HELIUM RESOURCES AND PRODUCTION IN ARIZONA

by Jon E. Spencer

INTRODUCTION

Gas fields in Arizona yielded the world's *richest* known helium gas between 1960 and 1977. This helium-rich gas, occurring in the Pinta Dome, Navajo Springs, and East Navajo Springs gas fields near Holbrook in northeastern Arizona, contained about 8-10 percent helium mixed mostly with nitrogen. These gas fields are also somewhat unique because the helium is not mixed with hydrocarbons. The world's *largest* known helium reserves are natural gas fields containing less than one percent helium, and are located in Texas, Oklahoma, Kansas, and Wyoming. These enormous fields contain much greater volumes of helium than Arizona's gas fields, but the helium is more expensive to extract because of its lower concentration.

All known helium occurrences in the state are within the Colorado Plateau and adjacent to the Defiance uplift (Figure 1). Arizona's only *major* helium source is at the south end of the Defiance uplift. The helium reservoir rock is primarily the Permian Coconino Sandstone, although helium has also been reported from red sandstones near the base of the Chinle Formation, and from the upper part of the Pennsylvanian (?)-Permian Supai Formation (Dunlap, 1969; Peirce and others, 1970). A single well in Devonian and Mississippian strata at the north end of the Defiance uplift (Teec Nos Pos oil and gas field, Figure 1) has produced helium, and at present, natural gas containing several percent helium is being vented from a well in the Black Rock field near Teec Nos Pos.

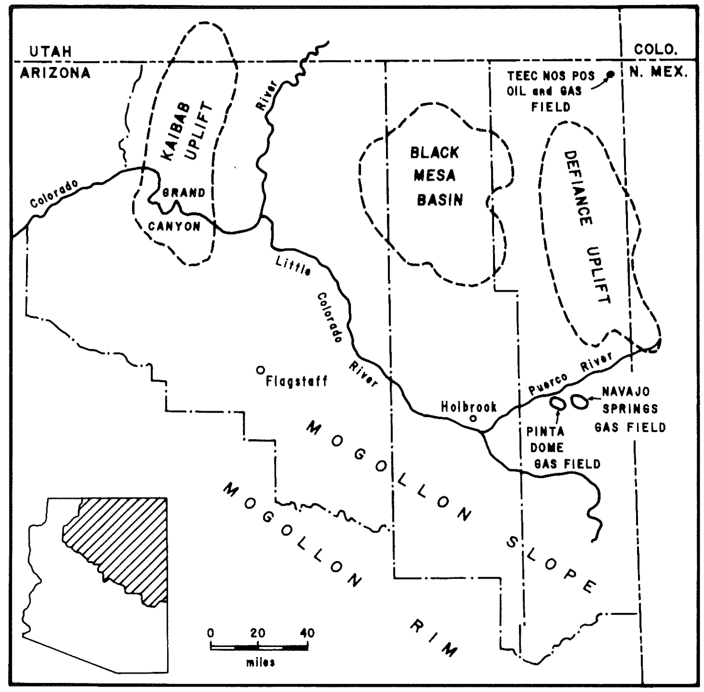

Figure 1. Index map of northeastern Arizona showing location of major geologic features (Dunlap, 1969).

GEOLOGY OF THE PINTA DOME, NAVAJO SPRINGS, AND EAST NAVAJO SPRINGS HELIUM FIELDS

The geology of the Pinta Dome, Navajo Springs, and East Navajo Springs helium fields is characterized by "layer cake" Colorado Plateau stratigraphy, with gentle warps of various sizes that locally produce structural traps for gas accumulation. Each helium field occurs within one of three domal structures separated by faults and closed structural contours. The helium and associated gases occur primarily in the porous Coconino Sandstone which is capped by impermeable shales of the lower part of the Moenkopi Formation. The following description of subsurface geology is based primarily on Dunlap's (1969) study of the area.

Stratigraphy

Lower Paleozoic strata are generally missing in and around the Defiance uplift; consequently, the Pennsylvanian (?)-Permian Supai Formation rests directly on Precambrian granitic crystalline rocks at a depth of approximately 3,000 feet (Figure 2).

The Supai Formation can be subdivided into three members: 1) a basal member composed of approximately 700 feet of siltstone and mudstone; 2) the middle Fort Apache Member, composed of 20-25 feet of dolomitic limestone; and 3) an upper member composed of about 1,000 feet of halite, gypsum, and anhydrite interbedded with shaley siltstone and mudstone. The upper evaporitic member represents the northeast margin of the Holbrook basin.

The Lower Permian Coconino Sandstone is 250-325 feet thick in the helium-producing area and is composed of fine-to-medium-grained, porous and permeable quartz sandstone. Porosity is variable and may be as high as 20 percent. This rock is a productive aquifer, as well as the primary helium reservoir rock in the Holbrook area. The gas-bearing zone is in the upper part of the Coconino Sandstone, whereas middle and lower zones are generally water bearing.

Lower Triassic Moenkopi Formation rests disconformably on Coconino Sandstone, with normally intervening Kaibab Formation completely missing in the Holbrook area. The Moenkopi Formation is composed of variably calcareous siltstone, mudstone, and silty sandstone. Micaceous siltstone and silty mudstone at the base of the Moenkopi Formation form an impermeable cap, preventing upward escape of gas from the underlying Coconino Sandstone.

The Upper Triassic Chinle Formation unconformably overlies the Moenkopi Formation. The basal Shinarump Member consists of 10-60 feet of conglomeratic sandstone and is locally a helium-bearing zone. It is overlain by the lower red member (Akers and others, 1958), which is composed of about 50 feet of sandstone, sandy siltstone, and mudstone, and is also locally helium bearing. The overlying Petrified Forest Member is a sequence of mudstone, siltstone, claystone, sandstone, gypsum, and limestone. Only the basal 200 feet of this member is preserved in the helium-producing area.

The late Tertiary Bidahochi Formation, consisting of 0-180 feet of lacustrine and fluviatile sediments, unconformably overlies the Chinle in some areas around the

SYSTEM OR SERIES		FORMATION	THICKNESS	LITHOLOGIC CHARACTERISTICS
Quaternary				Alluvium, sand and gravel
		UNCONFORMITY		
Tertiary		Bidahochi Formation	0-180	Grayish-brown calcareous sandstone interbedded with silty mudstone and volcanic ash; bentonitic
		UNCONFORMITY		
Triassic	Upper	Chinle Formation	650-850	Reddish-brown to grayish-blue mudstone and claystone with some silty sandstone; some limestone and gypsum in upper portion; siltstone and conglomeratic sandstone in lower portion
		UNCONFORMITY		
	Lower to Middle (?)	Moenkopi Formation	125-150	Brown to gray calcareous siltstone and mudstone; slightly gypsiferous; very silty
		UNCONFORMITY		
Permian	Lower	Coconino Sandstone	250-325	Light gray to buff, fine- to medium-grained sandstone; loosely to firmly cemented with silica
Pennsylvanian (?)		Supai Formation	1,700?	Reddish-brown sandstone, siltstone, and mudstone; some dolomitic limestone; thick interbedded evaporitic sequence in upper portion
		UNCONFORMITY		
Precambrian				Crystalline basement rocks

Figure 2. Generalized stratigraphy of sedimentary rocks exposed at the surface and encountered in the subsurface in the Pinta Dome-Navajo Springs area, Apache County, Arizona (Dunlap, 1969).

helium-producing area. In other areas, this formation has been removed by erosion and Chinle Formation is exposed at the surface. Quaternary sediments locally cover both formations.

Structure

The Pinta Dome, Navajo Springs, and East Navajo Springs helium fields occupy a broad structural saddle between the Defiance uplift to the north, and gently northeast-dipping

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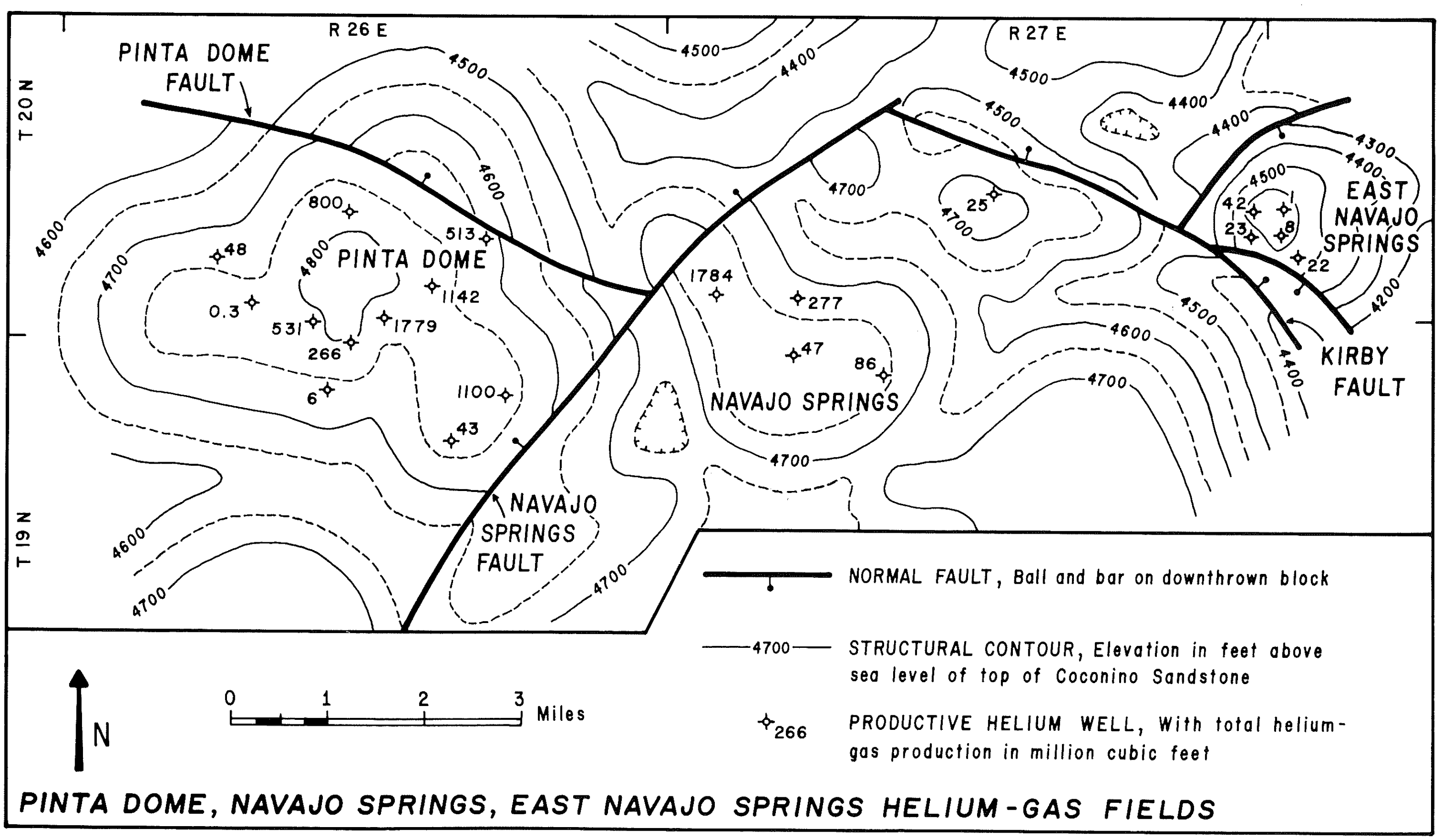

Figure 3. Structure-contour map of the top of the Coconino Sandstone in the subsurface in the Pinta Dome, Navajo Springs, East Navajo Springs area, Apache County, Arizona (Conley and Scurlock, 1976). Also shows location of productive helium-gas wells and amount of helium-gas produced from each gas well in this area (production data from Arizona Oil and Gas Conservation Commission, 1982).

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Helium Resources continued

strata of the Mogollon slope to the south and southwest (Figure 1). The saddle separates the structurally lower Black Mesa Basin to the northwest from a structural low to the southeast that may be part of the Gallup sag (Peirce and others, 1970). Within this regionally defined saddle are a number of smaller uplifts of low relief, some of which form traps for helium accumulation. The geometry of subsurface structures in the helium-producing area is known primarily from drill hole data (Dunlap, 1969; Peirce and Scurlock, 1972; Conley and Scurlock, 1976).

The Pinta Dome helium field occurs within the Pinta anticline, an east-west-trending, doubly plunging structure with about 100 feet of relief (Figure 3). Dips on the flanks of Pinta Dome are typically 0.5–1.5 degrees. The Pinta Dome fault offsets the northeast flank of the dome.

A northwest-trending anticline about three miles east of Pinta Dome forms the Navajo Springs helium field. This doubly plunging anticlinal structure has about 100 feet of structural relief, and is terminated northward by the Navajo Springs fault. The small East Navajo Springs helium gas field, about five miles east of the Navajo Springs field, lies immediately northeast of the Kirby fault (Figure 3).

ORIGIN OF HELIUM

Terrestrial helium has two sources: 1) primordial helium that was incorporated into the Earth at the time of its formation and is now derived from sources deep within the Earth, and 2) radioactive decay of uranium and thorium which are concentrated in the Earth's crust. Helium is composed of two isotopes: helium 4, which is produced by radioactive decay, and helium 3, which was created before the Earth formed and was incorporated into the Earth during its formation. High ratios of helium 3 to helium 4 in some hot springs associated with volcanic activity indicate the presence of a significant component of primordial helium probably derived from the mantle. Low ratios of helium 3 to helium 4 found in most, if not all, natural gas fields, indicate that this helium was primarily derived from radioactive decay of uranium and thorium.

The Coconino Sandstone contains very little uranium and thorium, and consequently could not be a significant source of helium in the Pinta Dome-Navajo Springs area. One possible source for the helium is the Precambrian crystalline basement beneath the sediments (Peirce and Scurlock, 1972). There is little information on the detailed nature of these rocks, but they include granitic rocks that likely contain small amounts of helium-producing radioactive elements. A problem with this potential source is that the Supai Formation, separating crystalline basement from Coconino Sandstone, contains hundreds of feet of impermeable evaporites. However, Supai evaporites wedge out rapidly to the northeast and northwest. Helium originating from the Precambrian basement could have migrated upward to the Coconino Sandstone where Supai evaporites are absent, and then migrated up-dip through Coconino Sandstone to structural traps above evaporitic Supai sediments. The presence of helium in clastic sediments between Supai evaporites may also result from up-dip lateral migration from evaporite-free areas. Fracturing may also permit upward migration of helium through evaporitic strata (Peirce and others, 1970).

Alternatively, helium may have originated from sediments overlying the Coconino Sandstone. Gamma ray logs from drill holes indicate that the Shinarump and Petrified Forest Members of the Chinle Formation, and the lower part of the Moenkopi Formation, contain significant amounts of radioactive material. In most areas, helium from these possible helium-source rocks would have had to migrate downward through relatively impermeable strata to reach the Coconino Sandstone. However, faulting has locally brought these potential helium-source rocks down and into contact with the reservoir rocks, perhaps eliminating this access problem (Dunlap, 1969).

HELIUM PRODUCTION IN ARIZONA

In 1961 Kerr McGee Corporation and Eastern Petroleum began production of helium from the Pinta Dome field near Holbrook, and opened the world's first commerical helium extraction and purification plant. The Navajo Springs and East Navajo Springs helium fields began production in 1964 and 1969, respectively. One well in the Teec Nos Pos oil and gas field produced helium during 1968 and 1969. Production of helium gas from all these fields ended by 1976 because the gas fields had either been depleted or had become unprofitable due to a large drop in helium prices. No helium has been produced in Arizona since this time (Figure 4).

Statistics compiled by the Arizona Oil and Gas Conservation Commission indicate that Arizona's gross helium gas production has been 9,238 million cubic feet, almost all of which came from the Pinta Dome-Navajo Springs area. Assuming an average helium content of 8.5 percent, about 785 million cubic feet of helium was produced from Arizona, valued at an estimated $27 million (based on the 1961 price of $35 per thousand cubic feet; U.S. Bureau of Mines, 1980).* This amount of production is comparable to the total annual world helium consumption during the early 1970s.

*The 1980 government price (average value) for helium was $35 per thousand cubic feet; the 1980 private industry price was $22.50 (U.S. Bureau of Mines, 1980).

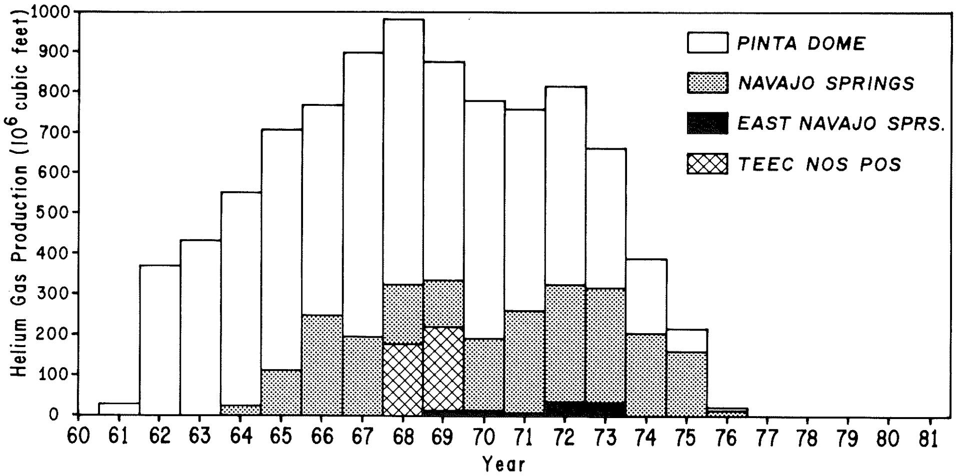

Figure 4. Annual helium production from helium-gas fields in Arizona (data from Arizona Oil and Gas Conservation Commission).

FUTURE OF ARIZONA'S HELIUM INDUSTRY

If crystalline rocks of the Defiance uplift are the source of the helium in the Pinta Dome and related helium-gas fields, then many other areas around the Defiance uplift may be promising targets for helium exploration. Much of the area around the Defiance uplift is within the Navajo Indian Reservation, and has had little, if any, exploration for helium. Wells drilled for helium exploration in this area generally penetrate only to the top of the Coconino Sandstone, although helium has also been reported from the underlying Supai Formation. It thus seems probable that other helium deposits await discovery in Arizona.

The cost of extracting helium from natural gas containing about 0.5 percent helium is about $13 per thousand cubic feet. Arizona helium can be extracted for significantly less since its concentration is much higher.

Natural gas reserves are being depleted at such a rapid rate that, if present trends prevail, there will be very little helium gas left within 30-40 years. When the demand for helium first exceeds the supply from natural gas, demand can be met with helium now in the federal storage reservoir. However, even this will run out eventually. When both natural gas reserves and the federal storage reservoir are depleted, the value of helium may increase a hundred to a thousand times. At such prices, the smallest helium gas fields would become highly valuable, and the Arizona helium industry could suddenly recover from decades of inactivity.

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Fieldnotes

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