Feasibility of New Helium Well Development in the Holbrook Basin, Arizona

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Introduction

The purpose of this report is to address the economic feasibility of development of helium resources in the Holbrook Basin, Arizona, and the potential for further exploration in the area. The Holbrook Basin is located in Northeastern Arizona and spans approximately 170 by 80 miles (Figure 1). Previous production in the area ceased in 1976, with much of the basin remaining unexplored for helium resources. Economics of helium production have also changed significantly in recent years.

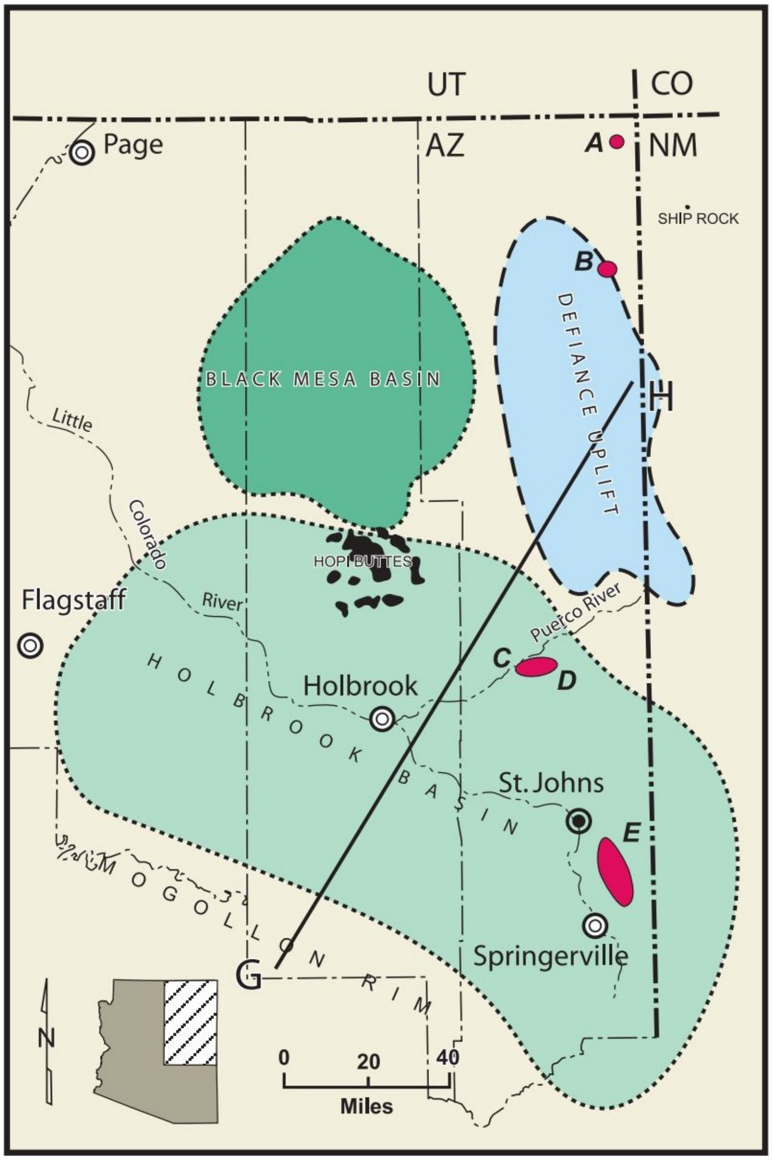

Figure 1. Regional map showing the location of the Holbrook Basin and areas where significant helium concentrations have been encountered in Northeast Arizona. A) Tohache Wash Field, B) Dineh-bi-Keyah Field, C) Pinta Dome Field, D) Navajo Springs Field, E) St. Johns-Springerville area (Rauzi & Fellows, 2003).

The economic feasibility of developing a resource is demonstrated by providing evidence of 1) resource marketability and 2) resource availability. To this end, the economics of helium and its uses in industry will be reviewed, as well as the geology of the Holbrook Basin and its potential for helium deposits. Methods and costs for processing and transporting helium will be briefly reviewed in reference to Desert Mountain Energy's plans for production. A review of past production and of Desert Mountain Energy's new wells in the region will help focus on the potential for future development of helium resources in the Holbrook Basin.

Economic Feasibility

Helium is a noble gas with an atomic number of 2. It is the second most abundant and second lightest element in the universe (Mueller, 2020). It is inert, non-toxic, colorless, and odorless. Its boiling point (-268.9°C) and freezing point (-272.2°C) are the lowest of any element on the periodic table. Helium's physical and chemical properties make it essential in a number of medical, scientific, and industrial applications (Table 1).

Table 1. Industrial uses and chemical properties of helium (Modified from Mueller, 2020).

Properties	Examples of Applications
Lowest boiling point (-268.9°C)	Refrigerant, as in: Superconducting sensing systems and cryogenic research (Rauzi & Fellows, 2003) Magnets in medical MRI/NMR equipment Quantum computing systems
Second lightest element	Lift for balloons Hard-drives
Smallest atomic radius (31 pm)	Leak detection
Inert (chemically and radiologically)	Carrier gas (semiconductor manufacturing, gas chromatography) Heat transfer medium in nuclear reactors
High thermal conductivity / specific heat	Gaseous cooling in fiber optics Semiconductor manufacturing
Inert + lowest boiling point (-268.9°C) + lowest freezing point (-272.2°C)	Pressurizing/purging of liquid-fueled rocket tanks and other fluid-driven systems
Inert + high thermal conductivity + highest ionization potential	Shielding in gas metal/plasma arc welding
Low solubility	Deep sea diving gas Surgical insufflation
High sonic velocity (972 m/s at 0°C)	Carrier gas for supersonic metal coating

Low index of refraction (n = 1.000036 at 0°C and 1 atm)	Solar telescopes High-resolution microscopes

The various applications for helium require different purities. Grades 5 and 6 (99.999% and 99.9999% by volume, respectively) are classified as research-grade helium (Mueller, 2020). Grade A helium is 99.997% pure. Grade 4 (99.99% pure) helium and lower are classified as balloon grade and are also used in air bags, heat-transfer applications, and leak detection. Crude helium is at least 50% pure and requires further refining for many commercial applications.

Because helium is extremely lightweight and non-reactive, it tends to float away once it enters Earth's atmosphere. This means that, despite it being the second most abundant element in the universe, concentrations of helium in Earth's atmosphere are extremely low (~5.2 ppm). There are two sources of terrestrial helium. The first is primordial ^3He, which was created before the Earth's formation and was deposited during formation of the planet (Spencer, 1983; Xiong et al., 2021). The second type, ^4He, continues to form from radioactive decay, primarily from unstable isotopes of uranium and thorium. ^4He makes up over 99.9% of helium found on Earth (Mueller, 2020). The ratio of ^3He to ^4He, as well as other isotope data, can be used to help determine a source in helium exploration. Anonymously high ^3He in crustal rocks is found at basaltic hot spots and is thought to reflect an ultra-deep source of helium, perhaps seeping across the core-mantle boundary (Xiang et al, 2021). A higher proportion of ^4He points to a source fed by radioactive decay, typically produced from uranium- and thorium-bearing minerals in Precambrian granitic or metamorphic basement rock (Spencer, 1983; Halford, 2018) and redistributed over time into overlying sedimentary strata that can act as a reservoir.

Resource Marketability

Helium is a non-renewable resource and cannot be replaced by other elements in a number of its applications (Mueller, 2020). In particular, helium is the only option for cryogenic applications that require extremely low temperatures (USGS, 2021). Even where substitutions are possible, helium is often the optimal choice where technological advances take advantage of its unique combination of attributes. The medical field, for example, is finding a rapidly expanding array of new applications for helium based on its physical and chemical properties (Berganza & Zhang, 2013), and space exploration continues to rely on helium in a variety of applications (Northon & Young, 2020).

Demand for helium has continued despite a sharp increase in price point over the past several years. This price increase can be seen in the results of the Bureau of Land Management (BLM) auctions of helium from the Federal Helium Reserve from 2015 to 2019 (Figure 2). These auctions have now ceased, opening more of the market to private suppliers of helium (Mueller, 2020). As research and advances in technology continue, the need for helium is projected to steadily grow.

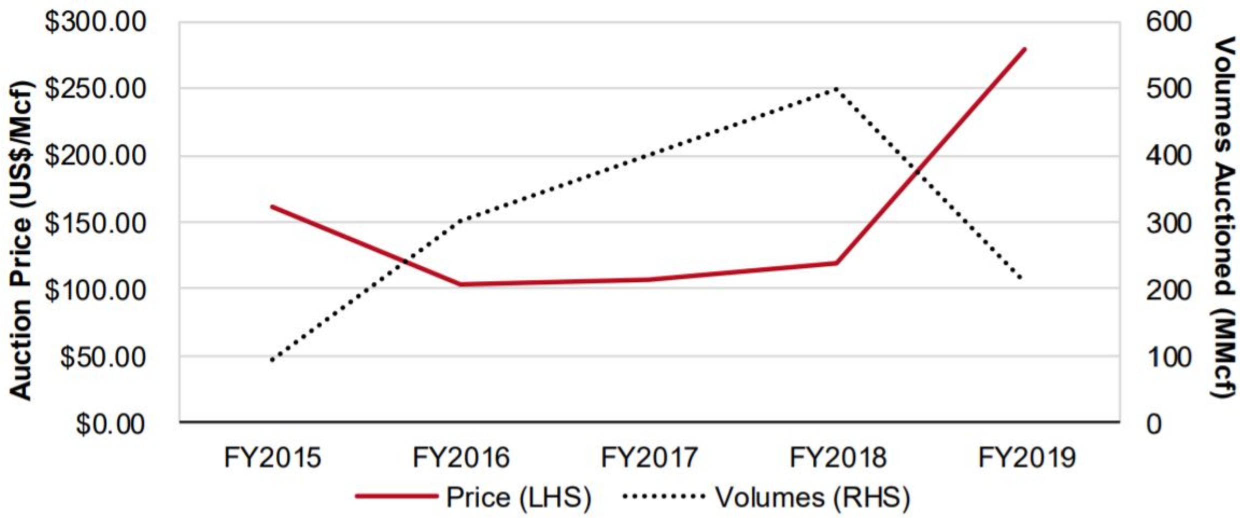

Figure 2. Sales of helium from the Federal Helium Reserve at BLM auctions, 2015-2019 (Mueller, 2020). LHS (left hand side) refers to the bid price, and RHS (right hand side) refers to the volumes offered at auction.

Resource Availability

Helium is predominantly found in the U.S. in natural gas wells, with concentrations of 0.3% or higher being considered economic to extract (Rauzi & Fellows, 2003). However, as natural gas prices have dropped and helium prices have skyrocketed, helium is being considered as a primary target for exploration. It is important to note that helium is generally cheaper to process when natural gas is not present (Mueller, 2020). This makes the reservoirs in the Holbrook Basin particularly interesting for exploration, as the carrying gas consists primarily of nitrogen with little to no CO_2 and natural gas, depending on the well (Ballard, 2019; Rauzi & Fellows, 2003).

Exploration Potential

Geologic Setting

The Holbrook Basin is part of a regional NW plunging syncline that also includes the Black Mesa Basin (Figure 3). It is part of the Colorado Plateau and consists of sedimentary strata of Paleozoic and Lower Triassic age (Ballard, 2019). The Pennsylvanian to Permian target strata (Coconino Sandstone and sandstones of the Supai Formation) are less than 4,000 feet in depth and rest unconformably on Precambrian basement rocks. Gas samples from the Coconino Sandstone at Pinta Dome show that the likely source of helium is radioactive decay in shallow crustal basement rocks (Halford, 2018). This is based on isotopic signatures of N_2 and noble gases. Halford (2018) also found significant faulting in the area through geologic mapping and interpretation of closely spaced well logs; at Pinta Dome, these faults could aid in the transport of helium via advection from the Precambrian basement source to structural traps in the Coconino Sandstone.

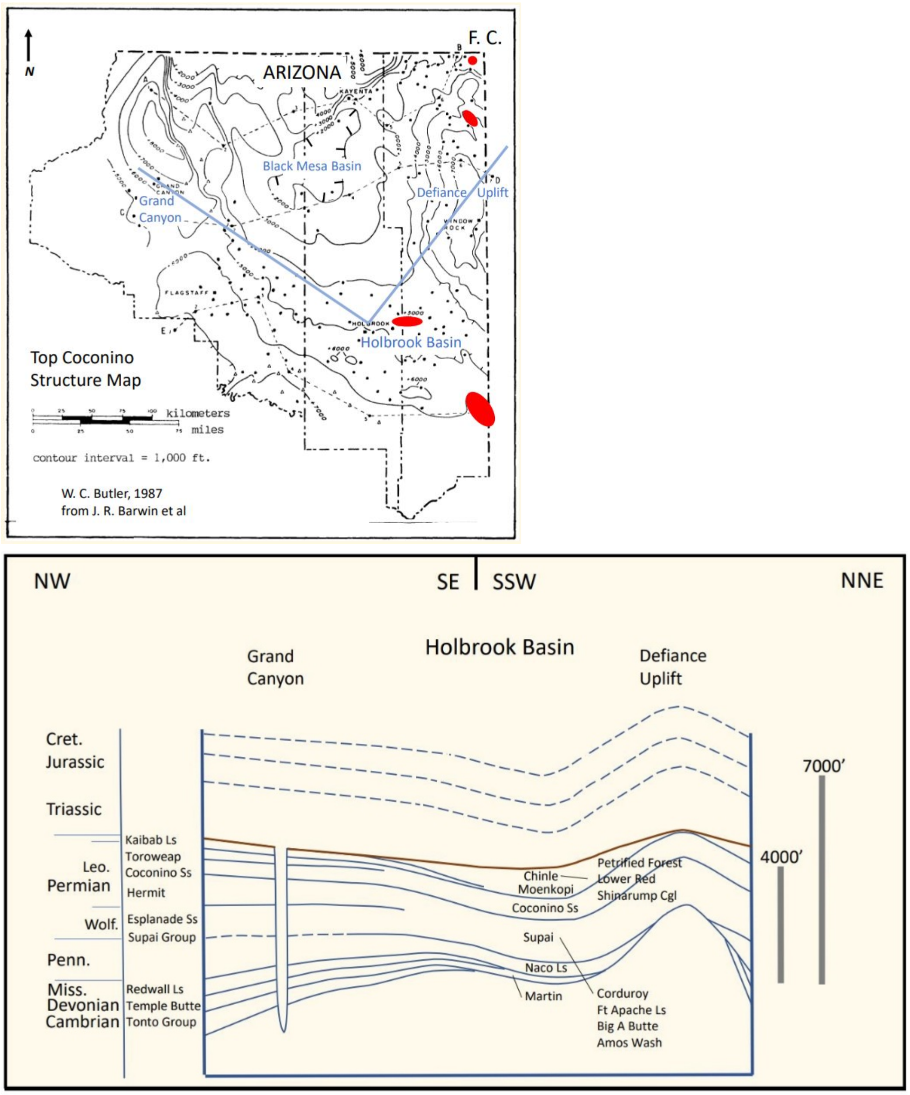

Figure 3. Geologic map showing the Holbrook Basin and a cross section from the Grand Canyon to the Holbrook Basin to the Defiance Uplift (Ballard, 2019).

Exploration History

Helium in the Holbrook Basin was reported from a non-productive oil test drilled to the Cambrian Tapeats Sandstone near Holbrook in 1927 (Rauzi & Fellow, 2003). Helium at Pinta Dome was discovered in 1950, when a well drilled in search of oil produced a very high concentration of helium (~8%) transported primarily by nitrogen, with little natural gas present (Rauzi & Fellows, 2003). Rauzi and Fellows (2003) report that Kerr-McGee constructed a plant to process helium nearby in 1961, and that production began at Navajo Springs in 1964 and East Navajo Springs in 1969; the plant closed and fields were abandoned in 1976 due to falling helium prices and a drop in production. Over the lifespan of the wells, the Pinta Dome and surrounding fields produced over 700 million cubic feet of Grade A helium which, at today's value of ~$300/MCF, would be worth approximately $210 million. Rauzi and Fellows (2003, p. 2) noted that, "the gas averaged 90 percent nitrogen, 8-10 percent helium, and 1 percent carbon dioxide." Figures 4 and 5 show a map of the area with productive wells and simplified stratigraphy of the region, respectively.

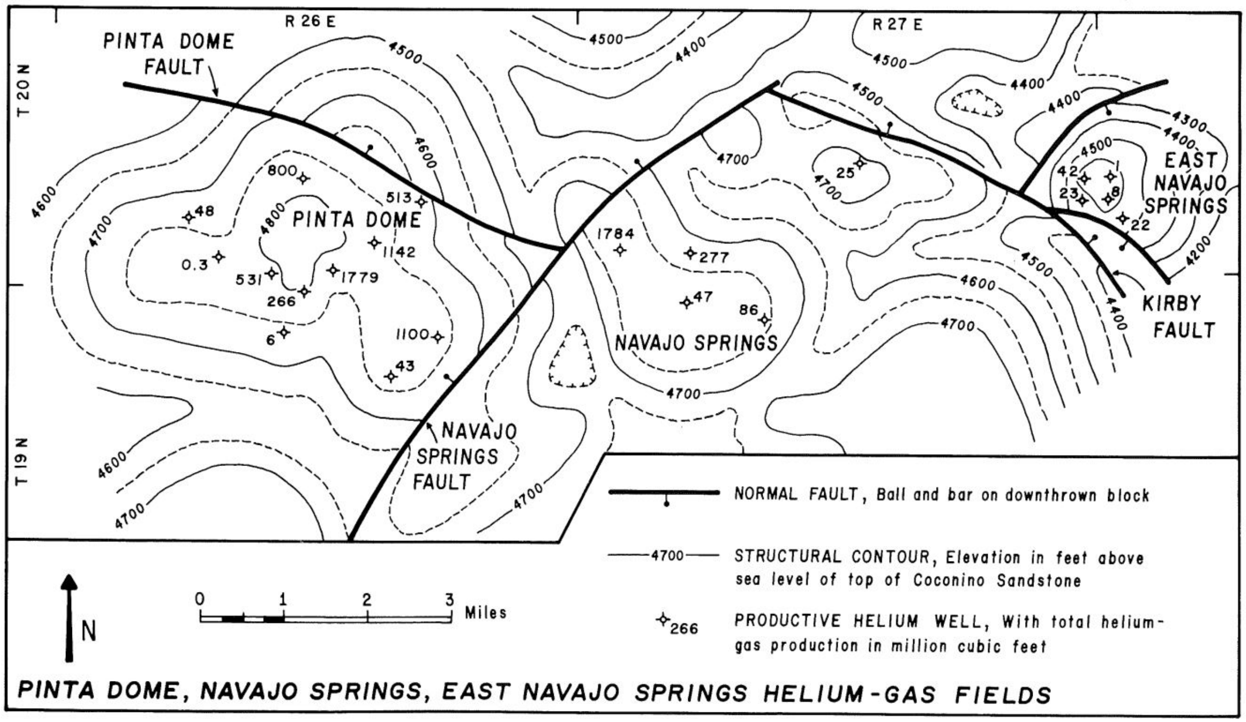

Figure 4. Regional map showing wells at Pinta Dome, Navajo Springs, and East Navajo Springs. Structural contours mark the top of the Coconino Sandstone (Spencer, 1983).

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 5. General stratigraphy of the Pinta Dome area (Spencer, 1983).

Helium deposits in the Holbrook Basin result from the same general principles as conventional natural gas deposits – both require a source and migration, as well as a reservoir, trap, and seal. The primary differences occur at the beginning of the process – helium sources are abiogenic rather than biogenic, and migration of ^{4}He involves escaping from the host minerals as well as from the source rock (Mueller, 2020). Where porosity and permeability are sufficient, the Coconino Sandstone and parts of the Supai Formation can act as reservoirs for the helium (Ballard, 2019). The Coconino Sandstone is fine- to medium-grained and silica-cemented. In many areas, it is so close to the surface that it lacks an effective overlying seal (Ballard, 2019), so drilling to find deeper deposits in the underlying Supai Formation is necessary. Small anticlinal structures at Pinta Dome, Navajo Springs, and East Navajo Springs trap helium (Rauzi & Fellows, 2013), but facies changes between shales, carbonates, and sandstones may also create stratigraphic traps in depositional cycles within the Supai Formation (Ballard, 2019). For example, some units, such as tight dolomitic limestones, make good seals; whereas others, such as porous sandstones, are good reservoir rocks. Faults are thought to be the primary mechanism of transport for helium deposits to accumulate in both the Coconino Sandstone and the Supai Formation (Halford, 2018). Helium concentration also appears to be enhanced in structural and stratigraphic traps near deep-seated igneous intrusions (Rauzi & Fellows, 2003) that were emplaced in the Holbrook Basin approximately 8.5-6 million and 4 million years ago (Arizona Geological Survey, 2021).

Recent Helium Discoveries in the Holbrook Basin

After closing in 1976, further development of wells in the Holbrook Basin ceased until economic changes stirred interest in the region once again. Demand for helium has increased in recent years as supplies have decreased. Desert Mountain Energy (DME), based in Vancouver, Canada, has access to much of the property in the Holbrook Basin outside the Pinta Dome region. Many of these areas have potential for untapped helium deposits, as historic production focused mainly on the Pinta Dome, Navajo Springs, and East Navajo Springs fields. Structural mapping in tandem with stratigraphic knowledge gained from previous drilling in the area will help determine the best places for exploration and new wells.

Desert Mountain Energy has recently completed 2 new wells in the Holbrook Basin, the State 10-1 and the State 16-1. Significant helium deposits were found in both wells (Desert Mountain Energy, 2020). Analysis of gas from the State 10-1 showed concentrations of 7.1321% helium, 77.0837% nitrogen, 4.0183% CO_2, and 2.6512% methane and other minor gases. This gas was found when the company perforated 5 feet into a limey sandstone unit in the Pennsylvanian Supai Formation. Based on open-hole well logs, the productive zone may be as much as 28 feet thick. Well logs show a drop in porosity in the middle of the target section, which may require additional perforations to produce.

Analysis of gas from the State 16-1 showed concentrations of 4.0904% helium, 90.2742% nitrogen, 0.0063% CO_2, and 3.5535% methane and other minor gases. Five feet of sandstone in the Supai Formation was also perforated in this well, with the potential productive zone being 61 feet thick. Two very dense layers of dolomitic limestone drop the porosity in a similar way to the State 10-1 well and will require additional perforations to enhance production.

Desert Mountain Energy plans to put these two new wells into production in late 2021, once it completes building a helium-separation plant in Navajo County, Arizona. The plant will be within approximately 1 mile of the closest well. While the total cost of the helium-separation plant is proprietary, construction of the plant is projected to save DME over 7.5 million dollars compared with other processing options (Robert Rohlfing, personal communication, 2021). The processing plant will use a combination of pressure swing adsorption and membrane technology to refine helium produced from the wells. The refining process is simplified by the low percentage of natural gas associated with the helium.

Refining helium at the plant will reduce transport costs and increase the value of the produced helium by providing industry with a more highly concentrated product. If production is successful, Desert Mountain Energy plans additional helium exploration in the Holbrook Basin. Based on the region’s historic and current helium grades, further exploration appears to be an idea with significant growth potential.

Conclusions

This is an excellent time for exploration and production in the helium industry. Demand and price points are up, and cessation of the BLM's auctions of federal helium reserves has opened more of the market to private suppliers. Helium's unique physical and chemical properties make it essential to many industries and technologies. As a non-renewable resource, helium deposits are projected to further increase in value over time.

Northeastern Arizona's Holbrook Basin is among the best places to look for helium. The 8-10% helium concentrations in older fields within the basin were some of the highest recorded in the world. At 7.1321% (State 10-1) and 4.0904% (State 16-1), both of Desert Mountain Energy's new wells show helium concentrations an order of magnitude above economic levels (0.3%) for natural gas wells. In addition, the location is near potential buyers, and the processing plant planned by Desert Mountain Energy will help minimize mid- and downstream costs. High tech companies and industries that require helium in California, Texas, and throughout the region will find it advantageous and cost-effective to order from a local domestic supplier.

Since drilling its two successful helium exploration wells in 2020, Desert Mountain Energy has seen a significant increase in stock value (Figure 6). It is clear that the company is doing something right in its exploration efforts and is producing results with high stock value as well as high grades of helium.

Figure 6. One-year chart showing stock prices for Desert Mountain Energy (DME website).

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