



The Emergence of the Helium Industry

The History of Helium Exploration, Part 1 of 2

January 2019 | Jon Gluyas

Helium was first observed during the 1868 solar eclipse as a dark adsorption line in the spectrum of the sun. Originally assumed to be a solar metal, it was given the name "helium" from the Greek word for the sun, "helios."

Although the element was also recognized in the spectrum of the gases emitted by Mount Vesuvius in 1882, it was not until 1889 during experiments conducted by William F. Hillebrand, that a sample of helium gas was finally obtained from uraninite. The experiments were repeated, at Uppsala by Per Teodor Cleve and Nils Abraham Langer in 1895, leading to a measurement of helium's atomic weight.

Helium is a monatomic gas at temperatures above 4 degrees Kelvin. With an atomic number of 2 and an atomic mass of 4 (or more rarely, 3), it has the smallest atomic radius of any element, 31 picometers. Helium is the second most abundant element in the universe after hydrogen, but it is exceedingly rare on

Earth; the atmosphere contains approximately 5.2 parts per million, the Earth's crust approximately 8 parts per billion and seawater approximately 4 parts per trillion.

Despite the rarity of helium on Earth, it is in some places concentrated. Natural gas deposits commonly contain trace amounts of helium in the parts per million, yet a few are known to contain up to 10-percent helium.

From Commoditization to Crisis

It was the accidental discovery of one such helium-rich natural gas accumulation at Dexter in Kansas, in 1903 that started the United States' helium boom. Little more than a novelty when first discovered, helium has become a key commodity. It is used extensively in medical cryogenics (particularly in magnetic-resonance imaging machines), analytical and lab applications, breathing mixtures, as a lift

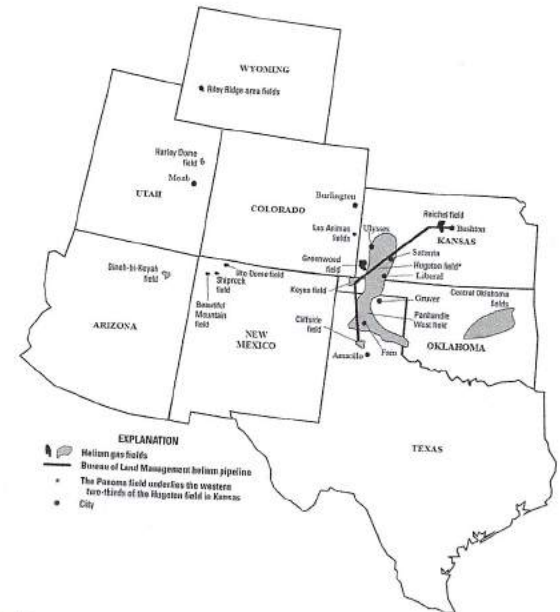
gas, for arc welding, leak detection and, contrary to popular belief, only a little (less than 10 percent) is used to inflate party balloons. There are few substitutes for helium and so, as its applications have become more common, demand has grown and supply is struggling to match demand.

The discovery at Dexter, followed by others in the Midwest, has allowed the United States to dominate the helium market since it began. However, new discoveries have not replaced the volume of helium used, and recycling is rarely possible. Helium will inevitably leak from any container due to its small atomic radius. Once free, it is lost to outer space – it is not confined to Earth by gravity.

While the United States' dominance of the helium market has declined, that of Algeria, Russia and, in particular, Qatar has risen as they too began discovering helium-bearing natural gases. Only 0.3 percent helium in a natural gas deposit will render helium the most valuable component. However, for one particular field, extracting the helium present at 0.04 percent concentration has proven economically feasible.

Many would regard this diversification of helium production as beneficial, but experience is already demonstrating that such diversification has not eased security of supply issues. From 2010 onward, several warnings about a helium supply crisis have been issued. These led cryogenics companies to issue supply curtailment notices to industrial and academic customers. It is easy to imagine the knock-on effects of this and, while few may worry about limiting the supply of party balloons, restrictions on use of medical scanners because of helium shortages could have fatal consequences.

From Accidental Discovery to Exploration



Major helium bearing natural gas fields in the United States. Courtesy of USGS.

It is against this complex backdrop that we decided to find a new helium province. Initially, we were astonished to discover that there was no existing helium exploration strategy. The choices available were either drilling adjacent to a known helium accumulation, or fortuitously discovering economic concentrations of helium while exploring for petroleum.

We changed that.

Late in 2015, following an approach from Thomas Abraham-James and Josh Bluett of Helium One, we sampled gas seeps from Tanzania within the East African Rift System. We were confident of its potential from hints of helium in previous literature and our understanding of the helium system.

To understand how the Tanzanian discovery stands out, let us take a look at the unusual world of helium discoveries.

Bo Sears, in the book, "The Future of Helium as a Natural Resource," recounts the story of that first well in Dexter, Kan. It was drilled just off the main street in Dexter by the Gas, Oil and Development Company. They hoped to find oil and/or natural gas and indeed hit a large reservoir of gas at 400 feet. There was much excitement in the town and people gathered, eager to see and hear the gas stream ignited, but the flame used to ignite the new-found gas was quickly extinguished. A second try was made to ignite the gas; it too failed.

Intrigued, the Kansas state geologist Erasmus Haworth sampled the gas and sent it to David F. McFarland at the Chemistry Department of the University of Kansas. McFarland published the results of the analysis in 1903 and of other natural gas accumulations from the Midwest in 1907.

The non-flammable gas sampled at Dexter was mainly nitrogen (82.7 percent) with some methane present (16.85 percent). The third most abundant component was helium at 1.84 percent. Of the other wells tested only the nearby Greenwell well at Dexter was of similar composition with 1.64 percent helium.

A couple of wells at Eureka, about 70 miles north of Dexter, also had more than 1 percent helium. Elsewhere in Kansas, Missouri and Oklahoma, helium abundance varied between about 0.2 and 0.5 percent. In all instances, including those from Eureka, methane was the most common component.

Interest in helium waned due to a lack of commercial applications for the gas.

This all changed in 1914 when the German chemist Géza Austerweil published "Die Angewandte Chemie in der Luftfahrt" ("Applied Chemistry in Aviation"). Austerweil highlighted the utility of helium as a buoyant, non-combustible gas for filling military balloons.

His report might have gone unnoticed if not for another event that year. In 1914, Allied aircraft attacked a German zeppelin. Incendiary bullets penetrated the airship's skin, but it did not catch fire. The incident led some British scientists to conclude that Germany had found an abundant source of helium. This

source was suspected to be either the coalmines at Anzin in France or Frankenholz in western Germany, which were known to have produced helium at rates estimated to be around 4,000 cubic meters a year. Despite the mistaken identity of the gas – for it was hydrogen in the blimp, not helium – these events prompted the first conscious search for large volumes of helium.

William Ramsay who, in 1904, had received the Nobel Prize for his work on the noble gases, led the search for “British” helium. The search proved unsuccessful in England and it was extended to Canada. Subsequently, J.C. McLennan, a professor at the University of Toronto, discovered helium concentrations of 0.1 to 0.33 percent in several natural gases from eastern Canada.

Once the military application of helium was recognized, the U.S. Geological Survey was tasked with investigating helium resources.

By 1921, helium had been found in natural gases from Kansas and northern Oklahoma, Texas, Ohio and Montana in reservoir rocks ranging in age from Silurian to Cretaceous, and at concentrations between 0.25 and 0.5 percent. A few gases with helium concentrations in excess of 0.5 percent were also found.

The most significant commonality of the discoveries was the occurrence of Precambrian granites and metamorphic rocks beneath them. This is true in Texas and Kansas and inferred from outcrop geology in Ohio. A further observation was that while nitrogen was always present in helium discoveries, nitrogen-rich natural gases did not necessarily contain helium.

The USGS also reported on helium discoveries elsewhere in the world. In Europe, small quantities of helium were found in natural gases in Italy, Hungary, Austria, Romania and Germany, as well as that already mentioned for France. Little information was available on the reservoir geology of these discoveries. The Survey noted that the helium content was very low in all but one European locality at Pechelbronn in Alsace (France), where helium was measured at 0.38 percent.

With helium present in such low concentrations, all “helium discoveries” require the gas to be processed to increase the helium concentration. The presence of helium in eastern Canada led to the development of the world’s first helium refining plant in Hamilton, Ontario. The L’Air Liquide Company modified an air separation unit and was able to produce helium at 87-percent purity with most of the remainder being nitrogen.

American Helium Dominance

The story of helium exploration in the 20th century belongs to the United States, and to the Midwest in particular, so it is here that we return after the end of the First World War. During the war, around 200 million standard cubic feet of helium had been produced from the Petrolia Field in Clay County, Texas. It was the mainstay of helium production in the United States, and to meet production requirements, a full-

scale helium plant was built at Fort Worth, Texas by the U.S. Navy. However, production from the Petrolia Field was in decline by the 1920s, and by the time the field was shut-in in 1929 the plant had processed approximately 46 million standard cubic feet of helium.

Five years earlier, in 1924, the Cliffside Field had been discovered a few miles northwest of Amarillo in the Texas Panhandle. It contained approximately 1.8 percent helium and substantial reserves, leading the U.S. government to build a processing plant in nearby Amarillo. The rising demand for helium during World War II was supplied by the discovery of helium in the nearby Panhandle Field in Texas, the Otis and Cunningham fields in Kansas, and the Rattlesnake Field in New Mexico.

Despite the successful discoveries, the U.S. government recognized that the conservation of indigenous helium resources was now necessary. It was also realized that substantial quantities of helium had unintentionally been vented from fields produced for methane. Thus the U.S. Bureau of Mines undertook a systematic survey of helium in producing gas wells, pipelines and natural gas seepages across the United States. More than 3,000 gas analyses are reported in two bulletins. The states in which helium was found in one or more gas sample in excess of 0.3 percent (the current economic threshold for separation of helium) included: Arizona, California, Colorado, Illinois, Indiana, Kansas, Kentucky, Michigan, Montana, New Mexico, Ohio, Oklahoma, Texas, Utah and Wyoming. However, only in Arizona, Colorado, Kansas, Michigan, Montana, New Mexico, Oklahoma, Texas and Utah (the Riley Ridge Field in Wyoming joined this group in 2011) did some samples exceed 1 percent helium. Thus the importance of the Midwest as the world's most prolific helium-producing region was proven.

That said, eight gas samples of 78 from Montana recorded 0.3 percent helium or greater with a peak of 3.91 percent from the Root No.1 well, Kootenai Dome, Fergus County and together with the Havre Field, also in Montana, and Bow Island in the adjacent Canadian province of Alberta a second petroleum province also emerged.

Mention should also be made of Michigan in which 39 samples out of 52 measured returned helium abundances of 0.3 percent or greater with a peak value of 1.11 percent in the Scipio Trend, the most bizarre oil discovery ever made. The Albion Scipio Field was discovered in fractured Silurian carbonates. The discovery well was drilled at a location dictated by the local clairvoyant after the interpretation of a dream experienced by the landowner. Ironically, it took geophysicists several decades to find the second field on the trend!

Following the Bureau of Mines reviews, Cliffside became the most important helium storage site in the world. By 1963, the U.S. government had begun to inject crude helium into the field from other fields in the United States. Crude helium is described as a helium-enriched, helium-nitrogen mixture obtained during first stage separation of helium-bearing natural gases.

Parts of Kansas and adjoining areas in Texas and Oklahoma have remained the most important areas for helium extraction, with the largest field being the Hugoton-Panhandle Field. Spanning Kansas, Oklahoma and Texas, the gas in the field contains 0.2-1.18 percent helium and is reservoirized in Permian carbonates sealed by anhydrite in a combination stratigraphic (Hugoton)-structural (Panhandle) trap. The Hugoton-Panhandle of Kansas, Oklahoma and Texas, along with the Panoma, Kan.; Keys, Okla.; Panhandle West, Texas and Riley Ridge, Wyo. fields are estimated by the USGS to contain 97 percent of the United States' 3.9 billion cubic meters of helium.

Explorer Historical Highlights (Click to View Column Archives)

A history-based series, Historical Highlights is an ongoing EXPLORER series that celebrates the "eureka" moments of petroleum geology, the rise of key concepts, the discoveries that made a difference, the perseverance and ingenuity of our colleagues – and/or their luck! – through stories that emphasize the anecdotes, the good yarns and the human interest side of our E&P profession.

If you have such a story – and who doesn't? – and you'd like to share it with your fellow AAPG Members, contact the editor.

Hans Krause is an AAPG Honorary Member, Distinguished Service Award winner and former chair of the AAPG History of Petroleum Geology Committee, and editor of Historical Highlights.



Jon Gluyas

Jon Gluyas is a geologist who has worked in both the petroleum industry and in academia. Gluyas specialized in oil field redevelopment as rehabilitation, learning his trade first in eastern Venezuela and subsequently the states of the former Soviet Union. In the mid-'90s he returned to his native UK and with others, founded his first oil company. Acorn Oil and Gas became the first company working in the North Sea to reactivate a completely abandoned oil field, the original one, Argyll. He then went on to found Fairfield Energy before moving to the academic sector in 2009, joining Durham University in the UK. Recently he has worked on carbon capture and storage and geothermal energy. He co-

organized the first ever geothermal/petroleum crossover meeting for the AAPG in Durham in 2016 and is currently working on decarbonizing the UK's heat demand, which accounts for half of all energy used and around 30 percent of all UK greenhouse gas emissions.

It was back in 1999 that Gluyas first recognized that the potentially precarious nature of the helium supply while reading a field development report for the company he was working for at the time. That company was not interested to make use of an accidental helium discovery, but the idea stuck and in academia, Gluyas sought to understand how helium formed, migrated from its source rock and accumulated. He teamed up with Chris Ballentine, now of Oxford University, an expert on noble gas geochemistry, and within a couple of hours of meeting made a pitch to Statoil (now Equinor) for funding. The pitch worked. It funded a doctorate for Di Danabalan, brought together other members of the team – Pete Barry and Colin Macpherson – and ultimately brought them into contact with Helium One and their quest for helium in the rift valley of Tanzania.

"The gas that wouldn't burn" storyboard at Dexter, Kan., reproduced with permission from American Oil and Gas Historical Society, AOGHS.org

Extended reading



Helium Shortages and Emerging Helium Provinces

The History of Helium Exploration, Part 2 of 2

February 2019 | Jon Gluyas

The search for new sources of helium is of paramount importance as a combination of declining production and increasing demand have made helium prices soar.

This follows a century in which the United States had a near monopoly on helium reserves and U.S. production met global demand. Although most of the helium production story has taken place in the United States, there are other nations that have produced and are producing helium. Details of production and exploration in these regions are scant, however.

Helium Beyond the United States

In a 2014 issue of the journal "Minerals," New Zealanders Steve Mohr and James Ward published "Helium Production and Possible Projections," in which they attempted to build the history of helium production for countries other than the United States. The data they assembled comes from documents

published by the U.S. Geological Survey Mineral Resources Program, which enabled them to collate the production from countries other than the United States. Helium has been produced in Canada, France, Poland, Algeria, Qatar, Russia and Australia, of which Algeria, Qatar and Russia have been the most significant.

Also in 2014, a paper by V.P. Yakutseni of the All Russia Petroleum Research Exploration Institute entitled, "World Helium Resources and the Perspectives of Helium Industry Development," reviewed helium occurrences, reserves and production and provided specific details of fields in Russia, Algeria and Poland. For Russia, most of the gases produced to date have been low in helium (0.1-0.25

percent in western Russia), and gases from the Caspian area, Arctic territories and western Siberia have been very low in helium (less than 0.03 percent). However, discoveries made in the latter half of the 20th century in eastern Siberia contain moderate amounts of helium (0.2-0.6 percent). The fields include the Kovykta Field that is reported to have the unusual property of containing only 1.5 percent nitrogen but 0.26-0.28 percent helium.

The production of helium in Algeria is from the giant Hassi R'Mel gas field, reported to have up to 0.19 percent helium, according to a 2014 report by independent consultant Richard H. Clarke, "The Global Helium Supply." Helium has been extracted from the liquefied natural gas process since 1995 with at least two new fields being added this decade with expected reserves of around 37 million cubic meters.

The world's largest gas field is North Field in Qatar and its extension into the Iranian South Pars within the Persian/Arabian Gulf. Field start-up was in 1997 and the gas is exported as LNG. The cryogenic process used to liquefy the gas also gives an opportunity for the extraction of helium, which in the case of North Field is only present at 0.04 percent. Elsewhere, such a low concentration would not be considered economically viable, but as a secondary product to LNG production, helium extraction is commercially feasible.

Future Market Share

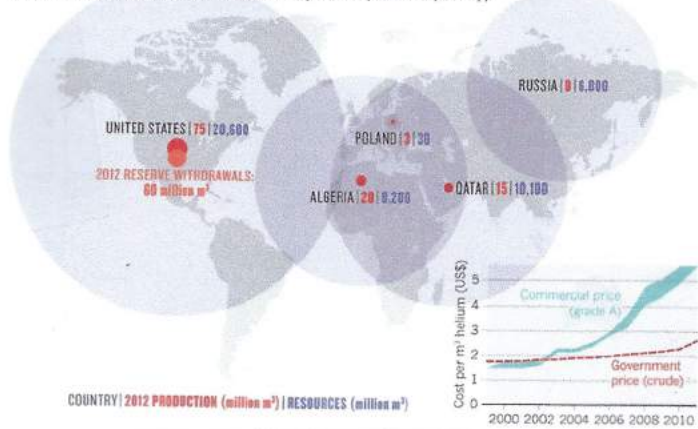
Mohr and Ward and Yakutseni made projections of likely future production based upon the summed reserve estimates from known producing countries plus China.

Their projections are quite different.

Mohr and Ward anticipate that the United States will continue to be dominant in the market throughout the 21st century, albeit with a reduced share of the market at around 30-40 percent.

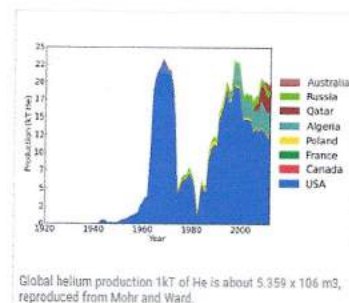
FLOATING SKYWARD

The price of helium from a US government stockpile has not kept pace with commercial prices (see graph). Most helium currently comes from the United States, but with price rises expected to continue, Russia is planning to tap its reserves, and other countries may increase production (see map).



Helium producing countries. Image from Mark Peplow's "Helium Reserves Under Pressure" from a 2013 issue of "Chemistry World."

Yakutseni states that the U.S. helium reserves are essentially at an end and that Russia will dominate the market based upon the reserves estimates for the collection of fields in Eastern Siberia at 16 billion cubic meters. These, together with the projected yet-to-find helium reserves from Eastern Siberia of 3,035 billion cubic meters, will allow Russia to dominate the market for decades to come.



An Exploration Methodology for Helium

The authors of this article participated in the most recent significant discovery of helium, and it was outside any of the countries considered by Mohr and Ward or Yakutseni. Working with start-up company, Helium One, natural gas seeps were sampled by Pete Barry in Tanzania's Western and Eastern rift arms of the East African Rift System in December 2015. By mid-2016, the analysis of the gas composition was finalized. The seeps were primarily nitrogen-helium mixtures with helium concentrations in the Eastern rift arm as high as 10 percent. As Diveena Danabalan reports in her 2017 doctoral thesis, "Helium: Exploration Methodology for a Strategic Resource," hydrocarbons were essentially absent.

The initiative to explore for helium in East Africa's Rift Valley had a dual origin. Back in 2012, Jon Gluyas of Durham University in the UK and Chris Ballentine, then with Manchester University, now with Oxford University in the UK, had begun a research program designed to develop an exploration strategy for helium based upon understanding the source of helium, "maturation" of the source rock, primary migration of helium from the source rock, secondary migration of the helium to the trap and helium accumulation processes. In 1999, Gluyas had found a report on an Asian gas-field with high helium concentrations and recognizing its value, tried to have the helium separated from the vent gases, but without success. Ballentine had a long history of research on the geochemistry of helium, having begun with his doctoral topic on the helium-rich Panonnian Basin of Hungary.

Gluyas and Ballentine met just 12 hours before giving a pitch to Statoil (now Equinor). After a 30-minute presentation and 60 minutes of questions, Statoil were on board. They provided the funding and Diveena Danabalan was appointed as a doctoral research student.

One of the primary objectives of Danabalan's research was to sample and analyze all of the gases in Statoil's portfolio. Unfortunately, we found no significant helium occurrences in their portfolio. We had to look elsewhere. Danabalan set up a website, the content of which promoted her doctoral research, while Gluyas and Ballentine trawled through their colleagues and associates in the petroleum industry. It was a desperate search – 18 months of the doctoral research time ticked by and all we had to show was a

comprehensive literature search. It did, however, ensure that we put serious effort into developing an exploration strategy – after all, we may well have to use that strategy in earnest to find any helium to analyze!

Then, two leads bore fruit. We got a chance to sample a producing field we knew to be helium rich in south Asia. The sampling instrumentation was shipped out, air tickets and visas obtained, only for a security issue to thwart us at the last moment. On the other side of the world, U.S. midwest helium producers Bo Sears and Scott Sears had seen Danabalan's website and invited her to come out and sample their wells. At last, we could begin to test our ideas on the mechanisms of helium generation, migration and entrapment. The first results from analysis of the gases sampled by Danabalan in the United States were published as an abstract for a talk at a Goldschmidt conference. Shortly thereafter, one of our team, Pete Barry got a call.

The second part of our story starts back in the 1950s. The Geological Survey of Tanganyika (now Tanzania) published a series of annual reports, or "records," as they were known. Among these records by T.C. James is a paper on thermal springs in Tanganyika. James was a very well-respected geologist. He had already published on metamorphic rocks of Western Tanganyika with professors John Sutton and Janet Watson (geology royalty of the day). His appointment to the Geological Survey of Tanganyika was even reported in "Nature." Nonetheless, when Thomas Abraham-James and Josh Bluett came across a secondary reference to the thermal springs report, "Investor's Guide to Industrial Minerals in Tanzania," they assumed there was a typing error, for it reported that some springs emitted gases in which the helium concentration was more than 10 percent. It was 2013-14 and at the time, Abraham-James resided in Tanzania, a gold and base metal prospector, and Bluett, who was a good friend to Abraham-James, was in country for a holiday. Ever the explorer, Abraham-James drove Bluett out to see the gold prospect he was evaluating.

Lying on the back seat of the Land Cruiser was the "Investor's Guide." Bluett flicked through it and, as a petroleum geologist, it was the reports on helium that caught his eye. He was fully aware of the supply crisis for helium and that most commercial production came from gases with less than 1-percent helium.

Further investigation was clearly imperative.

The geological Survey records by James proved decisive. The East African Rift of Tanzania could be of global significance. Helium has been recoded from thermal seeps at concentrations of 4.4 percent to 18.2 percent. Abraham-James and Bluett wasted no time – Helium One was founded and exploration licenses taken in the most prospective areas. At much the same time, the call was made to Barry at Oxford and the Oxford-Durham team brought onboard. We met at the Turf Tavern in Oxford and we discussed in muted tones the geology of the Rukwa area of Tanzania. According to the research

conducted by the Durham-Oxford team, helium concentrations in gases are likely to be at their highest in areas with ancient granitic basement and a recent (geological) heating event. Rukwa certainly met those criteria. We were thus set to test our hypothesis in a spectacular way.

In December 2015, Barry travelled to Tanzania and sampled the springs found by James in the 1950s.

Testing the Methodology

Had the sampling been successful?

There were some stressful moments as the sampling tubes were evacuated in Ballentine's Oxford laboratory, but all was well. By spring 2016, the high helium contents of the gases had been confirmed and the geological appraisal of the Rukwa area was undertaken using vintage seismic and well data. Simultaneous press releases were made by Helium One on the helium volumetrics (audited by Netherland Sewell and Associates of Houston) and by the Oxford-Durham team on the helium concentration and geochemistry of the nitrogen-helium seeps. The resource assessment for Rukwa suggests that the most likely prospective helium resource is 98.9 billion cubic feet while the range (P90-P10) is 25.5-322.2 Bcf.

With adjacent areas still to be evaluated, this makes Tanzania the most exciting new helium province to emerge this century, and probably the first-ever helium province to emerge while exploring for helium rather than petroleum. The discovery vindicated the exploration strategy we developed and the sampling and analysis methods that enabled quantification of the discovery.

What we now know is that the key elements for success in exploring for helium are determined to be:

- 1) Archean, or at least very ancient, granitic basement to source the 4He , (3He is primordial) from thorium and uranium decay,
- 2) a geologically recent event providing the heat and pressure to enable helium and other volatiles to escape from the crystal lattice,
- 3) the advection of released helium with carrier gases (usually nitrogen),
- 4) transport to the site of accumulation either as a solution in groundwater or as a free gas phase,
- 5) exsolution of the nitrogen-helium mixture at shallow depth, or partitioning of the dissolved gases into a pre-existing gas accumulation, or the trapping of a free gas phase.

From this list, it is clear that East Africa had the potential to be a location where helium has accumulated in the subsurface and it is not alone.

Author's note: Diveena Danabalan, Pete Barry, Colin Macpherson and Chris Ballentine contributed heavily to this article. Danabalan and Macpherson are with Durham University in the UK. Barry and Ballentine are with Oxford University.

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Extended reading



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