Oil & Gas Potential of Pre-Permian Strata, Eastern Holbrook Basin, Arizona

by

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OIL & GAS POTENTIAL OF PRE-PERMIAN STRATA, EASTERN HOLBROOK BASIN, ARIZONA Introduction

Pre-Permian strata have been the objective of several oil and gas tests drilled in the eastern Holbrook Basin, Arizona. This has been a reasonable and valid pursuit especially in light of the many shows of oil and gas recorded in pre-Permian units in wells drilled in the eastern Holbrook Basin (Peirce and Wilt, 1970; Conley and Giardina, 1979).

Most tests have targeted Devonian rocks, which are strongly petroliferous in outcrop south of the Holbrook Basin along the Mogollon Rim and in Salt River Canyon (Huddle and Dobrovolny, 1952) and contain asphalt in fractures between Payson and Pine (Conley, 1975). Geochemical analyses of Devonian mudstones in Salt River Canyon have a total organic carbon content of 2.81 percent and are within the oil generating window (Desborough, Poole, Daws, and Scarborough, 1984, p. 54). Devonian strata in northeastern Arizona, north of the Holbrook Basin, have produced approximately 100,000 barrels of oil in the Walker Creek Field (Rauzi, 1996). As a result, hydrocarbons may well have been generated in Devonian source rocks at depth in the eastern Holbrook Basin.

Stratigraphic or subtle structural traps in the eastern Holbrook Basin are likely in Devonian, Mississippian, and Pennsylvanian strata deposited in local depressions or embayments along the southwest margin of the Defiance-Zuni Uplift of Paleozoic age. Shows of methane and ethane gas in a recently drilled well north of Concho indicate that hydrocarbons may even be trapped in granite wash underlying pre-Permian strata.

The Defiance-Zuni Uplift in the eastern Holbrook Basin was one of generally low relief, at or slightly above sea level, during all of the Paleozoic era (McKee, 1951, p. 488; Peirce, 1976, p. 37). Transgressive deposits of Devonian through Pennsylvanian age wedge out against the southwest margin of the Defiance-Zuni Uplift (Beus, 1989, p. 290; Peirce, 1976, p. 48), an area which covers approximately 6,000 square miles of relatively unexplored country between Winslow on the northwest and Alpine on the southeast (Fig. 1).

As of this writing, only thirty wells have been drilled to Proterozoic basement along the southwest margin of the Defiance-Zuni Uplift in the eastern Holbrook Basin. Correlation of these wells (approximately 1 well per 200 square miles) form the basis of the accompanying isopach maps of Devonian, Mississippian, and Pennsylvanian strata (Figs. 2, 3, and 4). Northeast and northwest stratigraphic sections were prepared to show the stratigraphic

relationships between the pre-Permian strata and the underlying Proterozoic basement along the southwest margin of the Defiance-Zuni Uplift in the eastern Holbrook Basin (Figs. 5, 6).

Land and Drilling

State, federal, and private lands are available for leasing in the eastern Holbrook Basin. Most of the acreage is state and private. Federal land is found in isolated areas. State land is available on a non-competitive basis and carries a five-year term with a one-eighth royalty on any production. Federal land is available from the Bureau of Land Management on a competitive, or public auction basis. Federal lands receiving no bids in public auction are available on a non-competitive basis for two years following the public auction date. Federal land carries a ten-year term with a one-eighth royalty.

Drilling depths in the eastern Holbrook Basin are shallow to moderate, ranging from 2,400 feet to Proterozoic basement east of St. Johns, to 4,000 feet near Holbrook, and to 4,600 feet near Show Low. Proterozoic basement may be as deep as 6,500 to 7,000 feet in the southeasternmost part of the Holbrook Basin in the White Mountain region where recent drilling suggests the presence of a concealed evaporite, sabkha basin of Permian age (Rauzi, 1994). Current drilling density through pre-Permian rocks in the eastern Holbrook Basin is about 1 well per 200 square miles.

Potential lost circulation problems in Permian Kaibab Limestone, Triassic Shinarump Conglomerate, and surface volcanic rocks, where present, can be avoided by carefully considering the site-specific geologic conditions when planning the drilling and casing programs. Further problems and cost overruns in the eastern Holbrook Basin can be avoided by converting to salt-saturated mud when drilling through the extensive Permian salt (halite) deposits (Figs. 1-4) in the upper Supai Group of Peirce (1989). Use of freshwater or brackish mud through the salt section is discouraged. All casing cemented across halite zones should be with salt-saturated cement. Wait on cement times are longer, but the results are dependable.

General

Permian strata truncate Devonian, Mississippian, Pennsylvanian, and Proterozoic basement rocks along the southwest margin of the Defiance-Zuni Uplift in the eastern Holbrook Basin. Maximum submergence of the Defiance-Zuni Uplift may have occurred during the Mississippian (Stoyanow, 1936). The Mississippian rocks were subsequently eroded back to an

edgeline west of Devonian rocks (Fig. 1), probably by renewed, slow emergence of the uplift in Pennsylvanian through Permian time. As much as 2,000 feet of Permian strata were eventually deposited on the Proterozoic basement rocks of the Defiance-Zuni Uplift.

Devonian, Mississippian, and Pennsylvanian strata are the most extensive and prospective of the pre-Permian units in the eastern Holbrook Basin. Cambrian rocks are thin to absent in the eastern Holbrook Basin and are not addressed in this report. Ordovician and Silurian rocks are not recognized as having been deposited in this region.

Devonian

Devonian strata overlie a variable topography of Proterozoic and minor Cambrian rocks over most of the eastern Holbrook Basin (Figs. 5, 6). North of the Holbrook Basin, basal Devonian sands (McCracken) are productive where they were deposited around pre-Devonian topographic relief along the northwest margin of the Defiance-Zuni Uplift. Approximately 100,000 barrels of oil have been produced from these basal Devonian sands in northeastern Arizona at the Walker Creek Field (Rauzi, 1996). South of the Holbrook Basin, basal Devonian sands (Beckers Butte) were deposited on a surface of as much as 300 feet of local relief along the Mogollon Rim and in Salt River Canyon (Huddle and Dobrovolny, 1952). The isopach pattern of Devonian rocks (Fig. 2) indicates that similar pre-Devonian relief is present at depth in the eastern Holbrook Basin. Local depressions and embayments with similar basal sand deposits are probable along the entire length of the southwest margin of the Defiance-Zuni Uplift in the eastern Holbrook Basin.

Drifting plankton and algae, abundant flora of psilophytes (primitive land plants) and layers of lime mud rich in organic matter probably filled the local depressions and embayments (Teichert, 1965, p. 81). As a result, these areas may contain hydrocarbon source rock and significant potential for stratigraphic and subtle structural traps in the pre-Permian strata in the subsurface of the eastern Holbrook Basin.

Basal Devonian sands, 10 to 20 feet thick, usually occur below a thick sequence of darkbrown, petroliferous limestone in outcrops along the Mogollon Rim (Huddle and Dobrovolny, 1945). In like manner, basal sands deposited in local depressions and embayments along the southwest margin of the Defiance-Zuni Uplift may contain trapped hydrocarbons generated from organic-rich source rock. Such hydrocarbon source rock at depth in the eastern Holbrook Basin

may have geochemical analyses similar to or better than Devonian mudstones that crop out in Salt River Canyon. The Devonian mudstones in Salt River Canyon have a total organic carbon content of 2.81 percent and are within the oil generating window (Desborough, Poole, Daws, and Scarborough, 1984, p. 54).

Obviously, the sparse drilling density that currently exists in the Holbrook Basin makes it difficult to impossible to precisely pinpoint the localized areas of prospective pre-Devonian relief. Closely-spaced seismic coupled with surface geochemical analyses, however, across areas with reverses in isopach lines may identify and lead to drillable locations on such prospective areas. Areas of low magnetic susceptibility may indicate hydrocarbon accumulations that mask the higher magnetic susceptibility of underlying and surrounding rocks.

Drilling density through Devonian rocks in the Holbrook Basin is low, averaging about 1 well per 200 square miles. In spite of the low drilling density, shows of hydrocarbons have been reported from pre-Permian units in several wells drilled in the eastern Holbrook Basin (Peirce and Wilt, 1970; Conley and Giardina, 1979). The most recent encouragement includes a show of methane and ethane gas from granite wash underlying about 80 feet of Devonian strata in a well drilled about 15 miles north of Concho in 1996. As a result, Devonian strata continue to have potential as hydrocarbon source and reservoir rock at depth in the eastern Holbrook Basin.

Mississippian

The Mississippian Redwall Limestone maintains a fairly consistent thickness of about 100 feet across most of the Holbrook Basin and wedges out between Devonian and Pennsylvanian rocks along the southwest margin of the Defiance-Zuni Uplift (Figs. 3, 5). Mississippian rocks are not present in a broad area northwest of Heber (Fig. 3), probably because of late or post Mississippian uplift and erosion (Havenor and Pye, 1958, p. 78).

More than 800,000 barrels of oil and 385 million cubic feet of helium-bearing gas have been produced from Mississippian carbonate units in northeastern Arizona (Rauzi, 1996). As a result, the hydrocarbon and helium potential of Mississippian rocks in the eastern Holbrook Basin should not be dismissed, especially along the southwest margin of the Defiance-Zuni Uplift. Mississippian rocks may contain hydrocarbons or helium-bearing gas, especially where truncated between underlying Devonian hydrocarbon source rocks and overlying impermeable

Pennsylvanian shales. The potential for such hydrocarbon or helium-bearing traps around the perimeter of the broad area of missing Mississippian rocks northwest of Heber has not been tested by drilling.

Pennsylvanian

Many successful oil producers have become so by "chasing the sediments" in and from deep depositional basins. It is of particular interest, therefore, that the Pedregosa Basin in southeastern Arizona was the deepest depositional area of the state throughout Pennsylvanian and Permian time (Stoyanow, 1936, p. 535-576; Peirce, 1976, p. 47 and 51; Ross, 1973, p. 909; and Ross, 1978, p. 193). Furthermore, more hydrocarbons have been produced from Pennsylvanian rocks than any other unit in Arizona. All current methane gas production (about 1 million cubic feet per day) in northeastern Arizona is from Pennsylvanian carbonate units, and more than 17 million barrels of oil have been produced from igneous reservoir rock of Tertiary age intruded into Pennsylvanian carbonate units at the Dineh-bi-Keyah Field, which lies on the northern margin of the Defiance-Zuni Uplift in northeastern Arizona (Rauzi, 1996). Amazingly, mid-Tertiary volcanic/intrusive activity has enhanced hydrocarbon production from Pennsylvanian carbonate units in northeastern Arizona.

The fossiliferous Pennsylvanian strata at depth in the eastern Holbrook Basin, therefore, may very well have generated and trapped hydrocarbons, especially along the southwest margin of the Defiance-Zuni Uplift, where Tertiary volcanic/intrusive activity may have enhanced the hydrocarbon generation and potential of Pennsylvanian strata, much as it has enhanced the generation and production of hydrocarbons in northeastern Arizona. Several wells had shows of hydrocarbons from Pennsylvanian units in the eastern Holbrook Basin (Peirce and Wilt, 1970; Conley and Giardina, 1979). These shows indicate that Pennsylvanian strata are a legitimate objective for hydrocarbon accumulations in the eastern Holbrook Basin, and provide an additional objective in wells drilled to test underlying Devonian rocks.

Pennsylvanian strata are relatively extensive across the eastern Holbrook Basin and were more than likely continuous with the Pennsylvanian strata of the Pedregosa Basin to the south (Ross, 1973). These strata lap onto the southwest margin of the Defiance-Zuni Uplift where they unconformably overlie Devonian and Mississippian strata, and Proterozoic granite wash. Most of the shoreline clastic rocks of Pennsylvanian age in the eastern Holbrook Basin are

shales, calcareous siltstones, and silty limestones, indicating that the southwest margin of the Defiance-Zuni Uplift remained one of relatively low relief, at or slightly above sea-level throughout the Pennsylvanian.

Thickness of Pennsylvanian strata on the isopach map (Fig. 4) is essentially coincident with the thickness of the Naco Formation, primarily as defined on gamma ray--neutron logs in conjunction with a distinctive "caliper bench" in wells with a caliper log, along with an interpretation of sample logs. The term Naco is common in the literature and well logs covering this region but it may include units other than the Naco at its type locality at Bisbee (Ransome, 1904, p. 44-46).

The Pennsylvanian Naco Formation grades from unfossiliferous red beds in the western Holbrook Basin into fossiliferous carbonate beds in the eastern and southeastern part of the basin, where they are lithologically similar to the "Bough" zone of probable upper Pennsylvanian age in southeastern New Mexico (Kottlowski and Havenor, 1962, p. 77). The Bough zone produces oil from the Bluitt, Bough, and Allison Fields and appears to have similar relationships to the Matador arch as the Naco has to the Defiance-Zuni Uplift (Kottlowski and Havenor, 1962, p. 77).

Kottlowski and Havenor (1962, p. 82) postulated a north-trending "Holbrook Gulf" southwest of Holbrook extending southward to the thick marine section near San Carlos Reservoir (Fig. 4). The Defiance-Zuni Uplift may have formed an eastern boundary to this gulf much as the Florida peninsula forms an eastern boundary to the Gulf of Mexico today.

Massive to nodular fossiliferous limestones of Pennsylvanian age crop out in the southeasternmost part of the Holbrook Basin on the north side of Escudilla Mountain in 28-7n-31e (Wrucke, 1961, p. 24-25). These outcrops indicate that a fairly thick sequence of Pennsylvanian marine strata was deposited in this portion of the Holbrook Basin and is present at depth beneath the White Mountain volcanic field. A well drilled into the Permian Supai in 1993 on the south side of Escudilla Mountain in 23-6n-30e (Fig. 4) shows that the extensive volcanic rocks forming the White Mountains are not extensive at depth and have not been detrimental to the oil and gas potential of this region. This volcanism, in fact, may have locally enhanced the potential for oil and gas generation and accumulation as it has in northeastern Arizona. The bleeding oil from Permian carbonate units in the hole drilled south of Escudilla

Mountain attests to the presence of hydrocarbons at depth beneath the volcanic rocks in the White Mountain area (Rauzi, 1994, p. 7).

As a result, the large, organic-rich reefs and associated lagoonal deposits, suggested at depth by the fossiliferous Pennsylvanian rocks that crop out on the north side of Escudilla Mountain, have significant potential for generation, accumulation, and production of oil and gas along this part of the southwest margin of the Defiance-Zuni Uplift. Clearly, the White Mountain region of the eastern Holbrook Basin has favorable Pennsylvanian paleogeography and potential for hydrocarbon production and should not be overlooked.

Summary

In conclusion, the eastern Holbrook Basin occupies an area of 6,000 square miles with known source rock in the oil-generating window and a number of potential traps. The oil and gas shows in several of the <u>few</u> wells that have been drilled to Proterozoic basement in the eastern Holbrook Basin shows that pre-Permian units in this area, especially along the unexplored southwestern margin of the Defiance-Zuni Uplift have good potential for commercial accumulations of oil and gas.

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Fig. 1. Map Showing zero edgelines of Devonian, Mississippian, and Pennsylvanian rocks in the Holbrook Basin, Arizona, and location of stratigraphic sections A-A' and B-B'.



Fig. 2. Map showing thickness in feet of Devonian rocks in Holbrook Basin, Arizona (Modified from Conley, 1979).



Fig. 3. Map showing thickness in feet of Mississippian rocks in Holbrook Basin, Arizona (Modified from Peirce, 1979).



Fig. 4. Map showing thickness in feet of Pennsylvanian rocks in Holbrook Basin, Arizona (modified from Peirce, 1979).

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Fig. 5. Northeast stratigraphic section A-A' showing pre-Permian strata approximately perpendicular to the southwest margin of the Defiance-Zuni Uplift. See Fig. 1 for location of section. В

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Fig. 6. Northwest stratigraphic section B-B' showing pre-Permian strata approximately parallel to the southwest margin of the Defiance-Zuni Uplift. See Fig. 1 for location of section.

B'

(Feet)