NORTHERN ARIZONA PROVINCE (024)

By W.C. Butler

INTRODUCTION

This province covers about 59,000 sq mi, mostly in the southwestern part of the Colorado Plateau. Significant geologic features include the Grand Canyon, Kaibab Arch, Mogollon Highlands transition zone, Monument Uplift, Defiance Uplift, Black Mesa Basin, Holbrook Basin, and southern edges of the Kaiparowits and Blanding Basins.

The stratigraphic section shown for northeastern Arizona has demonstrated the highest petroleum potential in Arizona. See Wilson (1962), Butler (1988a), and Dickinson (1989) for synopses of the province's geology and evolution.

The lithologically and structurally complex basement of the Colorado Plateau area evolved from northwest-younging Proterozoic terranes sequentially accreted onto the Archean craton. As much as 12,000 ft of Middle and Late Proterozoic strata is preserved in possible rift-aulacogen depositional settings in central Arizona. Thick, unmetamorphosed, organic-rich Late Proterozoic strata deposited in backarc basins or continental lakes of north-central Arizona and south-central Utah have good petroleum potential. The plateau area, as a passive Paleozoic plate margin and buffered Mesozoic retro-arc platform, has been remarkably tectonically stable during Phanerozoic time. The area is characterized by blanket Paleozoic strata, as much as 6,000 ft thick, consisting of mostly shallow marine clastics and carbonates showing numerous disconformities. These strata accumulated during transgressions and regressions from both the northwest and southeast, onlapping and thinning toward the trans-continental arch – a northeast-trending positive area extending from the northeast into central Arizona. Convergence between North and South American tectonic plates, with reactivation of basement blocks, during the late Paleozoic created the plateau's fault-bounded basins and uplifts. One of these downwarps, the Blanding Basin of the Four Corners area, is a prolific petroleum producer from the Pennsylvanian Hermosa Group. All Hermosa Group plays, including Arizona's largest accumulation--and one of the most notable fields in the United States, Dineh-bi-Keyah--are assessed in the Paradox Basin Province (021).

Paleozoic strata are overlain by complexly intercalated Mesozoic strata that generally become thinner from Black Mesa Basin toward the Mogollon Rim highlands, where older strata crop out. Mesozoic strata were deposited in shallow marine shelf plus continental environments (coastal plain, piedmont, fluvial alluvial, eolian, lacustrine, and paludal). An apron of superjacent Oligocene to Pliocene volcanic flow rocks marks the southern province boundary; Pliocene and Quaternary volcanic fields (San Francisco Peaks) mark the center of the province. Incised rivers, such as the Colorado and Little Colorado Rivers, and their steep canyons are spectacular Quaternary features of the northern province. Flushing of hydrocarbons is a detrimental factor in these rapidly downcut areas. Late Tertiary erosion of the plateau with unloading of the crust, and consequential uplift, is another detriment because potential reservoirs are rendered underpressured.

Structurally, the Colorado Plateau is typified by long, northwest-trending Laramide monoclines and other gentle crustal warps; small fold axes are 10-15 mi long, but most are 30-65 mi long, and some even extend to 80 mi. A section of the Cordilleran hingeline may be present in the northwesternmost part of the province; platform and miogeosynclinal Paleozoic strata and Mesozoic continental to coastal strata comprise its stratigraphic section. The hingeline is considered the southern extension of the Sevier Thrust Belt of Utah; strata here were thrust eastward during the Late Cretaceous followed by regional extension during the Neogene and Quaternary. On the basis of seismic data, the basement depth in the resultant extensional basins is known to be 26,000 ft below sea level. Because this area has Great Basin physiography, it was not considered in the Colorado Plateau Province. Farther east, to the western edge of the Kaibab Arch, high-angle north-trending normal faults cut the plateau; they exhibit displacements of as much as several thousand feet. The net effect of this crustal extension is growth of the Great Basin at the expense of the Colorado Plateau and possible rupture of older traps.

The southern part of this province represents a structural transition from the saddles, troughs, benches and arches of the gentle northeast-dipping Mogollon Slope to an extremely complex horst-graben or half graben detachment fault regime. The zone exposes uplifted and dissected Precambrian igneous, metamorphic, and sedimentary rocks next to Tertiary basin deposits and has very low to no petroleum potential. During the Jurassic and Cretaceous Periods this transition zone became the edge of a magmatic arc fully developed in southwestern Arizona (active subduction to the southwest). The arc was a highland source area; streams drained northeastward depositing up to 5,000-7,500 ft of sediment in northern Arizona.

A cluster of 10 small oil and gas fields, discovered between 1954 and 1971, produce from structural traps in Devonian, Mississippian, and Pennsylvanian strata in the extreme northeastern part of Arizona. The three largest of these fields (Dry Mesa, East Boundary Butte, and Teec Nos Pos) have a combined cumulative production of about 2.2 MMBO and condensate, and 12 BCF of gas. Twenty-five mi south of these fields is Dineh-bi-Keyah (1967) which is the province's only oil field of significant size; it has an estimated ultimate recovery of 20 MMBO from Oligocene syenite sills. Sill reservoirs were very locally sourced by Pennsylvanian black shale and dolomite matured by the heat of the igneous intrusions. Cumulative production through 1993 for all fields in Province 024 is 20 MMBO and condensate; about 25 BCF of flammable gas; and, 9.3 BCF of helium. Methodical exploration of the province is inadequate; most wells were drilled as promotional ventures rather than on the concepts of modern petroleum geology. Some large structures have never been drilled, and the deeper reservoirs are rarely tested.

Depths in feet for the deepest boreholes in each of the seven northernmost counties (including northern Apache County, which is the only producing area to date) are 0, 480 ft, 3,206 ft, 7,070 ft, 7,210 ft, 7,780 ft, and 8,461 ft. Drilling density is about 155 sq mi per borehole, including Apache County, and about 420 sq mi per borehole, excluding the productive area.

Four plays were assessed. The Hurricane Fault-Uinkaret Plateau Play (2401) was assessed qualitatively only; the other three plays were assessed quantitatively and include the Late Proterozoic (Chuar-Sourced) and Lower Paleozoic Play (2403), the Oraibi Trough Play (2402), and the Holbrook Basin Anticline and Stratigraphic Traps Play (2404).

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CONVENTIONAL PLAYS

2401. HURRICANE FAULT–UINKARET PLATEAU PLAY (HYPOTHETICAL)

This oil and associated-dissolved gas play of northwestern Arizona is unproductive, hypothetical, and highly speculative. The play is in north-central Mohave County north of the Colorado River and almost entirely east of the Hurricane Fault. Drag and reverse drag folds along the Hurricane Fault and gentle plateau folds provide structural traps. The play is based on evidence of hydrocarbons in the system, such as numerous live shows in boreholes of the region (particularly from Pennsylvanian-Permian rocks), plus common strong fetid odors, stains, seeps, and tar in outcrops. The abandoned shallow Virgin oil field 15 mi north produced minor amounts of oil from the Triassic Moenkopi Formation.

Reservoirs: Potential reservoirs are Devonian (Martin and Temple Butte Formations), Mississippian (Redwall Limestone), Pennsylvanian (Callville Limestone and Supai Groups), and Permian (Supai Group, Queantoweap and Esplande Sandstones, Coconino Sandstone, and Toroweap Formation). These formations have all produced good hydrocarbon shows. The Temple Butte is an olive-gray, silty and sandy supratidal, irregularly-bedded carbonate. The Redwall is a massive, light-gray, shallow, open-marine, equatorial carbonate. The 1,000-ft-thick Supai is a complex set of mostly clastic beds that are light-gray to red, calcareous and gypsiferous mudstones, siltstones, and cross-bedded sandstones of estuarine to intertidal tropical origin. The Hermit consists of reddish fine clastics deposited in distal fan, floodplain, and fluvial environments. The Coconino is an eolian, well-sorted, cross-bedded and rippled, buff quartz sandstone. The Toroweap has intercalated fine-grained, contorted sandstones, siltstone, mudstones, dolomite, gypsum, and fossiliferous cherty limestone representing deposition in a low-energy marine to sabkha environment. As much as 2,000 to 2,500 ft of this total stratigraphic section may have reservoir potential.

Source rocks: Source rocks probably containing type I organic matter now in the thermal zone of oil generation may include the mudstones and carbonates of the same above-noted formations, but also include the Kaibab Limestone (gray, fossiliferous, cherty, aphanitic) and, less likely, the Hermit Shale; however, stronger evidence for better source rocks is lacking and hence degrades the petroleum potential.

Traps: Recurrent Miocene and younger normal faulting of a Laramide-formed monocline formed drag and reverse-drag folds along the high-angle Hurricane Fault (east side up and west side down). Southwestward updip migration of hydrocarbons may have been trapped in these folds or against the fault. Gentle northwest-trending anticlines to the east on the Uinkaret Plateau (Giardina, 1979) have not been adequately explored, and possible tilted oil-water contacts may have prevented discovery of accumulations in those folds that have been drilled. Targets are most likely 3,500-4,500 ft deep, but conceivably could cover a wide range of from 500 to 6,000 ft deep. Migration time is unknown but was probably Laramide.

Numerous disconformities, porosity-permeability pinchouts, and fine clastic units (for example, Hermit Shale and Moenkopi Formation) are potential seals. Gypsiferous beds of Permian age could provide additional seals.

Exploration status and resource potential: Methodical exploration has been lacking. Less than 25,000 ft of strata have been drilled in all boreholes of this play. Borehole control is sparse and irregularly distributed, averaging about one per 400 sq mi. Some major folds have been tested but none adequately. The ration of good shows to dry holes is greater than 1.0 for boreholes 1,000-5,000 ft deep, and hence the area is encouraging as a result of the shows, good reservoir qualities, and abundant structural and stratigraphic traps

2402. ORAIBI TROUGH PLAY

This confirmed oil and associated gas play is mostly in northeastern Arizona but extends into southeastern Utah, southwestern Colorado, and northwestern New Mexico between the Defiance Uplift on the east and the Monument Uplift and Kaibab positive areas on the west. Although it is a confirmed play, 99 percent of the play is south of the production in Devonian, Mississippian, and Pennsylvanian strata of northeasternmost Arizona. The basis of the play is a close association of Late Devonian and Early Mississippian source and reservoir strata with northwest-trending anticlines and stratigraphic traps in the northeast-trending Oraibi Trough. which formed in mid-Paleozoic time. This play does not consider Hermosa Group production from Pennsylvanian carbonate-mound reservoirs on the Arizona part of the southern shelf of the Blanding-Paradox Basin, which is assessed in province 021.

Geographically, the center of the Oraibi Trough nearly coincides with the greater Black Mesa structural basin formed during Laramide time. The total stratigraphic southeast-thinning section from outcrop to basement is 4,000-9,000 ft thick roughly, 40 percent is Paleozoic foreland restricted-shelf strata, and the remainder is a mix of continental to shallow-marine strata of Mesozoic age. The maximum combined thickness of the Devonian-Mississippian section is about 1,000-1,250 ft (Beus, 1989). Pennsylvanian strata (as much as 1,800 ft thick) are a secondary consideration for reservoir and source rocks in this play. Strata of all three periods pinch-out against the Defiance Uplift.

Reservoirs: The best reservoirs are in relatively small but widespread deltaic clastic wedges or lenses of the Upper Devonian McCracken Sandstone Member (as much as 250 ft thick) of the Elbert Formation (Kashfi, 1983). These medium- to coarse-grained and medium- to well-sorted sand bodies splay westward off the Defiance erosional basement into the trough and are encased by less porous and less permeable strata deposited during east-west transgressions and regressions. The McCracken Sandstone and the pelletal dolomite, skeletal and pelletal carbonate mudstone, and sandy dolomite of the upper part of the Elbert Formation are productive in the Paradox Basin. Also having reservoir potential are the superjacent porous, cherty, crinoidal and pelletal Mississippian carbonates and the Pennsylvanian Hermosa Formation and Supai Group clastics. Seals include waxy shale and anhydrite of the Elbert Formation, or dense massive limestones and dolomites of the Redwall Formation and Leadville Limestone, or redbeds, calcareous siltstones and mudstones, and thin gypsum units of the Triassic Moenkopi Formation.

Source rocks: The best source rock may be the Aneth Formation, which is about 85 percent within the oil-generation window having maturities of R_o 0.90-2.1 percent ; it probably contains 0.50-1.03 percent TOC of type II and III (Tucker, 1983) in the richest areas. Lithologically, it is a dark, glauconitic, argillaceous aphanitic dolomite interbedded with dark carbonaceous shale and siltstone and minor limestone and evaporites. Given outcrops having thermal maturities of R_o 0.41-0.60 percent, the floor of the oil window is in Devonian rocks and may range from +3,000 ft to -500 ft in elevation. Shallower Pennsylvanian strata may have been matured by igneous intrusions of Tertiary age, such as at the Dineh-bi-Keyah oil field on the Defiance Uplift. Geophysical signatures (gravity and magnetic), suggesting shallow intrusions, similar to the Dineh-bi-Keyah area, can be found along the perimeter of the Defiance, that is, the eastern margin of this play. Intrusive centers, such as Hopi Buttes and the Carrizo Mountains, are excellent areas to evaluate for structural traps associated with source rock matured by the heat of cooling igneous rock. In addition to the significant live shows in boreholes, the Devonian rocks in this play, and particularly in outcrops along the Mogollon Slope, are known for their strong fetid odor, seeps, asphalt-filled fractures, and other hydrocarbon impregnations.

Traps: Both structural and stratigraphic traps are plentiful. Total structural relief in the play is 6,000-7,000 ft, providing good flow gradients up the Mogollon Slope to the south and towards the east-west margins of the trough, particularly toward the Defiance Uplift. Subtle long-distance facies changes and fluid migration probably characterize northeastern Arizona. Up-dip facies changes and stratigraphic wedge-outs are prevalent. Vuggy biohermal or other carbonate mounds may present yet another highly probable trap in the Mississippian and Pennsylvanian strata. Significant disconformities between Mississippian and Pennsylvanian strata and between Pennsylvanian and Triassic strata also provide a speculative trapping mechanism. The cumulative axial lengths of major anticlines is 350 mi and that of monoclines is 225 mi. Structural closure on the upfolds is 500-1,000 ft. Regional Jurassic tilting of the Colorado Plateau in this area may have displaced the oil-water contacts off the structural center. Drilling depth to all traps is 3,300-7,500 ft.

Timing and generation: Timing of generation and migration is not known, but could have reasonably occurred from early Cretaceous to early Tertiary time; hence, migration could have been prior to structural trap formation. Present-day heat flow is 1.13-1.80 HFU, and the present-day geothermal gradient is 1.05-1.90¡ F/100 ft.

Exploration status: Because about 98 percent of the play is on Native American land, exploration essentially did not begin until the mid-1960's, when it was first permitted. Cumulative production from Devonian and Mississippian reservoirs has been 908,000 BO and 1.3 BCF of gas. The Redwall Limestone at Dry Mesa field has produced about 802,000 BO from fractured dolomite on an anticline that has 35 ft of closure. Average borehole depth in the play is 4,350 00 ft. Drilling density in the play is about one borehole per 185 sq mi; less than 2 percent of the area has been drilled to the Coconino Sandstone. Less than 1 percent of the area has been drilled to the Devonian. Drilling density is much higher, however, if only the northeasternmost part of the play is considered, where density is one borehole per 6-7 sq mi to an average depth of 5,770 ft. The play is grossly under-explored, and many obvious large upfolds are untested.

Resource potential: The probability that this play "works" (a product of the all attributes) is about 40 to 45 percent for oil and associated gas. The median size of undiscovered accumulations is 1.5 MMBO, and the probable median number of accumulations is 5.

2403. LATE PROTEROZOIC (CHUAR-SOURCED) AND LOWER PALEOZOIC PLAY (HYPOTHETICAL)

About one-third of the area of this unusual hypothetical oil and thermal gas play is in north-central Arizona and two-thirds in south-central Utah of the Paradox Basin Province 021 (see play 2108). The play is hypothetical and highly speculative, being defined on the inference that the Late Proterozoic Chuar Group sourced reservoir units within itself and in superjacent Paleozoic reservoirs, primarily the Cambrian Tapeats Sandstone. Measured thickness of the group in the eastern Grand Canyon ranges from 5,370 to 6,400 ft. Potential accumulations are associated with large Colorado Plateau structural traps (see province description). Boundaries for this play are ill-defined because so few boreholes have penetrated the Chuar; consequently, its regional occurrence and facies are poorly understood. See Rauzi (1990) for additional information.

Reservoirs: Reservoirs, probably underpressured, include numerous fine clastic (mostly siltstone) beds in the Chuar Group (if sufficiently fractured), the superjacent sandstone of the Sixtymile Formation, the Tapeats Sandstone (150 to 400-ft-thick cross-bedded beach deposit), and possibly other Paleozoic sandstones if extensive vertical migration has occurred. There have been significant petroleum shows in every Paleozoic system and also in Triassic strata. Multi-billion-barrel-size accumulations of hydrocarbons are present in the Permian and Triassic "tar sand triangle" and the Circle Cliffs-White Canyon areas of south-central Utah. Their origin is a long-standing enigma; some explorationists suggest the Chuar Group may have been their source, but this hypothesis remains as only one of several possible explanations. There is one field in this play, the Upper Valley oil field (discovered 1964) of south-central Utah that has produced more than 20 MMBO from Permian and Triassic reservoirs.

Source rocks: The Walcott Member (Elston, 1989) is organic-rich gray to black mudstone and siltstone containing thin sequences of sandstone and stromatollitic crypto-algal, pisolitic dolomite probably deposited in lacustrine to tidal flat environments. Stratigraphically, where measured, the 850- to 1,100-ft-thick Walcott Member of the Chuar Group is the youngest member of the Kwagunt Formation and is, according to current knowledge, the richest unit. Total organic carbon (algal type) has been documented as high as 10 percent in the dark mudstones; 3 percent TOC is average for the source-rock component of the Walcott. Thermal maturity of the Chuar Group is partially within the assumed oil-generation window, (R_o 0.8-1.35 percent). Perhaps half of the mature source rock is greater than R_o 1.35 percent (the oil floor) and in the gas generative phase. Upper Paleozoic and Mesozoic outcrops in the play area have R_o values between 0.5 and 0.6 percent, indicating that they have not been deeply buried. In the Arizona part of the play, the top of the Chuar Group is probably at R_o 0.8-1.0 percent.

Drilling depths to potential accumulations are from 2,000 to 13,000 ft (average 6,500 ft) for oil and from 6,000 to 20,000 ft (average 9,000 ft) for gas. Depth to the top of the Chuar Group at the Utah-Arizona state line in the center of the play is about 13,000-13,500, ft implying that Arizona is oil-prone and Utah is gas-prone. The Utah source beds are more mature, having been buried deeper in the Kaiparowits Basin area than in the Arizona Kaibab Plateau area. Chuar depths on the west side of the play near the Arizona-Utah state line are relatively shallow, at about 5,000 ft, due to the north-trending Kaibab uplift.

Timing and migration and Traps: Timing of generation and migration are two big unknowns in this play. Laramide is suspected as being reasonable for timing, but questions remain. If migration occurred prior to the Late Paleozoic uplifts or barriers, accumulations may be a long distance from the play area. If migration occurred after Late Paleozoic and Laramide deformations, ample structural traps would be available. Stratigraphic traps (porosity and permeability pinchouts and major disconformities and angular unconformities) are also known to be present but are not necessary to make this play work. Within this play the combined axial lengths of anticlines is 552 mi, and that of monoclines is 464 mi. Drilling of large anticlines has been unsuccessful to date; many large anticlines are undrilled; and the wells that have been drilled may have missed accumulations due to unusual hydrologic situations (Allin, 1990). These structures are large enough to permit very large accumulations. Graben-like structures in the basement aulocogen (?) could also trap hydrocarbons. The Bright Angel Shale is probably an excellent seal overlying the Tapeats. Other seals in the Paleozoic section include impermeable carbonates, fine clastics, and evaporites.

Exploration status and resource potential: If the Chuar is a good source rock as currently believed, one would expect to find relic oil or seeps in this play; however no Chuar seeps have been reported in the Grand Canyon or in the paleo high areas, such as around the Kaibab Arch. On the other hand, more than a dozen shows have been encountered in the Paleozoic section in Arizona west of longitude 112°. Some of the Cambrian penetrations in the play encountered only the Bright Angel Shale and Mauv Limestone but did not test the lower potential reservoir in the Tapeats Sandstone; thus exploration to the Chuar is nearly nonexistent. The Tidewater Kaibab Federal 1–A well (logged 1957), Kane County, Utah, found oil and gas shows in both the upper Tapeats Sandstone (15 ft of oil at a depth of about 4,850 ft) and in the Chuar Group (at a depth of about 5,900 ft). Other Chuar tests are currently being permitted or drilled.

2404. HOLBROOK BASIN ANTICLINE AND STRATIGRAPHIC TRAPS PLAY (HYPOTHETICAL)

The Holbrook Basin is a nonproducing hypothetical oil and associated gas play in east-central Arizona. The Little Colorado Rivers flow northwest through the center of the basin. The play has a structural component (the northwest-trending Holbrook Anticline) near the southwest basin margin, and a stratigraphic trapping component to the northeast. Rapid facies changes and updip pinchouts characterize the basin.

The shallow Holbrook Basin, in a shallow shelf environment, formed over a Precambrian depression beginning in the Pennsylvanian period, was filled with Permian sabkha sediments, and was later modified by mild Laramide tectonism. Maximum present-day structural relief is only 1,500 ft. About 400 ft of Devonian and Mississippian strata disconformably overlie the basement and are subjacent to the play. The thickest strata (3,000-4,250 ft) in the basin are cyclic, Pennsylvanian and Permian, interbedded clastics (including redbeds) and carbonates (brown dolomites and dark micritic limestones) with basin-centered evaporites (anhydrite, halite and potash) and lesser dark, calcareous shales; these strata comprise both the reservoir and source rocks. Specifically, the Horquilla Limestone and Naco Formation (900 ft thick), Supai Group (900-1,350 ft thick), and the Coconino, Glorieta, and DeChelly Sandstones (1,000-2,000 ft) are potential reservoirs. About 70-85 percent of the Pennsylvanian section and 90-95 percent of the Permian section is clastic. These units have good porosity and are disconformably overlain by Triassic outcrops; Quaternary basalt, which had no adverse affect on the source rocks, covers the extreme southeastern part of the basin. Production of helium (probable Precambrian source) from a faulted anticline at nearby Pinta Dome indicates that the Permian reservoirs have very little leakage. The thick salt mass of the basin is used to store commercial natural gas (Peirce, 1981), and demonstrates effective seals.

Source rocks, timing, and migration: Source rocks are primarily the Naco Group and Supai Group, which includes the thin, black Fort Apache Limestone. The evaporite facies of the Supai Group may have preserved much of its mixed type I and II organic matter. Regionally, limited testing has shown TOC values in the carbonates of the Supai to be at least 1-2 percent. In late 1993, 40 mi southeast of the Holbrook Basin the Alpine-Federal #1 geothermal test well encountered an excellent live (bleeding) oil show and two other significant indications of hydrocarbons in the Supai Group (Rauzi, 1994). The intrusive igneous dikes found in this section had virtually no thermal effect on the host strata. The entire Late Paleozoic section is within the oil-generation window and ranges from R_o 0.65-1.1 percent. Present-day geothermal gradients range from 1.2 to 1.6¡ F/100 ft. Present-day heat flux immediately surrounding the basin is much higher; these areas have good geothermal resource potential. Timing for generation and migration is unknown, but it was probably during the Laramide.

Traps: Depth to traps is 500-4,000 ft; tops to evaporites within the Supai Group occur at depths of 1,000-2,450 ft. Traps include the Holbrook Anticline, which has an axial length of about 60 mi and a maximum closure of about 250 ft. The anticline may be a result of either evaporite dissolution (collapse structure) or mild Laramide northeast-southwest compression, or both. Other secondary folds trend northeast and may also trap hydrocarbons. Northeast updip migration of petroleum could also be trapped stratigraphically. The Paleozoic units thin and pinch-out toward the Defiance positive area; the magnitude of the disconformities increases in that direction providing various mechanisms for accumulation. Interfingering evaporite or impermeable carbonate beds could seal these accumulations.

Exploration status and resource potential: Although drilling in the Holbrook Basin has been frustrating, it is also promising because of the high number of live oil and gas shows and strong fetid odors in Late Paleozoic outcrops of the area. Abundant shows occur at depths between 1,100-3,200 ft. Some boreholes have encountered as many as eight shows. Oil stains, asphaltic oil, and dead heavy oil have been encountered in many wells. However, even with these shows, proof of an adequate source rock, and the possibility of fresh-water flushing, inhibit a higher exploration effort. The crest of the Holbrook Anticline may be offset at depth, and the more recent off-surface-structure boreholes seem to find the best shows. The basin has a drilling density of about one borehole per 45 sq mi. Many of the wells were drilled specifically for potash. Probably less than 20 boreholes have been drilled below 3,600 ft. Many explorationists in Arizona have observed that wells tend to be drilled haphazardly, and the drilling in the basin has been inconclusive with many structures left to be tested. Although this is a high-risk frontier area, leasing and drilling in the last 10 years have been fairly encouraging.

UNCONVENTIONAL PLAYS

There are no unconventional plays described in this province report. However, unconventional plays listed in the surrounding provinces may include parts of this province. Individual unconventional plays are usually discussed under the province in which the play is principally located.

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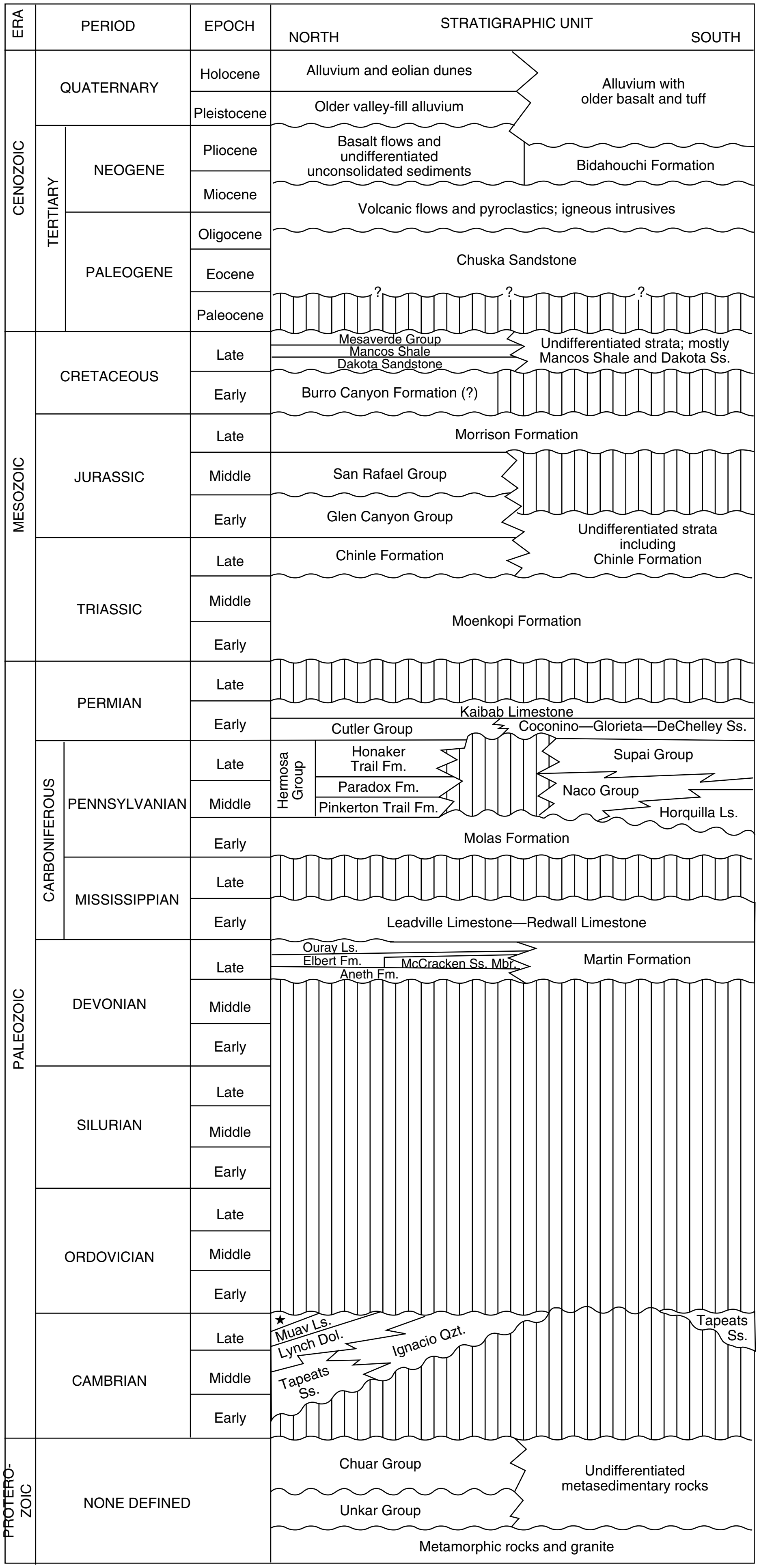

★Bright Angel Shale