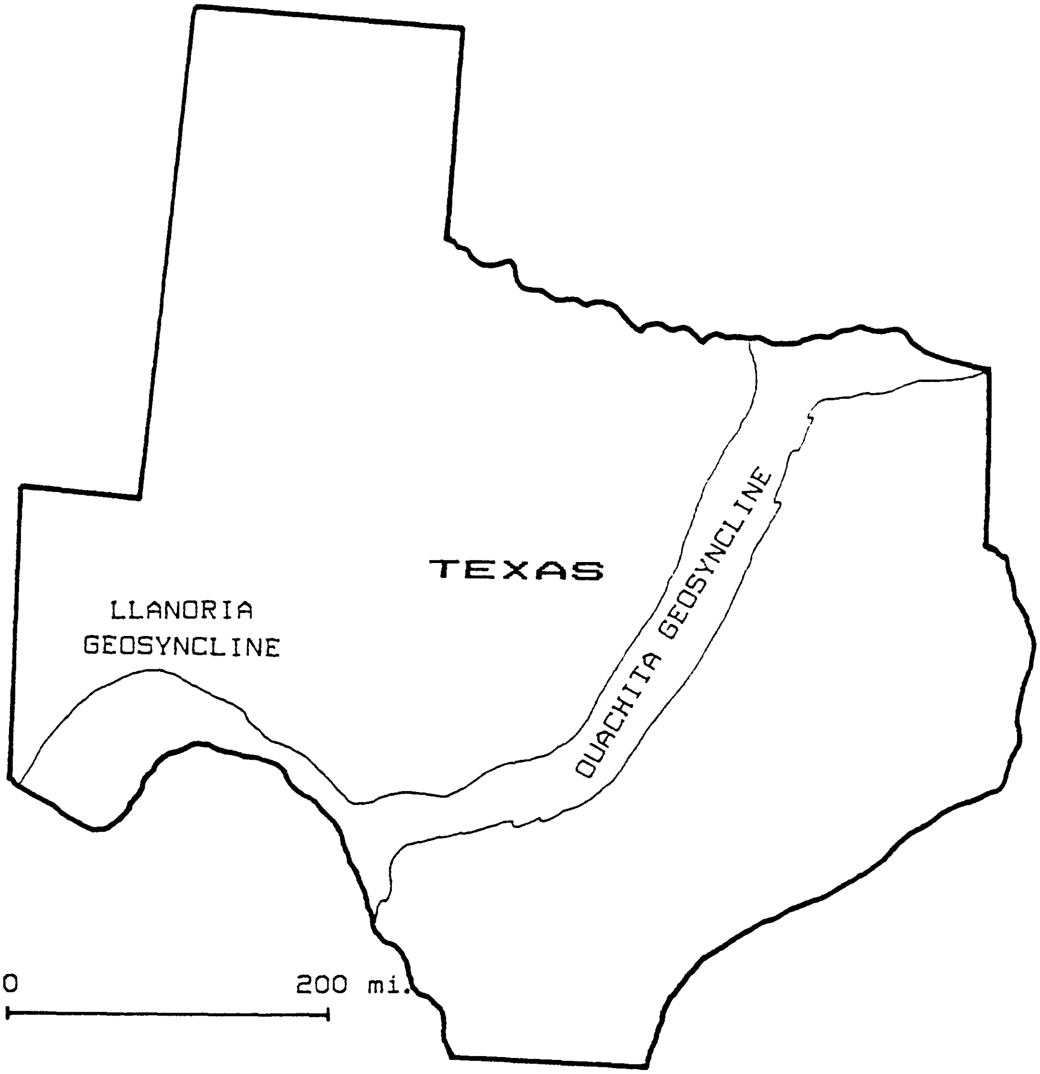

Figure 2. Approximate location of the Ouachita geosyncline and the portion referred to as the Llanoria geosyncline. Modified from King (1978).

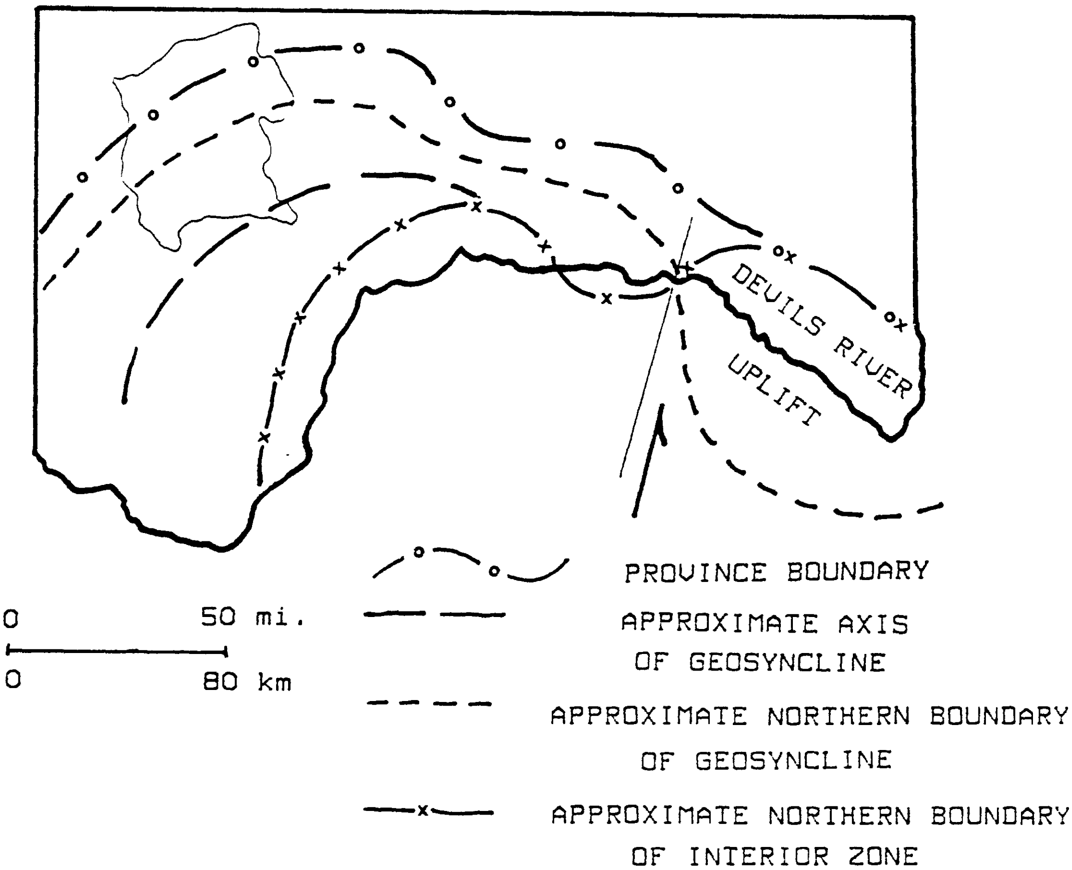

Figure 3. Location of frontal and interior zones within the Marathon fold belt province. Modified from Flawn and others (1961).

structural complexities in this province suggest poor reservoir and trap qualities for much of the Paleozoic section of rocks.

The eastern part of this province is underlain by a subsurface high, the Devils River Uplift, which is part of the interior zone (Flawn and others, 1961). This part of the province is considered to have poor hydrocarbon potential because of the degree of metamorphism of interior zone rocks and the shallow depths at which these rocks are encountered (Table 1).

STRATIGRAPHY

Rocks in the Marathon fold belt province range in age from Cambrian to Recent. At the Marathon basin, the stratigraphic section ranges in age from Cambrian to Recent; the thickest units are of Pennsylanian age. Mesozoic and Cenozoic rocks are thin near the Marathon basin and thicken to the south in southern Brewster County.

EARLY PALEOZIOC ROCKS - MARATHON BASIN

Sediments deposited in the Llanoria geosyncline during its formative phase, Cambrian to Pennsylvanian time (Table 2), indicate a starved basin; sedimentation rates were low and water depths may have been considerable (Flores, 1972, 1974, 1975; Folk, 1973; Folk and McBride, 1976; Hall, 1957, and McBride, 1970). These rocks are known from exposures and from bore hole data in the Marathon basin. They may also exist in the Big Bend area but they would be covered there by over 13,000 feet (3939 m) of younger rocks. The following descriptions of the early Paleozoic rocks are taken from King (1937) except where otherwise noted.

Cambrian System

The Dagger Flat Sandstone is a buff colored sugary sandstone which grades upward into a shaley sandstone with some calcareous beds. The thickness of this unit is unknown, its base is nowhere exposed in this area. Well data suggest that the formation may be as much as 1600 feet (485 m) thick (King, 1980).

Ordovician System

Ordovician age rocks comprise about 2000 feet (606 m) of shale, muddy limestone and chert with minor amounts of conglomerate, boulder beds and sandstone.

The Marathon Limestone overlies the Dagger Flat Sandstone. It ranges in thickness from 500 to 1000 feet (152 to 303 m) and consists of flaggy limestone, greenish clay shale, sandstone and intraformational conglomerate beds.

Table 1. Depth to metamorphosed rock from selected wells from the eastern part of the province. Data from Sellards and others, 1932.

Well Name	Total Depth Feet (Meters)	Depth to Paleozoic Feet (Meters)	Rock Type
Harrison 1, Plateau Oil Co. 0.5 mile north of Del Rio	3,507 (1,070)	3,148 (960)	Talcose shale
Russel & Weathersby 1, East Del Rio Oil Co. 1 mile east of Del Rio	3,350 (1,022)	2,800 (854)	Altered shale
Stevenson 1, Transcontinental Oil Co. 4 miles north of Del Rio	4,412 (1,346)	2,423 (739)	Schistose shale

Table 2. Columnar section of rocks from the area near the Marathon basin. Data from King, 1937 and 1978.

Period	Group	Formation
Quaternary		Gravels
Cretaceous	Fredricksburg Trinity	Eagle Ford
Permian		Wolfcamp
Pennsylvanian		Haymond Dimple Limestone Tesnus Formation
Mississippian		
Devonian		Caballos Novaculite
Ordovician		Maravillas Chert Woods Hollow Shale Fort Pena Formation Alsate Shale Marathon Limestone
Cambrian		Daggar Flat Sandstone

The Alsate Shale is composed of shale in the northern part of the Marathon basin and grades into a limestone rich unit toward the southern part. The unit ranges in thickness from 25 to 145 feet (7.6 to 44 m) possibly attaining a thickness of 350 feet (106 m).

The Woods Hollow Shale is a greenish clay shale with interbedded sandy limestone, limey sandstone and nodular conglomeratic limestone. This formation ranges from 300 to 400 feet (91 to 121 m) thick in the Marathon basin.

The Maravillas Chert is composed of interbedded limestone and black chert with some conglomerate beds. It ranges in thickness from 100 to 200 feet (30 to 61 m) in the northwestern part of the Marathon basin and thickens southward to 400 feet (121 m).

Devonian System

The Devonian System is represented by siliceous beds of the Caballos Novaculite. This formation contains bedded chert in the northwestern part of the Marathon basin and novaculite toward the south. It ranges in thickness from 200 to 600 feet (61 to 182 m). A significant unconformity between the Caballos Novaculite and the overlying Pennsylvanian Tesnus Formation that may represent all of Mississippian time is noted by King (1937). In a subsequent report, King (1980) indicates that the upper part of the Caballos Novaculite and the lower part of the Tesnus Formation contain Mississippian age rocks, the boundaries being uncertain.

LATE PALEOZOIC ROCKS - MARATHON BASIN

From early Carboniferous to Permian time great quantities of clastic material were deposited in the Llanoria geosyncline attaining a thickness of over 16000 feet (4848 m). These rocks are primarily sandstone, limestone and shale and represent the filling phase of the geosyncline (Table 2). Descriptions of these rocks are summarized from King (1937) except where noted.

Pennsylvanian System

With the exception of the lowest part of the Tesnus Formation, which is of Mississippian age, this formation makes up the lower part of the Pennsylvanian System in the Marathon basin. The Tesnus Formation is composed of sandstone and shale. It ranges in thickness from 300 to 6500 feet (91 to 1970 m) from north to south in the basin. Black shales are present in the northern part of the basin; these grade into sandstone, arkose and quartzite to the south.

The Dimple Limestone contains moderately thick, gray, sandy limestones with some highly bituminous beds. The thickness of this formation is variable from 500 to over 1000 feet (152 to

303 m) in the Marathon basin.

The Haymond Formation is composed of thinly bedded sandstone and shale with massive arkose beds and boulder bearing mudstone. This formation attains a thickness of over 3000 feet (909 m) thick in the basin.

The Gaptank Formation consists of limestone, sandstone, shale, conglomerate beds and boulder beds in the lower part of the unit. This unit attains a thickness of over 1800 feet (545 m) in the basin.

Permian System

Permian rocks are known from outcrops in the Glass Mountains north and west of the Marathon basin and from bore hole information from within the basin (Table 2). Although they attain a thickness of 5000 to 7000 feet (1515 to 2121 m) in the Glass Mountains Permian the thickness of known Permian rocks in the Marathon basin is about 1600 feet (485 m) (King, 1980). Bore hole information indicates the presence of Wolfcampian rocks below a thrust plane in the eastern part of the basin (King, 1980).

MESOZOIC ROCKS - MARATHON AND BIG BEND AREAS

Cretaceous System

Cretaceous rocks encircle the Marathon basin to the west, south and east. These rocks are predominately Lower Cretaceous in age near the basin and the section expands to the south where both Upper and Lower Cretaceous rocks are well developed. Cretaaceous rocks range from 400 to 1000 feet (121 to 303 m) near the Marathon basin to 6000 feet (1818 m) in the Big Bend area (Fig. 4). The following descriptions of Cretaceous rocks are taken from King (1937) except where noted.

The Trinity Group is composed of the Glen Rose Formation and Maxon Sandstone. The Glen Rose Formation is a limestone with interbedded marly limestone and sandstone. It increases in thickness from 50 feet (15 m) near the Marathon basin to 600 feet in the Big Bend area (Maxwell, 1968). The Maxon Sandstone is a well-indurated, medium to coarse grained brown sandstone. It ranges from 100 feet (30 m) thick near the Marathon basin to 10 feet (3 m) in the Big Bend area (Maxwell, 1968).

The Fredricksburg Group in the Marathon basin area is composed of the Walnut and Commanche Peak Formations and the Edwards Limestone. The Walnut and Commanche Peak Formations contain marls and soft limestones respectively. In the Marathon basin area these rocks are approximately 50 feet (15 m) thick. The Edwards Limestone is a massive limestone unit with a thickness of about 200 feet (61 m) near the basin.

The formal Fredricksburg Group name is not used by Maxwell (1968) in his description of Cretaceous rocks of the Big Bend

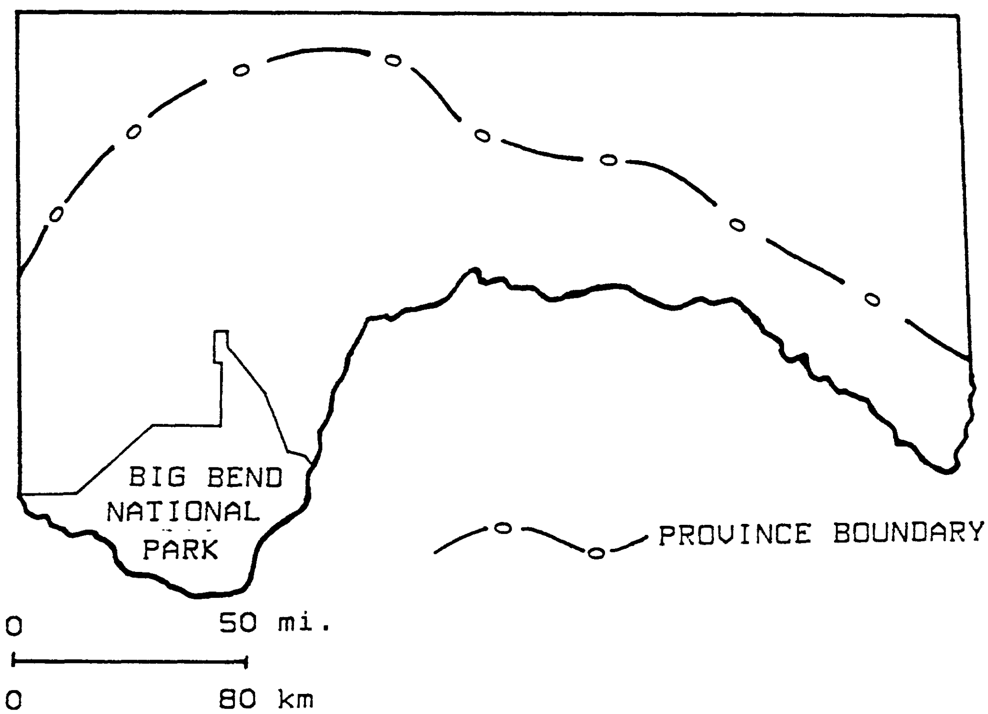

Figure 4. Location of Big Bend National Park.

area. Rocks in the Big Bend area that occur in the same general stratigraphic position as rocks of the Fredricksburg Group in the Marathon area are divided into four formations by Maxwell (1968). The following description of these four formations is taken from Maxwell (1968).

Above the Maxon Sandstone lies the Telephone Canyon Formation. This unit contains thin, nodular marly limestone and marl and it ranges in thickness from 40 to 130 feet (12 to 40 m).

The Del Carmen Limestone is a massive, dense, cherty, ledge forming limestone. It ranges from 350 to 450 feet (106 to 136 m) in thickness.

The Sue Peaks Formation consists of shale, marl and nodular limestone. It is approximately 75 feet (23 m) in the area.

The Washita Group of the Marathon basin area is composed of the Georgetown Limestone, Del Rio Clay and Buda Limestone. The following descriptions of these three formations are from King (1937).

The Georgetown Limestone is a thin to thickly bedded limestone and attains a thickness of about 200 feet (61 m) on the west side of the basin. The Del Rio Clay is composed of about 20 feet (6 m) of drab shale and sandy limestone. The Buda Limestone comprises about 60 feet (18 m) of thickly bedded, light colored limestone. The youngest Cretaceous beds in the Marathon area are considered to be the same as the Eagle Ford Formation of central Texas. These rocks consist of buff to gray, thinly bedded, flaggy limestones which also resemble the flaggy Boquillas Formations to the south.

In the Big Bend area, rocks that occupy the same stratigraphic position as the Washita Group of the Marathon basin, are divided by Maxwell (1968) into the Santa Elena Limestone, the Del Rio Clay and the Buda Limestone. The following descriptions of these rocks is taken from Maxwell (1968).

The Santa Elena Limestone is a massive, thickly bedded, dense, cherty limestone with some thinly bedded marly limestone near the base. It ranges in thickness from 750 to 850 feet (227 to 258 m).

The Del Rio Clay varies in thickness from about 1 to 125 feet (.3 to 38 m). It is composed of light gray clay, clay shale and thinly bedded limestone.

MESOZOIC ROCKS - BIG BEND AREA

Cretaceous System

The Buda Limestone is a light colored, brittle, nodular limestone with some marl. It is about 100 feet (30 m) thick in this area.

A thick sequence of over 3600 feet (1090 m) of Cretaceous rocks is present in the Big Bend area (Table 3). The following

Table 3. Columnar section of rocks from the province in the Big Bend National Park area. Data from Maxwell and others, 1968.

Geologic Age	Group	Formation
Recent and Pleistocene		Alluvial Deposits
Oligocene or Younger	Big Bend Park	South Rim Formation
		Chisos Formation
Eocene		Canoe Formation
	Tornillo	Hannold Hill Formation
Paleocene		Black Peaks Formation
Cretaceous (Gulfian)		Javelina Formation
		Aguja Formation
	Terlingua	Pen Formation
		Boquillas Formation
Cretaceous (Comanchean)		Buda Limestone
		Del Rio Clay
		Santa Elena Limestone
		Sue Peaks Formation
		Del Carmen Limestone
		Telephone Canyon Fm.
		Maxon Sandstone
		Glen Rose Formation
Paleozoic		Paleozoic Sedimentary and Metamorphic Rocks

description of these rocks is summarized from Maxwell (1968).

The Boquillas Formation is compossed of gray and yellow-brown flaggy limestones and marly limestone. It may exceed 800 feet (242 m) in this area.

The Pen Formation is made up of gray-blue gypsiferous marl and clay with some concretionary limestone and limey sandstone. It ranges in thickness from 200 to 600 feet (67 to 182 m).

The Aguja Formation marks the transition from marine conditions to continental conditions. The lower part of the formation consists of 500 to 700 feet (152 to 212 m) of marine sandstone and clay. The upper part of the formation is from 300 to 700 feet (90 to 212 m) thick and contains non-marine clays coal layers, brown to yellow brown sandstone and large dinosaur bones and wood fossils.

The Javalina Formation ranges from 350 to 850 feet (106 to 258 m) in thickness in the area. It also contains dinosaur bones and wood fragments. The formation consists of clay and sandstone; the clays are commonly bentonitic.

CENOZOIC ROCKS - BIG BEND AREA

Nearly 6000 feet (1818 m) of Paleogene rocks are present in the Big Bend area. These rocks consist of non-marine sandstone, clay, tuff and ash beds, mudstone, conglomerate and lavas. The following description of these rocks is taken from Maxwell (1968).

The Paleocene Black Peaks Formation is composed of varicolored clay, interbedded sandstone and conglomerate. It attains a thickness of 850 feet (258 m) in the area.

The Eocene Hannold Hill Formation ranges in thickness from 356 to 770 feet (108 to 233 m) in this area. It consists of soft conglomeratic sandstone and clay.

The Canoe Formation, also Eocene in age, is about 1170 feet (355 m) thick in the area and it is composed of a lower cross bedded sandstone and an upper zone of tuff, mudstone, tuffaceous sandstone, indurated tuff and lavas.

The youngest Eocene rocks are those of the Chisos Formation. It is composed of indurated tuff, mudstone, tuffaceous sandstone, ash, lavas, sandstone and conglomerate. It ranges in thickness from 1500 to 2600 feet (455 to 788 m).

The South Rim Formation is Oligocene or younger in age and is composed of lava flows, ash beds, tuff, flow breccias, sandstone and conglomerate. It ranges in thickness from 1000 to 1500 feet (303 to 455 m).

Pleistocene and Recent deposits occur in thicknesses from 100 to 500 feet (33 to 152 m) in the region. These deposits are mainly clay, silt, sandstone and conglomerate.

SOURCE ROCKS

Few wells have been drilled in this province and little subsurface data are avilable. From general lithologic descriptions given in the literature it appears that source rocks are not common in the province. King (1937) mentions almost 300 feet (91 m) of Pennsylvanian (Tesnus) black shale in the northwestern part of the Marathon Basin which grades into a thick sandstone to the southeast. Maravillas and Caballos strata both contain some black cherts, black shales and bituminous limestones (McBride, 1970). No data were found regarding thermal maturity levels of potential source rocks.

BURIAL HISTORY AND MIGRATION

Little is known, in detail, about the burial history of potential source rocks in this province. In deep wells drilled in the Marathon Basin the Caballos Novaculite has been shown to range in depth from the surface to over 9500 feet (2879 m) (King, 1980). The Maravillas chert ranges in depth from the surface to over 9700 feet (2939 m) (King, 1937). The Tesnus Formation encountered in most of these deep wells is relatively thick, probably of a sandy flysch nature and not a potential source rock. Assuming an average geothermal gradient of 1.6 F per 100 feet, deposition during Devonian to Mississippian time and present depth these beds could have produced ydrocarbons.

Numerous faults mapped in the area (King, 1937) could have provided avenues of migration for hydrocarbons generated.

HYDROCARBON OCCURENCE

The only known field in this province is the Pinion gas field in southern Pecos County (Fig. 5). This field was discovered in 1982 with production from the Dimple Limestone, Tesnus Formation and the Caballos Novaculite (Adams and others, 1984).

IDENTIFIED PLAYS

Only a single play was identified in this province. Structure is an important element in the geology of this province and it probably is the primary control over presence and distribution of hydrocarbon resources. For this reason, and because known hydrocarbon occurrences are so limited, plays were not defined on a stratigraphic basis.

FRONTAL ZONE PLAY

The play boundary is coincident with the frontal zone boundary (Fig. 5). shown by Flawn and others (1961). Reservoir quality rocks in the Pennsylvanian section are probably best developed in the upper part of the Tesnus Formation where relatively open folds exist along with substantial thicknesses of sandstone and interbedded shales exist (King, 1937).

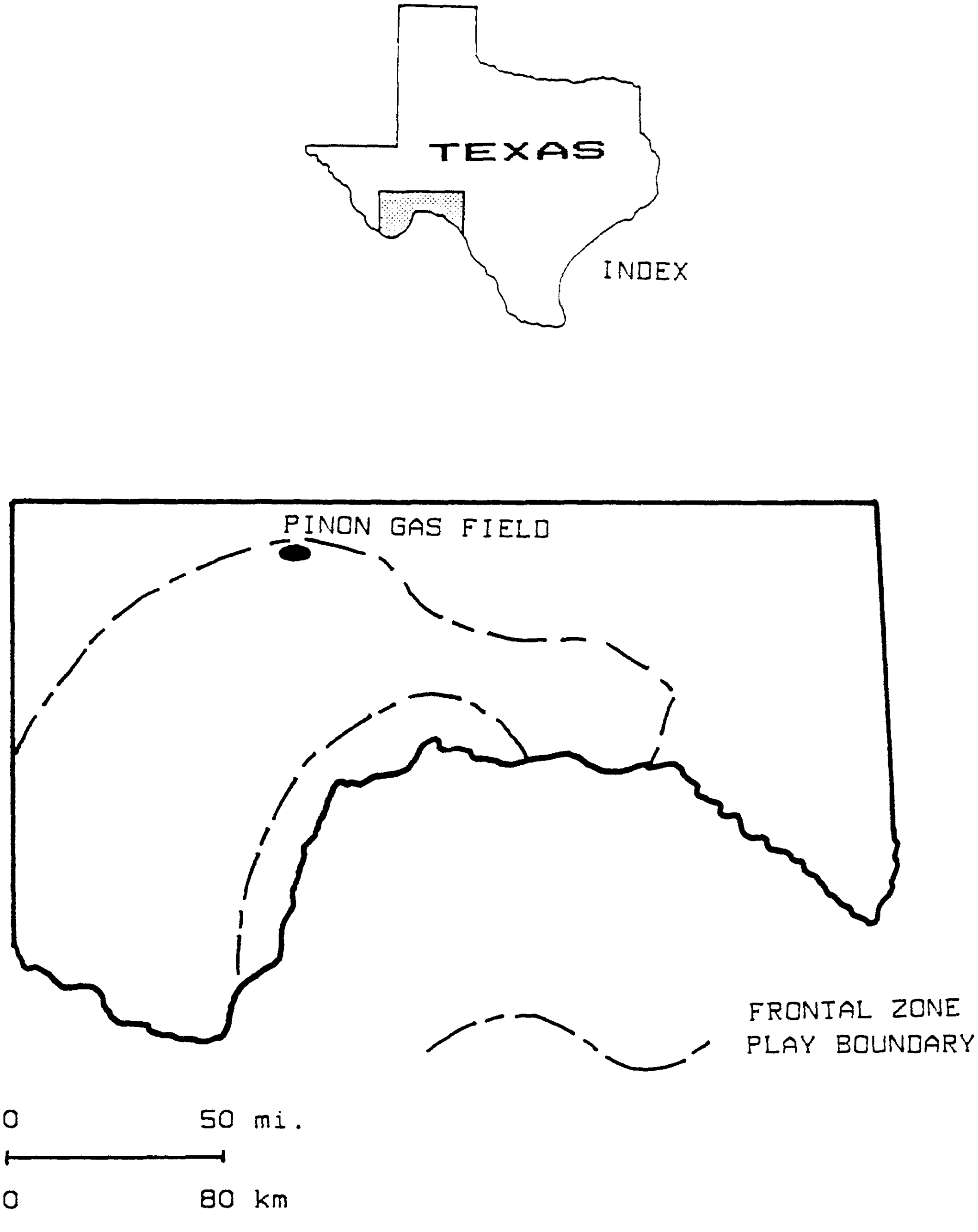

Figure 5. Location of frontal zone play and the Pinon gas field.

The Caballos Novaculite may form suitable reservoirs where fracture porosity exists. Traps are expected to be primarily structural, formed by open folds or larger anticlines, which have not been destroyed by tectonic events. Seals in the upper Tesnus Formation may be formed by thick layers of interbedded shales and those in the Caballos Novaculite are probably due to the overlying shales in the lower Tesnus Formation. Potential hydrocarbon source rocks in this play include the Maravillas Chert (McBride, 1970) and black Pennsylvanian shales in the northwestern part of the province. These reservoir rocks range from the surface to depths of 10,000 feet (3030 m).

SUMMARY

The Marathon fold belt province does not appear to contain significant amounts of undiscovered hydrocarbons. The area has not been heavily explored, probably as a result of the lack of success from the wells that have been drilled. This lack of information with regard to quality and quantity of source and reservoir rocks introduce a high degree of uncertainty in the assessment process.

The degree of metamorphism and the effects of structural deformation displayed in surface rocks, and inferred from well data in the Marathon basin, do not indicate the presence of favorable traps. South of the Marathon basin, in the Big Bend area, there is a much thicker sequence of Cretaceous rocks. These rocks have not been subjected to the degree of structural deformation or metamorphism that the Paleozoic rocks of the Marathon basin have undergone, however, there is an absence of known source beds within these rocks. The Cenozoic rocks in the Big Bend area neither contain known source beds nor appear to have ever been deeply buried.

REFERENCES

Adams, D. R., Collier, W. W., Gail, G. J., Gaines, R. B., Gibson, W. R., Miller, H. A. Jr., Pause, P. H. and Robbins, L. D., 1984; Oil and gas developments in West Texas and eastern New Mexico in 1983. American Association of Petroleum Geologists Bulletin, vol. 68, no. 10, p. 1341-1348.

Flawn, P. T., Goldstein, A. Jr., King, P. B., and Weaver, C. E., 1961, The Ouachita System: Texas University (Bureau of Economic Geology) Publication 6120, 401 p.

Flores, R. M., 1972, Delta front-delta plain facies of the Pennsylvanian Haymond Formation, northeastern Marathon Basin, Texas: Geological Society of America Bulletin, vol. 83, p. 3415-3424.

Flores, R. M., 1974, Characteristics of Pennsylvanian lower-middle Haymond delta-front sandstones, Marathon Basin, West Texas: Geological Society of America Bulletin, vol. 85, p. 709-716.

Flores, R. M., 1975, Short-headed stream delta: Model for Pennsylvanian Haymond Formatin, West Texas: American Association of Petroleum Geologists Bulletin, vol. 59, no. 12, p. 2288-2301.

Folk, R. L., 1973, Evidence for peritidal deposition of Devonian Caballos Novaculitee: The American Association of Petroleum Geologists Bulletin, vol. 52, no. 4, p. 702-725.

Folk, R. L. and McBride, E. F., 1976, The Caballos Novaculite revisited part I: origin of novaculite members: Journal of Sedimentary Petrology, vol. 46, no. 3, p. 659-669.

Hall, W. E., 1956, Marathon folded belt in Big Bend area of Texas: Bulletin of the American Association of Petroleum Geologists, vol. 40, no. 9, p. 2247-2255.

Hall, W. E., 1957, Genesis of "Haymond boulder beds", Marathon Basin, West Texas: Bulletin of the American Association of Petroleum Geologists, vol. 421, no. 7, p. 1633-1641.

King, P. B., 1937, Geology of the Marathon Region, Texas: U.S. Geological Survey Professional Paper 187, 148 p.

King, P. B., 1978, Tectonics and sedimentation of the Paleozoic rocks in the Marathon region, west Texas, in Mazullo, S. J., ed., Tectonics and Paleozoic facies of the Marathon geosyncline, west Texas: Permian Basin Section, Society of Economic Paleontologists and Mineralogists Publ. 78-17, p. 5-37.

King, 1980, Geology of the eastern part of the Marathon basin: U.S. Geological Survey Professional Paper 1157, 40 p.

Maxwell, R. A., Hazzard, R. T., and Wilson, J. A., 1968, The geology of Big Bend National Park, Brewster County, Texas: Texas University (Bureau of Economic Geology) Publication 6711, 320 p.

McBride, E. F., 1970, Stratigraphy and origin of Maravillas Formation (Upper Ordivician),West Texas: Bulletin of the American Association of Petroleum Geologists, vol. 54, no. 9, p. 1719-1745.

Morgan, H. J., 1952, Paleozoic beds south and east of Ouachita folded belt: Bulletin of the American Association of Petroleum Geologists, vol. 36, no. 12, p. 2266-2274.

Procter, R. M., Lee, P. J., and Taylor, G. C., 1982, Methodology of petroleum resource evaluation: Petroleum Resource Assessment Workshop and Symposium, Circum-Pacific Energy And Mineral Conference, Third, Honolulu, 1982 (unpublished manual): Geological Survey of Canada, 60 p.

Sellards, E. H., Adkins, W. S., and Plummer, F. B., 1932, The Geology of Texas, vol. 1: Texas University (Bureau of Economic Geology) Publication 3232, 1007 p.