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by ***Steven J. Maione***
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Helium Exploration – A 21st Century Challenge

As we enter the first decade of the 21st Century worldwide helium demand is rising as many high tech industries are developing new commercial applications that are dependent on the unique physical properties of helium. The need for continued adequate supplies of helium in the 21st Century will be critical. To fulfill the anticipated future demand for helium, a new approach to helium supply is likely needed soon – the deliberate search for helium-rich gas reservoirs.

In December 2005 the 100th anniversary of the discovery of helium in natural gas will be celebrated in Dexter, Kansas. Up until 1905 helium was a laboratory curiosity, having only been discovered on Earth in 1895. The detection of helium in natural gas at Dexter was followed in the next three decades by many discoveries of small to giant gas fields in Kansas and the Panhandle regions of Oklahoma and Texas that held helium concentrations between 0.5% and 2%. Some contained upwards of 7% helium. In later decades helium-rich oil and gas fields were discovered in Colorado, New Mexico, Arizona and Wyoming, with some holding as much as 10% helium. Helium has been produced in commercial quantities at few other sites around the world. Although Canada, Russia, Poland and Algeria have produced helium in commercial quantities, none have discovered reserves or helium concentrations comparable to those found in the United States. As a consequence, the United States has been the world's principal source of helium for over 80 years, and both the U.S. petroleum industry and the U.S. government have played key roles in establishing ample supplies of helium throughout the 20th Century.

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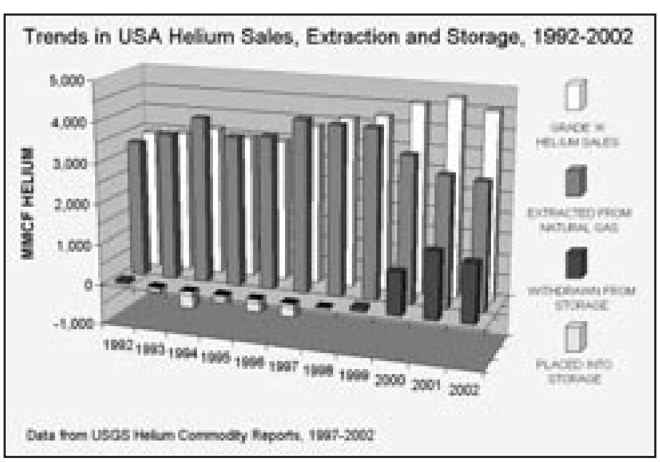
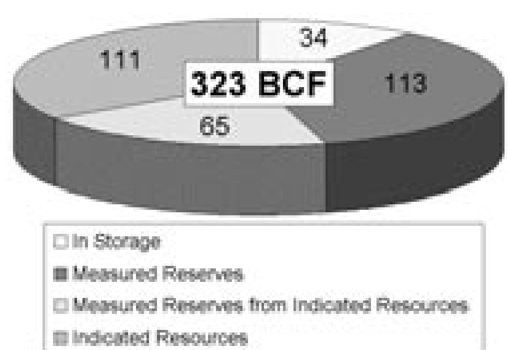
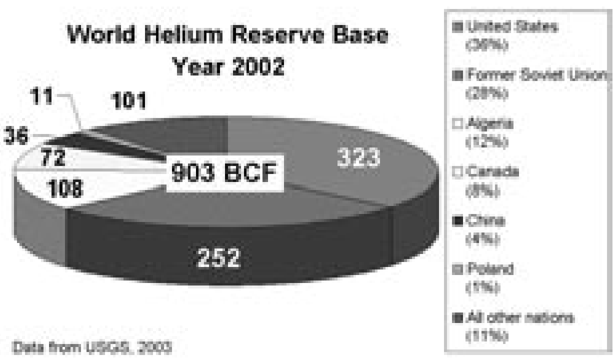
Nearly all helium gas reserves have been discovered serendipitously during the normal course of oil and gas exploration and development. As a result, there has been little need to develop any special geological expertise to target helium-rich gases in order to provide an adequate supply of helium. Scientific and industrial applications that were developed during the 20th Century that required helium were sustained by the abundant and reliable supply of helium associated with high BTU gas production.

Review of the geologic framework of helium accumulations, and recent findings from ancillary fields of study that include isotope and noble gas geochemistry, geohydrology, seismology, volcanology, mineral exploration and geothermal exploration provide grounds for formulating strategies for the exploration of helium-rich natural gas. The principal source of helium is from the steady rate of **North American Explorationists** *continued on page 28*

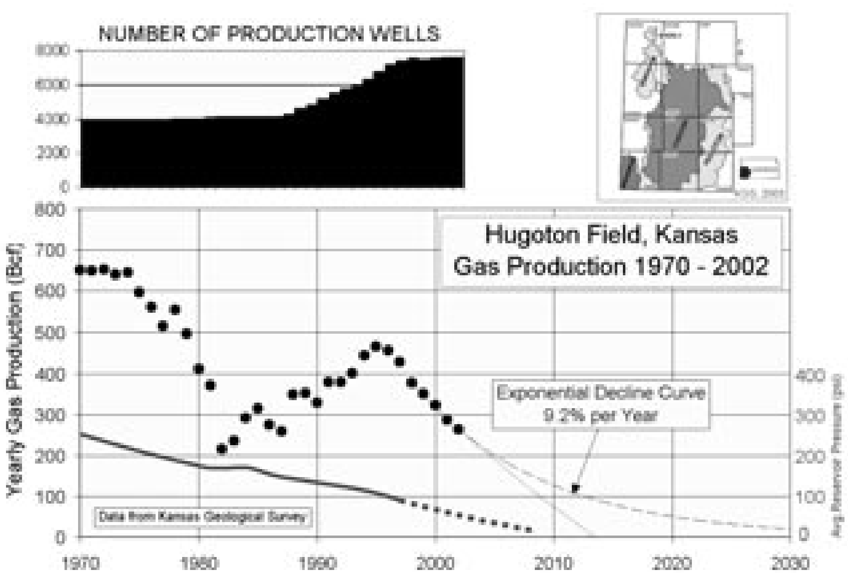




U.S. Measures Helium Reserves and indicated Helium Resources (2001) from USGS Minerals Yearbook, 2002 radioactive decay of uranium (average: 2.8 ppm) and thorium (average: 10.7 ppm) found throughout the crust. Over geologic time substantial radiogenic and some nucleogenic helium, will accumulate within the mineral crystal lattices and microfractures in crustal rocks. Degassing of this helium from the crust has been the subject of many studies, including deep crust research drilling. Concentration profiles of helium in ultradeep wells and that found in confined groundwater systems that hold helium concentrations orders of magnitude higher than can be accounted for by steady-state helium diffusion, have demonstrated the necessity for periodic tectonism to increase fracture permeability of the crust and allow advective transport of helium. Helium soil gas and helium groundwater surveys adapted for uranium and hydrocarbon exploration have long revealed the association of high helium flux with faults, lineaments and natural springs.



World Helium Reserve Base Year 2002



Gas production and production well count history of the Kansas portion of the Hugoton Gas Field 1970-2002. Exponential decline curve based on 1998-2002 period. Historically the Hugoton-Panhandle Gas Field (KS, OK, TX) has been the principal source of helium in the United States since the 1950's. The current production decline rate and declining average reservoir pressure indicate that in less than 10 years the production of natural gas (and helium) in the Kansas portion of the Hugoton field will be at or near abandonment conditions.

Recent recordings of short-term, voluminous discharges of helium following strong earthquakes have aptly demonstrated the role of seismicity in periodic releases of helium from the crust.

While ^{4}He flux is largely accounted for by degassing of radiogenic helium from the crust, the rare ^{3}He isotope originates from the mantle, where the isotopic composition of helium is ~1000 times greater than that found in the Earth's crust (mantle ^{3}He/^{4}He ratio = ~10^{-5}, Crust ^{3}He/^{4}He ratio = ~ 10-8). The discovery in 1969 of ^{3}He flux from mid-ocean ridges and subsequently in volcanoes, intra-plate hot spots, and high-temperature geothermal systems has provided earth science with a highly sensitive tracer of mantle-derived gases. He-rich gas fields have variable but mostly distinctively elevated ^{3}He/^{4}He ratios, providing evidence that degassing and release of mantle volatiles accompanied significant releases of helium from the crust. Commencement of magmatic activity within a volume of long-stable, aseismic crust would mobilize long-held helium as levels of seismicity, crustal heat flow and rock temperatures increased.

Formation of economic helium-rich gas deposits can develop when periodic episodes of high helium flux are swept up by an overlying regional aquifer, effectively transported and concentrated in a reservoir trap. Because helium has very high diffusion rates in sedimentary rock, high-density rock seals are needed to effectively slow the relentless flux of helium through the sedimentary column and into the atmosphere where it would eventually be lost into space. Rock types such as anhydrite, salt, or dense (Paleozoic) shale provide the most effective top (or lateral) seals. The first sandstone or carbonate reservoir (commonly Paleozoic or Mesozoic in age) above the crystalline basement is favorably situated to capture, transport and "temporarily" hold helium-rich gases. Effective helium transport in an aquifer and retention of helium in a trap are further augmented if the reservoir is underpressured. A negative pressure gradient across the cap rock of an underpressured reservoir would be effective in retaining a higher concentration of helium for a longer period of geologic time. Field studies indicate an underpressured reservoir with a cap rock of anhydrite or salt provides the ideal geologic framework for the accumulation of helium gas.

Incorporating recent isotopic studies of noble gases by Ballentine and Lollar (2002), a geologic model is presented to explain the collection, movement and accumulation of over 600 BCF of helium in the Hugoton-

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Panhandle gas field and adjacent areas. The model recognizes the key sequential geologic events that occurred to form the world's largest helium-rich gas district. These geologic events included 1) uplift of the Rocky Mountains, 2) development of an east-dipping, underpressured hydrogeologic system of basal Paleozoic clastics and carbonates, 3) deposition of Permian shale, anhydrite, and salt, and 4) Late Oligocene–Early Miocene volcanism of the Spanish Peak region of southeast Colorado.

Not since the helium gas boom years in the Four Corners area of the Southwest in the 1960s has the American petroleum industry given much thought to targeting helium-rich gas fields. As the 21st century begins the need for the exploration for additional helium reserves is beginning to be apparent as the Mid-Continent gas fields, long the principal world source of helium, are nearing depletion. A goal for the American oil and gas industry should be to accept this challenge, and with improved geologic models and exploration strategies, to locate and develop new helium deposits.

Biographical Sketch

Steven J. Maione, senior staff geologist for the Reservoir Technologies Division of Core Laboratories, received degrees in geological engineering and a Masters in geology from the Colorado School of Mines. In 1971 he joined Union Oil Company of California (now Unocal Corp.) as an exploration petroleum geologist in Casper, Wyoming.

In 1974 he joined Unocal's Geothermal Division and participated in geothermal exploration projects in North America, Philippines, Indonesia and Japan. In 1992 he transferred to Sugar Land, Texas, and rejoined the Unocal oil and gas exploration division and participated in teams evaluating new venture opportunities, including China.

In 1997, Steve became an Associate of Valenti Engineering Services of Kingwood, Texas, where he carried out 3-D seismic interpretations. He joined Coherence Technology Company (CTC) in Houston in 1998, specializing in integrating Coherence Cube seismic volumes in 3-D seismic interpretations. Following acquisition of CTC by Core Laboratories, his seismic interpretation activities for the Advanced Reservoir Geophysics Group now include integration of rock properties derived from seismic (LambdaMuRho, or LMR™ analysis) in pursuit of the wily hydrocarbon.

Steve is a registered professional geoscientist with the State of Texas, a member of the Houston Geological and Geophysical Societies, the Society of Exploration Geophysicists, Sigma Xi, Rocky Mountain Association of Geologists, and a 32-year member of the American Association of Petroleum Geologists. His interest in the science and geology of helium followed his work as an exploration manager of a geothermal joint venture in Japan in the early 1980s. There he adapted the newly emerging isotopic science of ^{3}He/^{4}He ratio measurements of gas and water samples in pursuit of the wily geotherm.