Helium in New Mexico: Origins, Uses, Economics, Geologic Distribution and Exploration Possibilities*

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Abstract

Helium's unique physical and chemical properties lend it to many uses for which there is no substitute. In addition to its well-known property of being a low-density ("lighter-than-air") gas, its boiling point is –269^{o}C, the lowest of any substance; it, therefore, has invaluable uses as a coolant. It is also inert and nonreactive with other substances in all but the most extreme conditions; so it has application as a nonreactive atmosphere. Its main uses are as a coolant in magnetic resonance imaging (MRI) instruments and an inert atmosphere in semiconductor manufacturing. Its use as a lifting gas is relatively minor.

The U.S. does not import helium but instead exports it, providing 85 percent of the world's helium production. Helium sales in the U.S. increased from 4 to 4.5 BCF from 1998 to 2010. During this same time period, domestic production of helium decreased from 4 BCF to 2.8 BCF. The shortfall in production has been filled by withdrawing helium from storage. As demand has exceeded production, prices have risen from $42/MCF in 2000 to $75/MCF in 2010. The trends of increasing demand and decreasing production indicate a need to identify and develop new sources of helium.

Helium gas has been produced from eight oil and gas fields located on the Four Corners Platform of northwestern New Mexico since 1943. Almost 950 MMCF helium have been produced from reservoirs of Permian, Pennsylvanian, Mississippian, and Devonian age on the Four Corners Platform in San Juan County. Concentration of helium in gases produced from these reservoirs ranges from 3 to 7.5 percent.

In northwest New Mexico, elevated levels of helium in natural gases occur not only in Paleozoic reservoirs on the Four Corners Platform but also in Paleozoic reservoirs in the deeper parts of the San Juan Basin located east of the Four Corners Platform. The regional set of orthogonal faults that offset Precambrian basement throughout the deeper parts of the San Juan Basin may have acted as migration pathways that transmitted helium from its basement source into overlying Paleozoic reservoirs.

Helium has not been extracted from produced gases in the New Mexico part of the Permian Basin where the concentration of helium in most reservoir gases is significantly less than 0.1 percent. However, gases with helium contents ranging from 0.3 to almost 1.0 percent occur in Pennsylvanian and Permian reservoirs along the northwest flank of the basin. The helium originated by radiogenic decay of Precambrian granitic rocks and migrated vertically into Pennsylvanian and Permian reservoirs through regional, high-angle, strike-slip faults. Known accumulations of helium-rich gases are located near these faults. In this area, lower and middle Paleozoic strata are only a few hundred feet thick, resulting in short vertical migration distances between the Precambrian source and helium-bearing reservoirs.

Other basins and areas in New Mexico are characterized by helium-rich gases and are of significant exploratory interest. These areas include the Chupadera Mesa region of eastern Socorro and western Lincoln counties in the central part of the state, the Tucumcari Basin in the east-central part of the state, and a wide region across Catron and southern Cibola counties in the west-central part of the state. Elevated levels of helium are found in Pennsylvanian and Permian gases in these areas; gases with 3.5 percent helium have recently been discovered in Permian reservoirs on Chupadera Mesa. This is the highest known concentration of helium in any New Mexico gases outside of the Four Corners Platform.

Conclusions

- Almost 1 BCF of helium has been produced from 8 oil and gas pools on the Four Corners Platform in San Juan County since 1943.
- In the San Juan Basin, productive He accumulations are located over orthogonal systems of high-angle faults that acted as migration pathways for He generated in granitic Precambrian rocks.
- Although no He has been produced from deep San Juan Basin, potential in Devonian, Mississippian and Pennsylvanian reservoirs is indicated by elevated He concentrations.
- In the Permian Basin, gases with He contents from 0.35% to almost 1% have been produced from reservoirs along the northwest flank of the basin. NE-SW-trending faults define exploration fairways.
- Frontier exploration areas characterized by He-rich gases in Pennsylvanian and Permian reservoirs include the Tucumcari Basin, the Chupadera Mesa area, and a wide region across Catron and Cibola counties. These areas are of exploratory interest and have attracted helium explorationists and drilling.
- New sources of helium must be discovered, developed, and produced in order to maintain access to advanced technologies that enhance our lives. The market provides incentives for exploration.
- At sufficient concentrations and at sufficient helium prices, methane becomes the byproduct of helium production.

Helium in New Mexico:

Origins, Uses, Economics, Geologic Distribution and Exploration Possibilities

Ron Broadhead

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A Division of New Mexico Tech

Presentation made to Permian Basin Section SEPM
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Acknowledgments

- ***New Mexico State Land Office for providing partial funding***
- ***Messrs. Ben Donegan, the late Wheeler Sears, Bo Sears, Scott Sears, Phelps White (geological and isotopic data on Chupadera Mesa wells)***

Organization of talk

- **What is He? - properties, origins**
- **Two simple exploration models**
- **Economics and uses of He**
- **Where do we get it now?**
- **Distribution in New Mexico**

1. *Where has it been produced?*
2. *Relationships to other gases in the reservoir*
3. *Distribution in San Juan Basin*
4. *Distribution in Permian Basin*
5. *Other basins – likely sources of future supplies*

- **Conclusions**

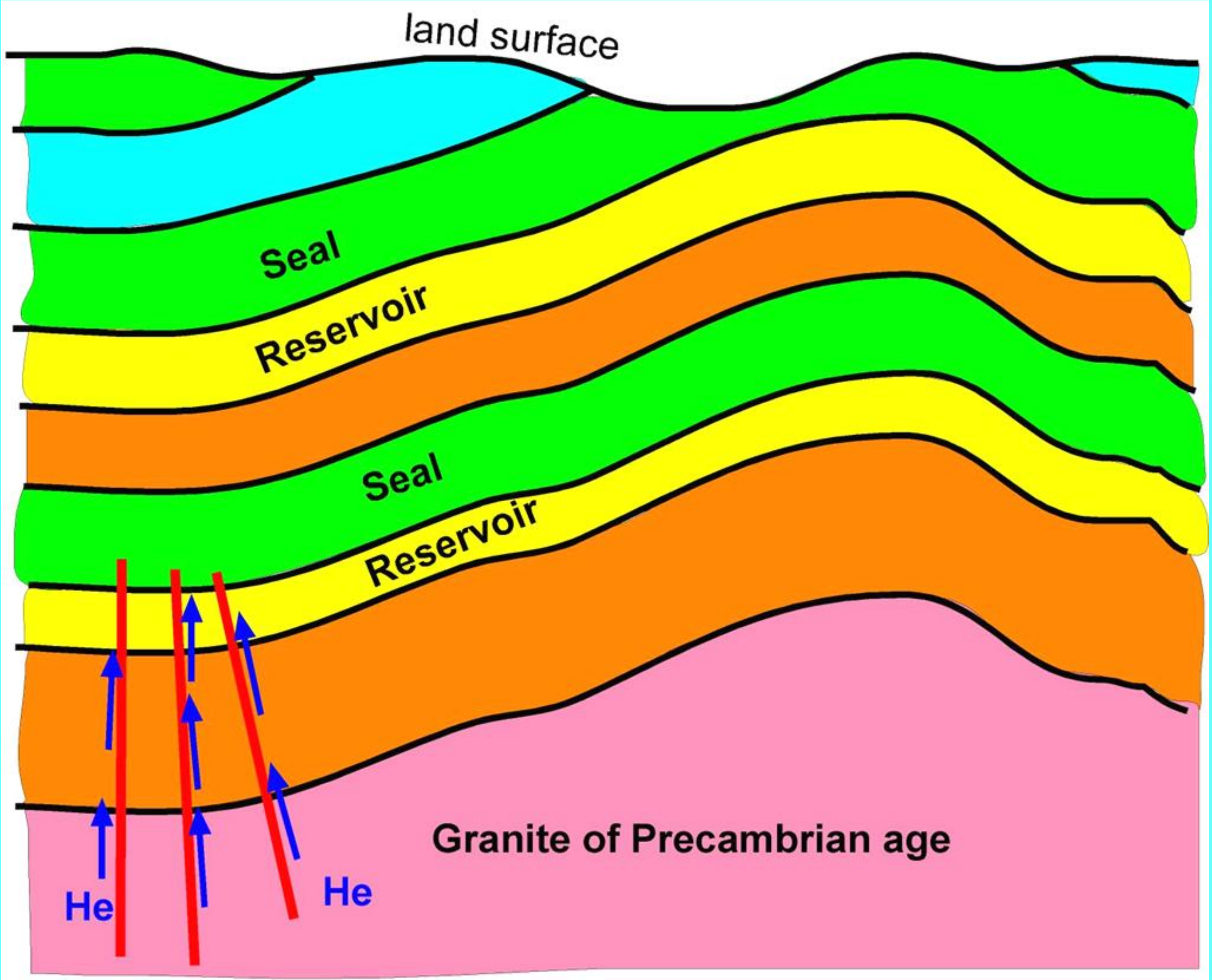
What is helium?

- **Simple element with 2 protons and 1-2 neutrons; occurs as either ^{3}He or ^{4}He – a Noble gas**
- **2nd most common element (after H) in universe**
- **^{4}He is far more abundant than ^{3}He in earth's crust and atmosphere; ^{3}He is less than 0.001% of ^{4}He in atmosphere**
- **Ubiquitous on earth in low concentrations (0.0005% of earth's atmosphere)**
- **Boiling point –269ºC (*lowest of any substance*)**
- **Density = 0.179 g/l at STP (*lighter than air*)**
- **Chemically inert and nonreactive – does not combine with other atoms except in conditions not obtained for prolonged periods of time naturally on earth – occurs as an He molecule consisting of a single helium atom**
- **Gas with a very high thermal conductivity**

What is the origin of earth's helium?

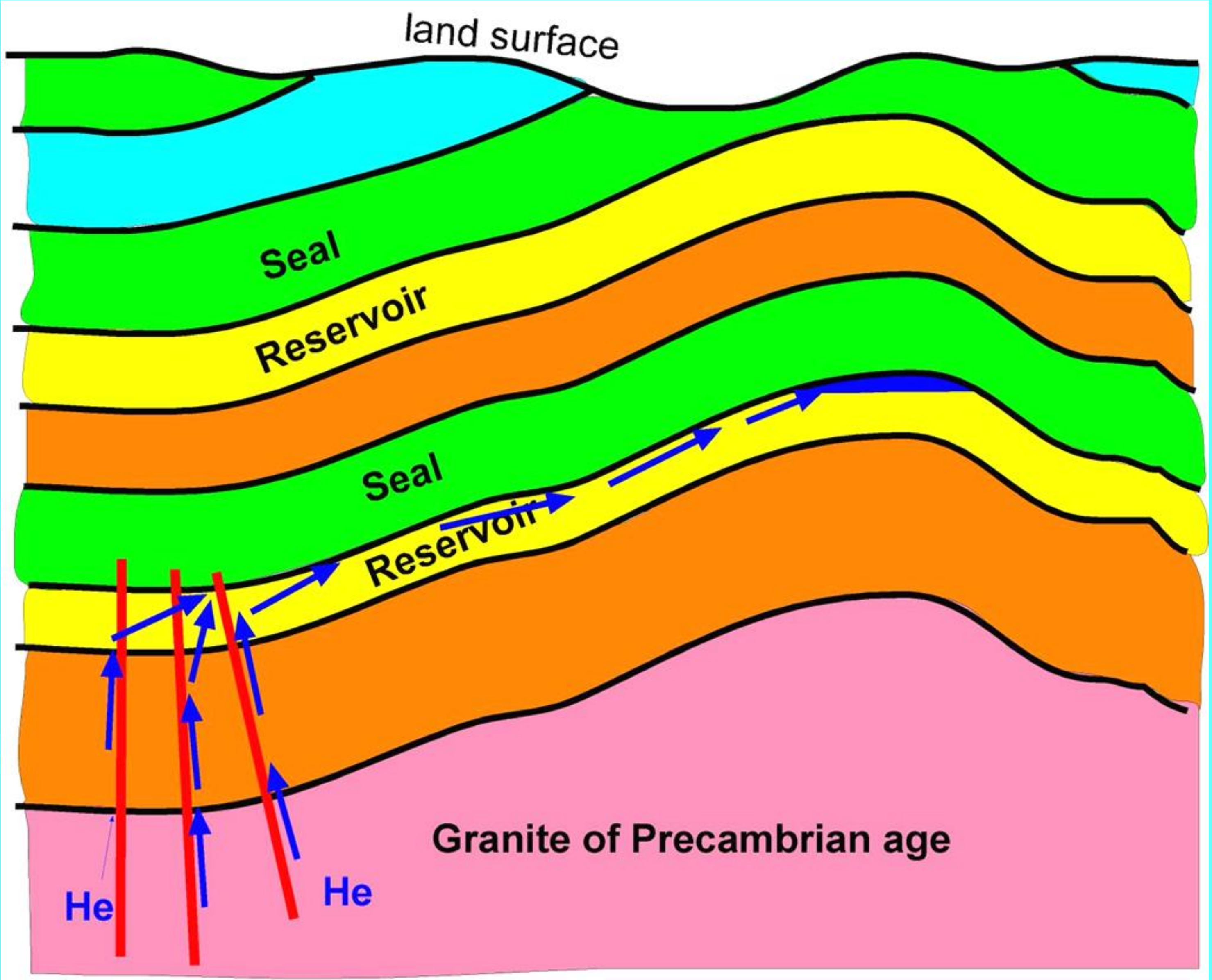
- **^{4}He originates from radiogenic decay of uranium and thorium in crustal rocks (mostly granites)**
- **^{3}He is mostly primordial and is derived from the mantle**
- **A very minor amount of ^{3}He may be derived from neutron capture by ^{3}H in crustal reservoirs; clays rich in ^{6}Li –evaporitic settings**
- **Some helium in atmosphere may be derived from cosmogenic sources (outer space – *<u>we are not alone!</u>*)**

How does He get out of the granite and into crustal reservoirs?



- **For ^{4}He derived from granite, the granite is impermeable so the He migrates out of the granite along fault/fracture faces or from the upper surface of basement**
- **For juvenile ^{3}He that comes from the mantle, the He can migrate upward into the crust along extensional faults of Tertiary and Quaternary age**

Helium exploration model #1



What is helium used for?

- Cryogenics (primary use)
- Inert atmosphere for growing Si and Ge crystals – COMPUTER CHIPS (primary use)
- Manufacturing fiber optics (primary use)
- Manufacturing LED screens (primary use)
- Pressurizing and purging (primary use)
- Cooling medium for nuclear reactors
- Welding
- Leak detection
- Synthetic breathing mixtures
- Lifting (blimps)
- He^3 is used in radiation sensors & possible future energy source (fusion)
- *Makes you sound funny*

The major cryogenic use is in magnetic resonance imaging (MRI) instruments (cools the electromagnet)

Helium economics

- **He sales in U.S. increased from 4 BCF in 1998 to 4.9 BCF in 2011, an increase of 23%**
- **It's a byproduct of natural gas production - Domestic production has fallen from 4 BCF in 1998 to 2.9 BCF in 2011 as production from established gas fields in KS, TX, OK has declined**
- ***Shortfall in production filled by withdrawing He from underground storage at 2.0 BCF/yr***
- ***At present rates of withdrawal, storage will be depleted by 2019***
- **U.S. does not import helium but exports it, providing 85% of world's helium, thereby assuring a supply for our domestic manufacturers and helping our balance of trade**
- **U.S exports about the volume we produce, leaving storage withdrawal to satisfy domestic consumption**

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Helium economics (continued)

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- Prices have risen as production has fallen below demand.
- Private industry price for crude He in 2000 was \$42 to \$50 per MCF (thousand ft^3)
- Current federal price is about \$80 per MCF
- Private supplier price may exceed \$140 per MCF
- He^3 is now selling for \$14,000/ft3 (more on He^3 later)

Distribution of He in natural gases in U.S.

He content of gas (mole %)	Percent of U.S. gas reservoirs
< 0.1%	55.6%
0.1 – 0.3%	26.8%
> 0.3%	17.6%

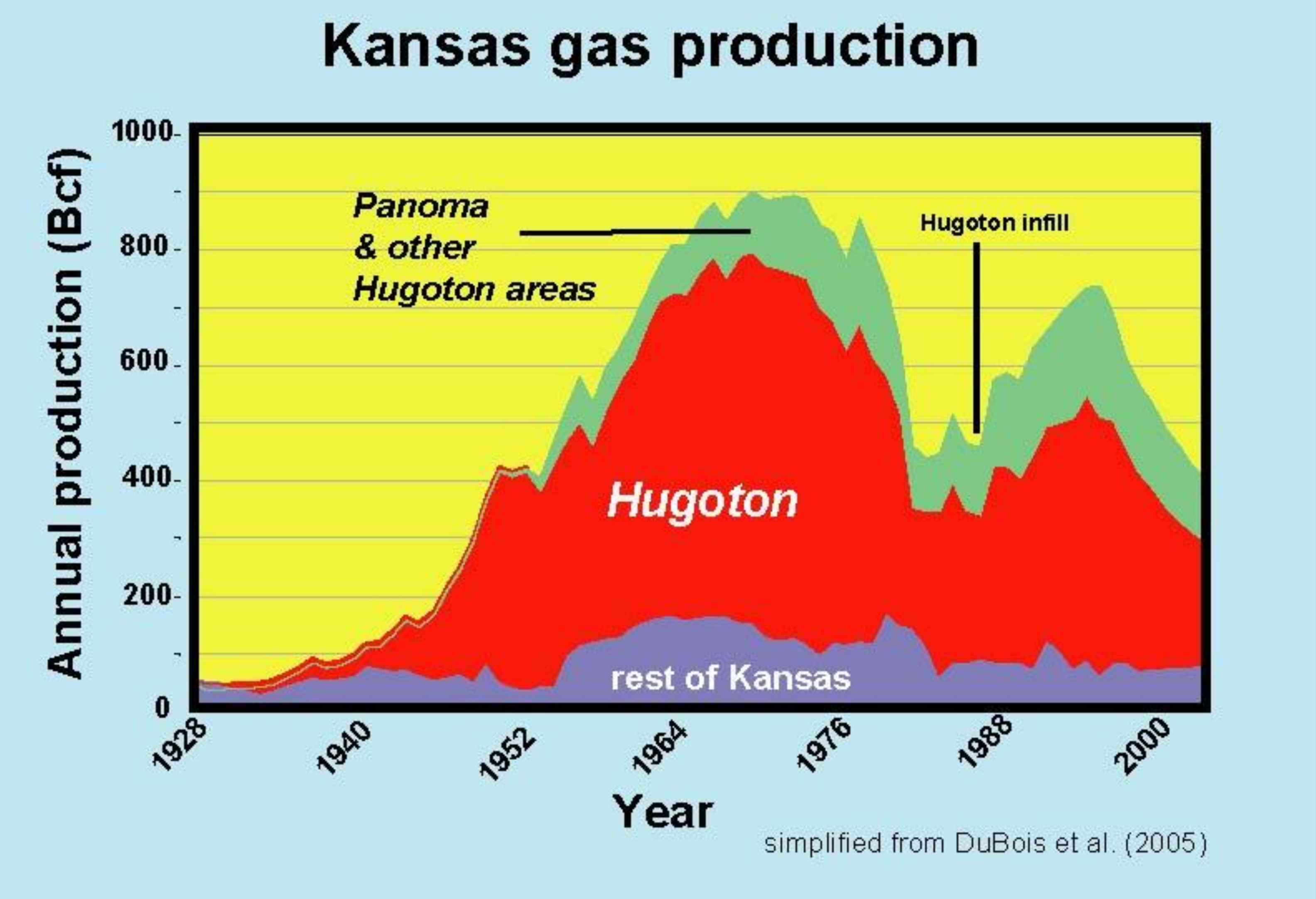
Tongish (1980, U.S. Bureau of Mines)

5 reservoirs contain 97% of identified He reserves in U.S. and are the main sources of He

Reservoir	*State*	*He content of gas (mole %)*
Hugoton	**KS, OK, TX**	**0.2-1.18%**
Panoma	**KS**	**0.4-0.6%**
Keyes	**OK**	**1.0-2.7%**
Panhandle West	**TX**	**0.15-2.1%**
Riley Ridge	**WY**	**0.5-1.3%**

Pacheco (2002); Parham and Campbell (1993); U.S. Bur Mines/BLM data

Main sources are produced for hydrocarbon gases. As reservoirs deplete, volume of He extracted from gas decreases (e.g., Hugoton field in Kansas); *hence* a shortage develops.



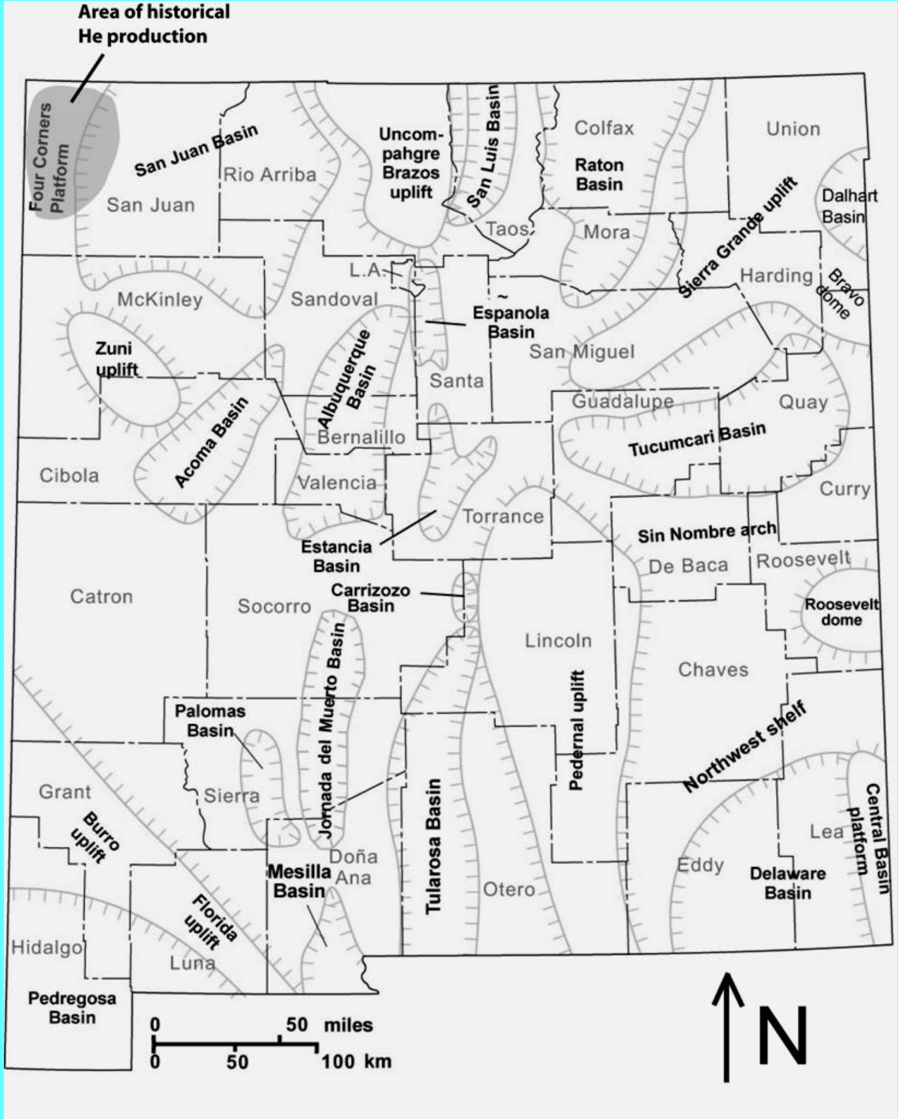
No helium?

Then what happens to the manufacture of computer chips, LCD TV's, fiber optic cables, the internet, etc.? MRI's?

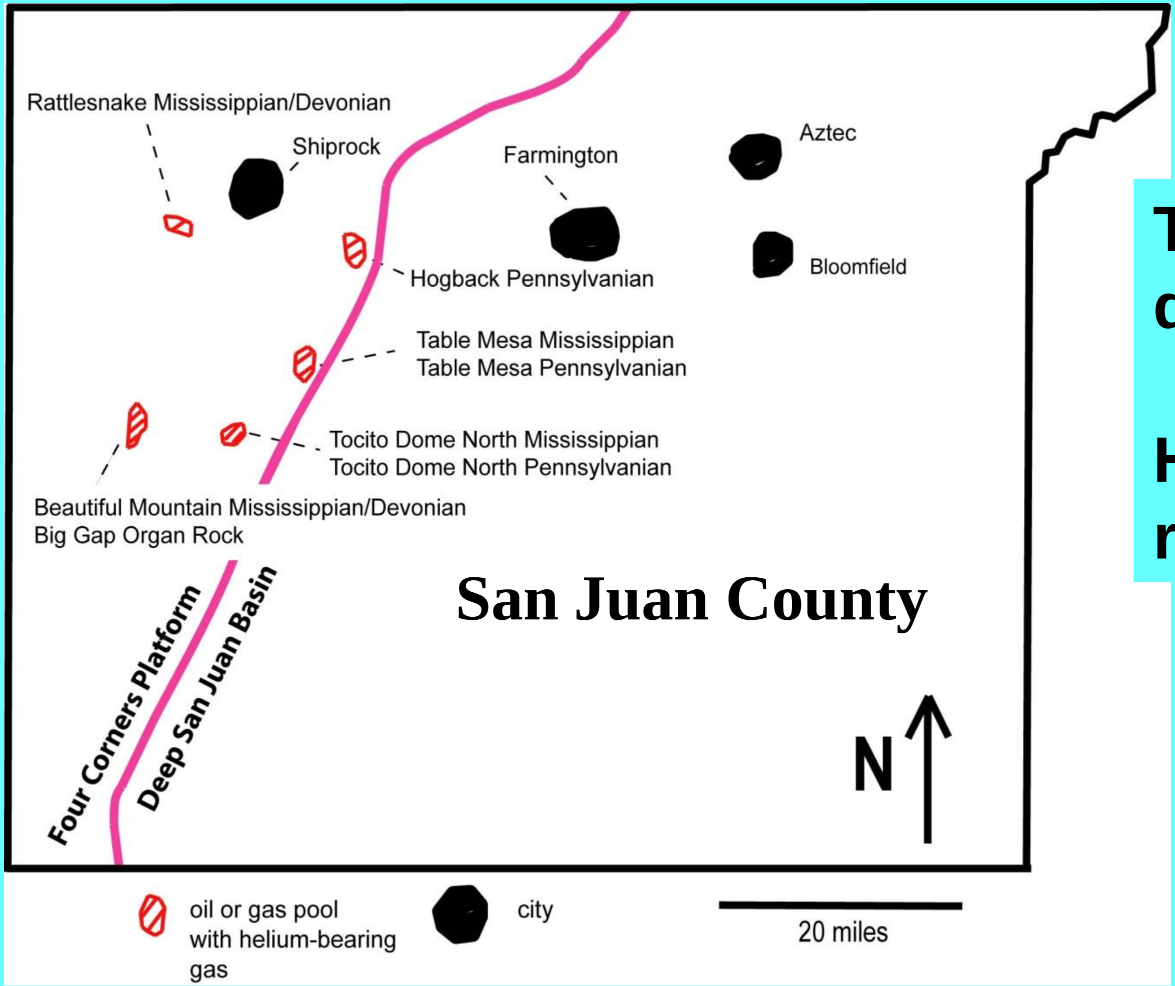
Helium Geology in New Mexico

Historical He production in New Mexico

All Helium produced in NM has come from reservoirs on Four Corners Platform. First production in 1943. Used as a lifting gas for the military in WWII.



Productive strata are Devonian through Permian in age



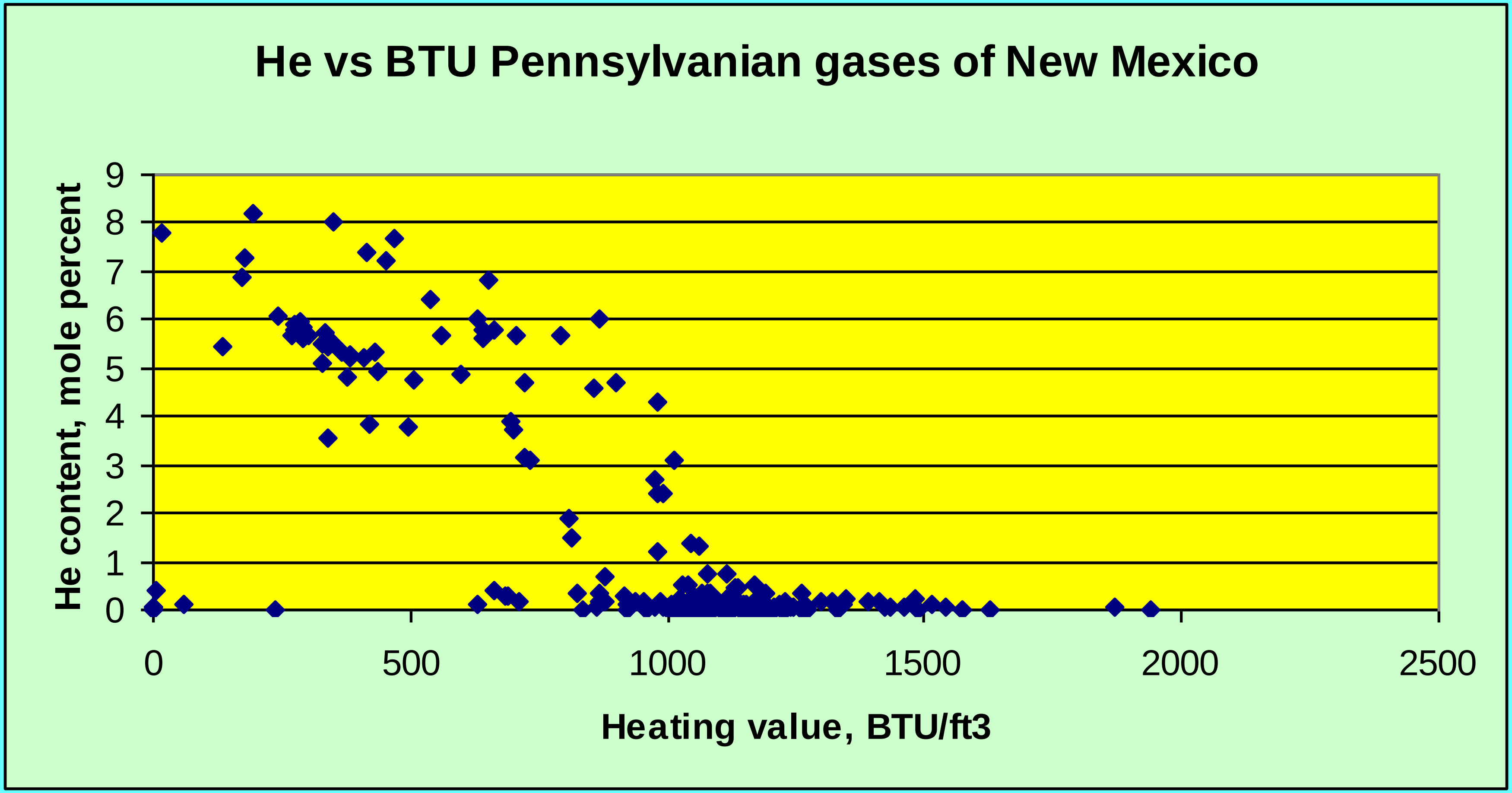
Total production to date is almost 1 BCF

He contents of gases range from 3.2 to 7.5%

from Broadhead and Gillard (2004)

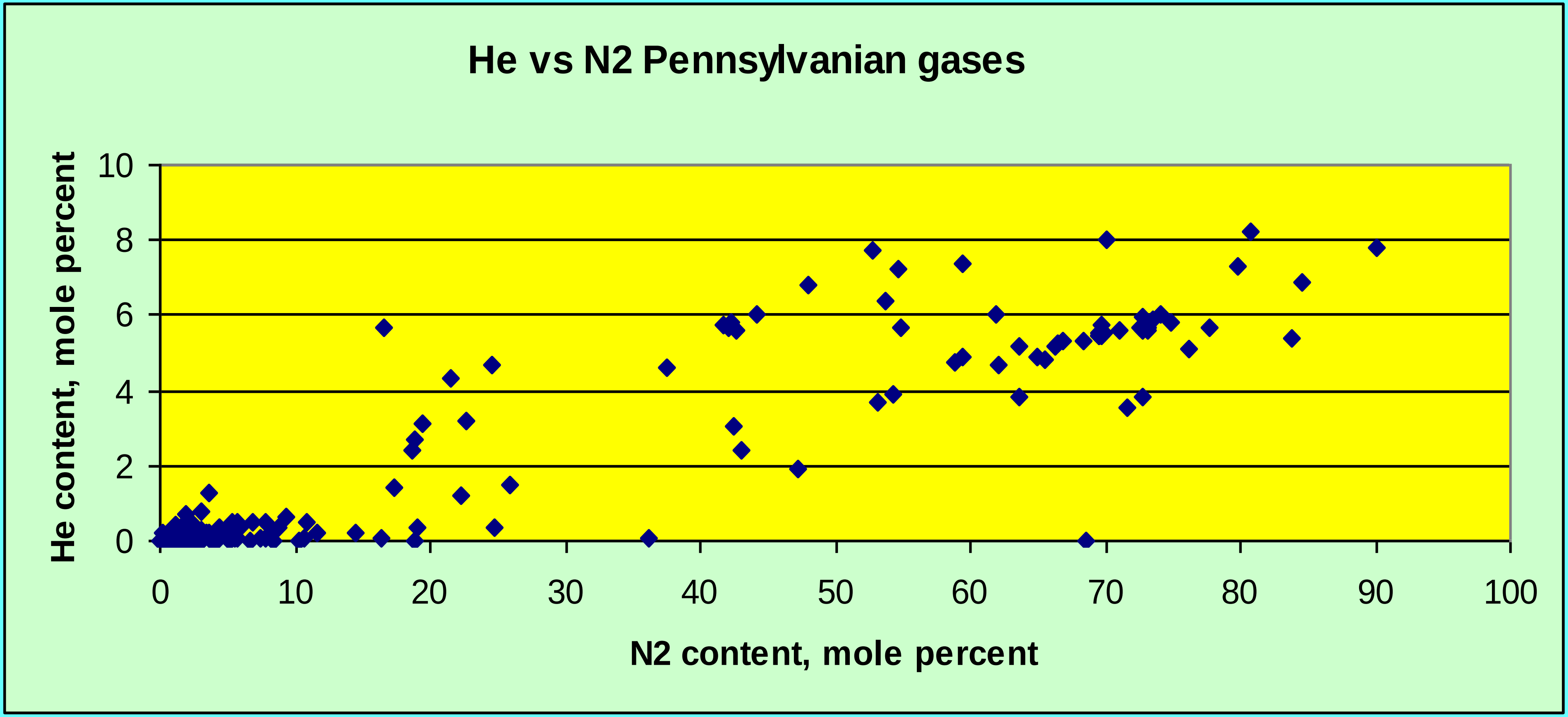
Only Big Gap & Beautiful Mountain are currently productive

Relationships of He to other gases in the reservoir



from Broadhead and Gillard (2004)

Pennsylvanian gases of New Mexico



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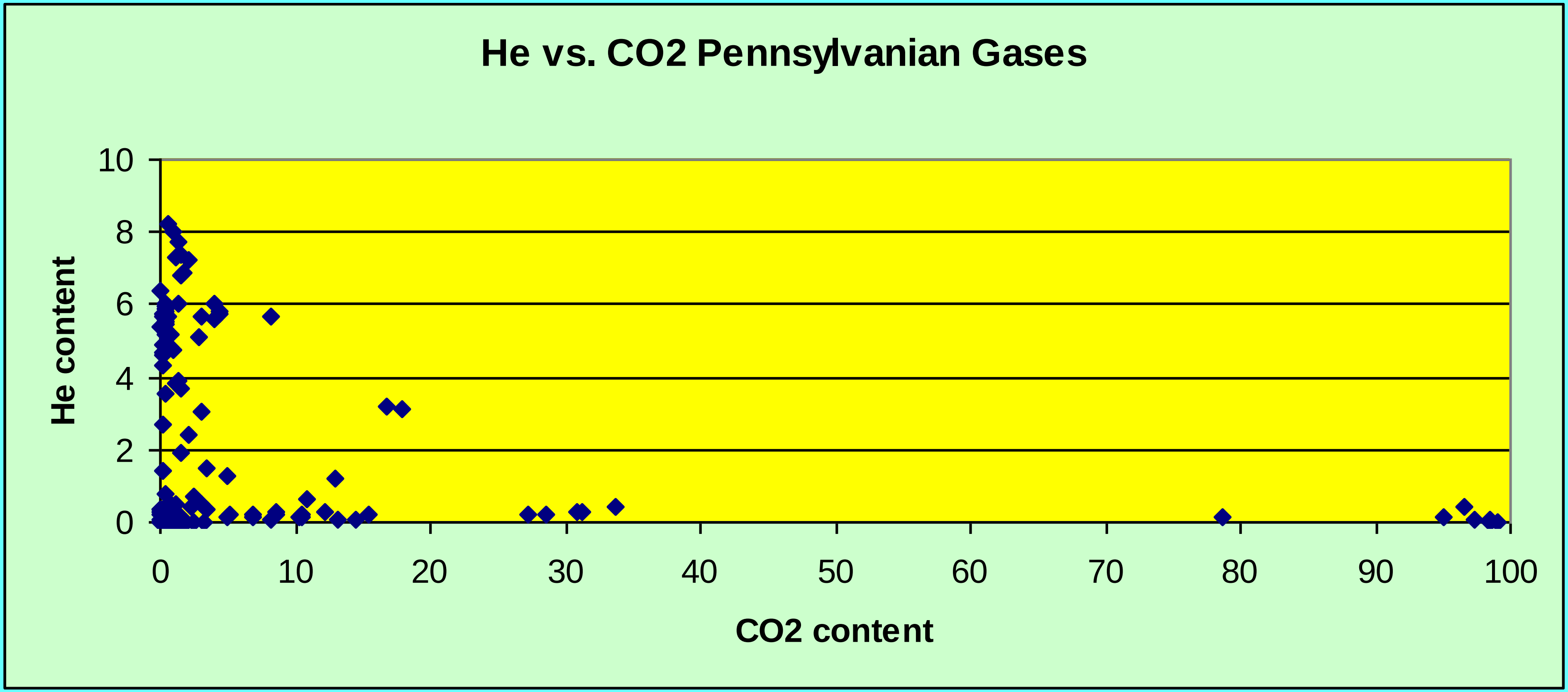
Pennsylvanian gases of New Mexico



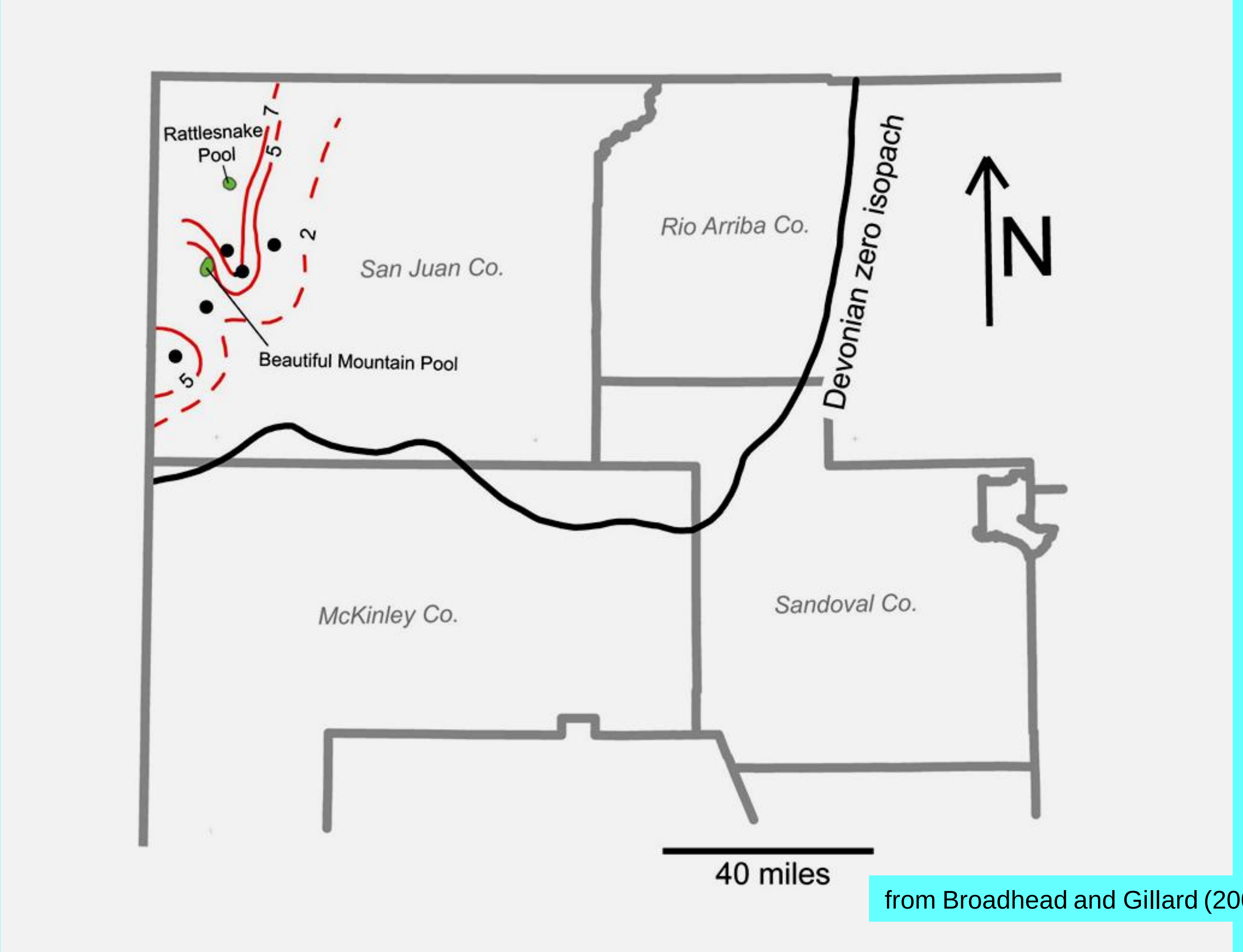
from Broadhead and Gillard (2004)

He in San Juan Basin Northwestern New Mexico

Geologic system	He content of gases	He produced commercially (estimated)
Quaternary	no data	0
Tertiary	Tr-0.01%	0
Cretaceous	Tr-0.27%	0
Jurassic	no data	0
Triassic	8.92-9.1%	0
Permian	0.52-5.5%	179 MMCF
Pennsylvanian	0-8.2%	446 MMCF
Mississippian	0.1-7.5%	323 MMCF
Devonian	2.45-7.99%	
Silurian	Silurian strata not present	0
Ordovician	Ordovician strata not present	0
Cambrian	no data	0
Precambrian	0.11% (1 sample)	0

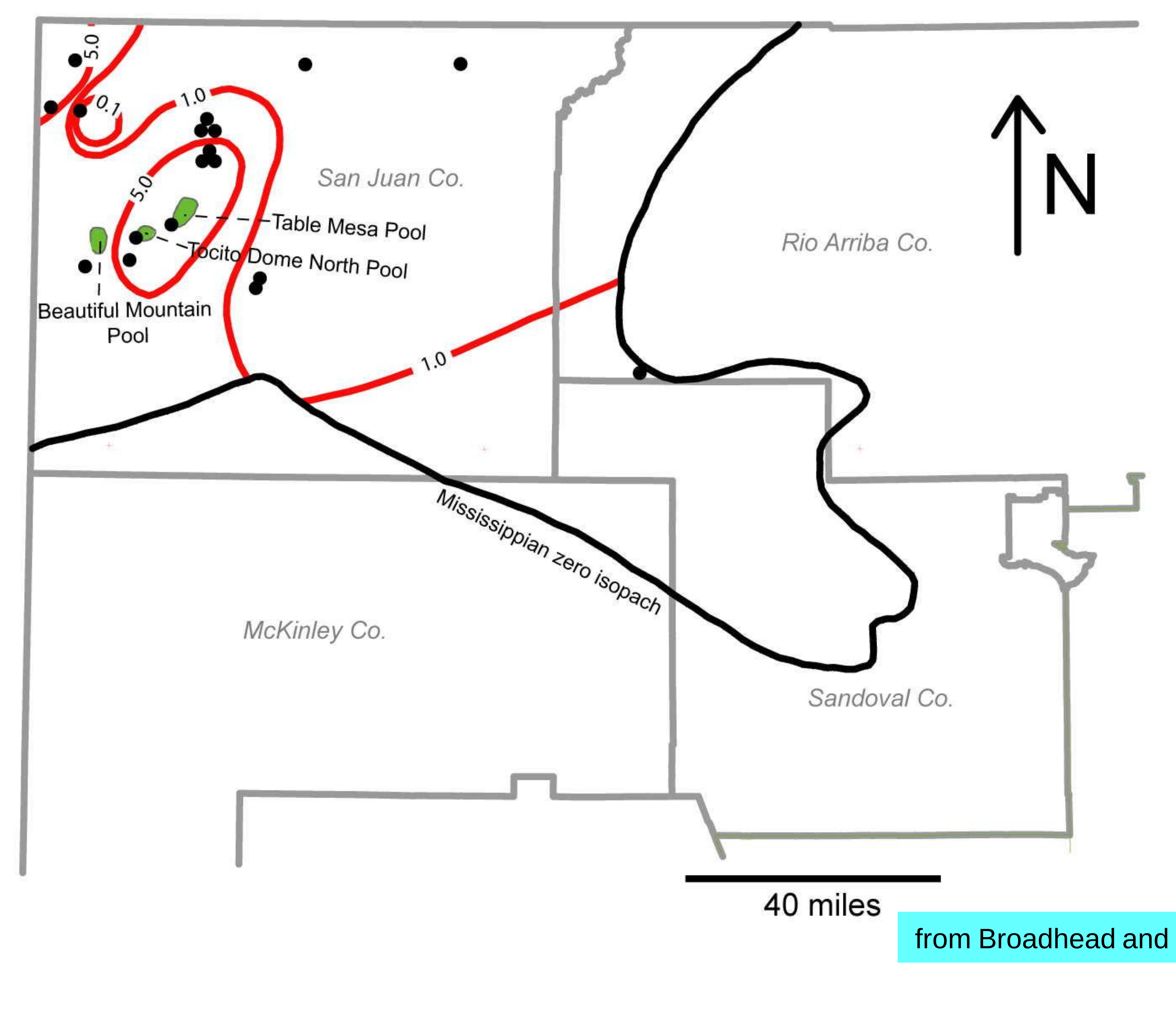
from Broadhead and Gillard (2004)

He in Devonian gases
San Juan Basin



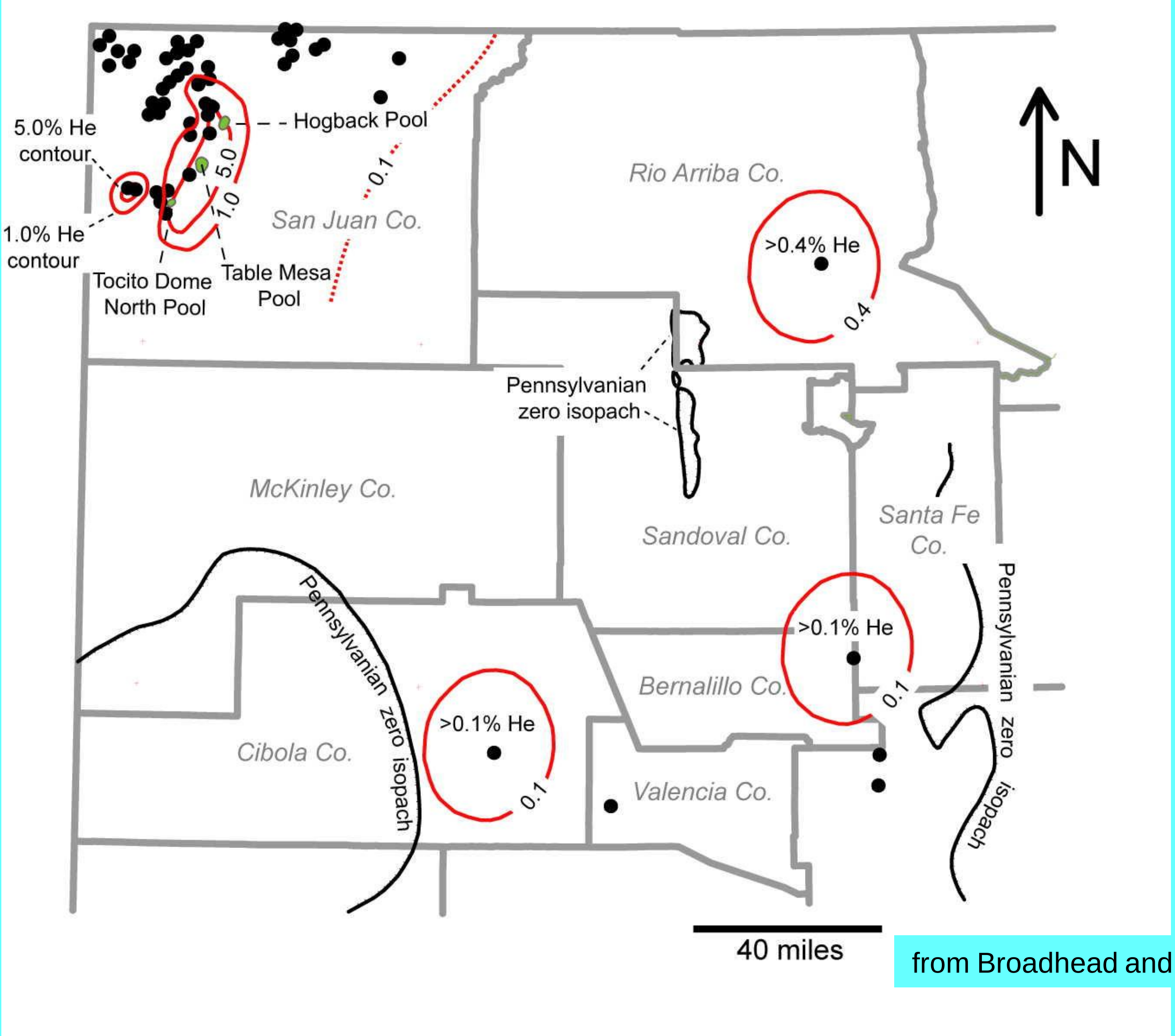
from Broadhead and Gillard (2004)

He in Mississippian gases
San Juan Basin



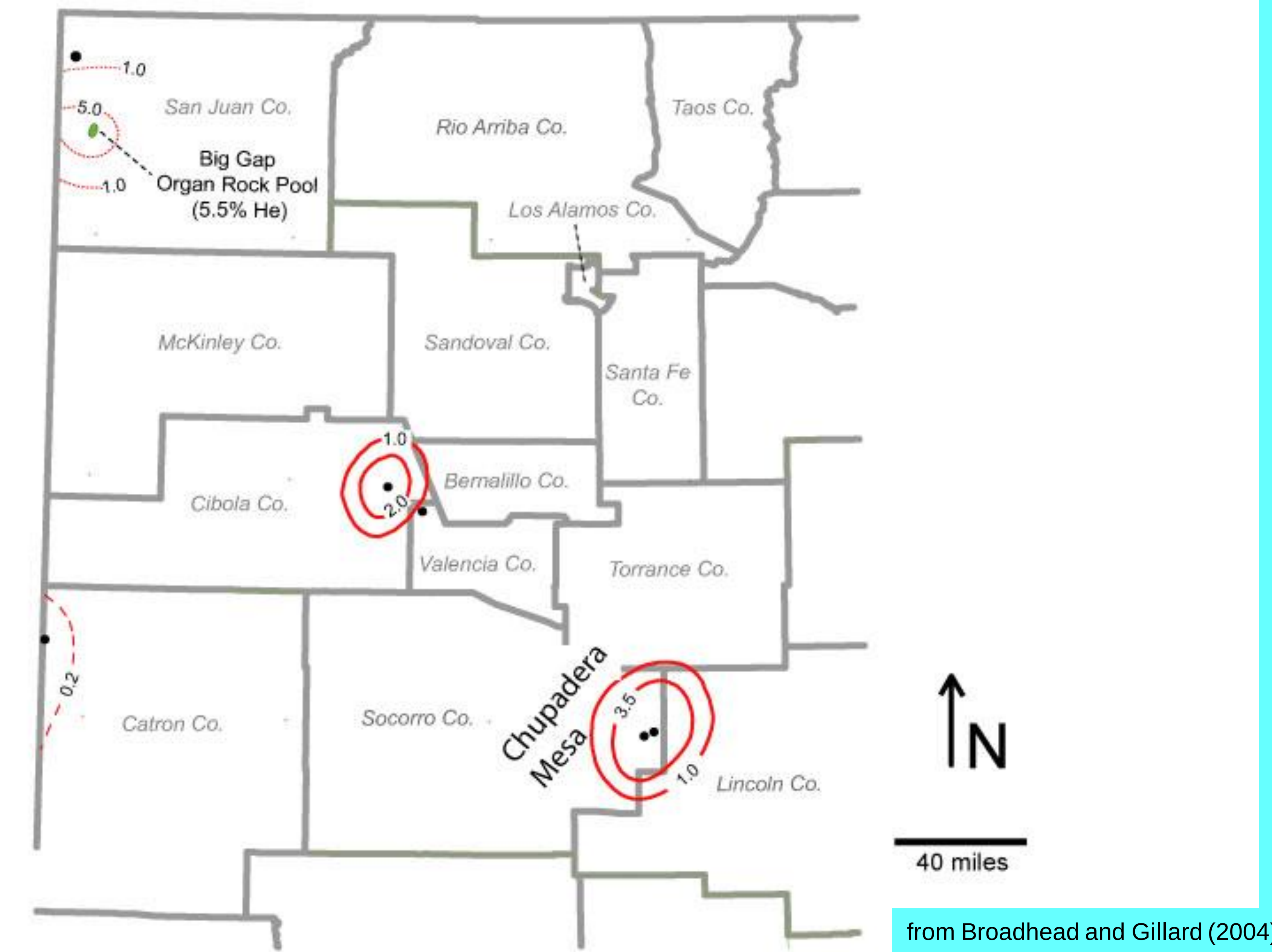
from Broadhead and Gillard (2004)

He in Pennsylvanian gases
San Juan Basin



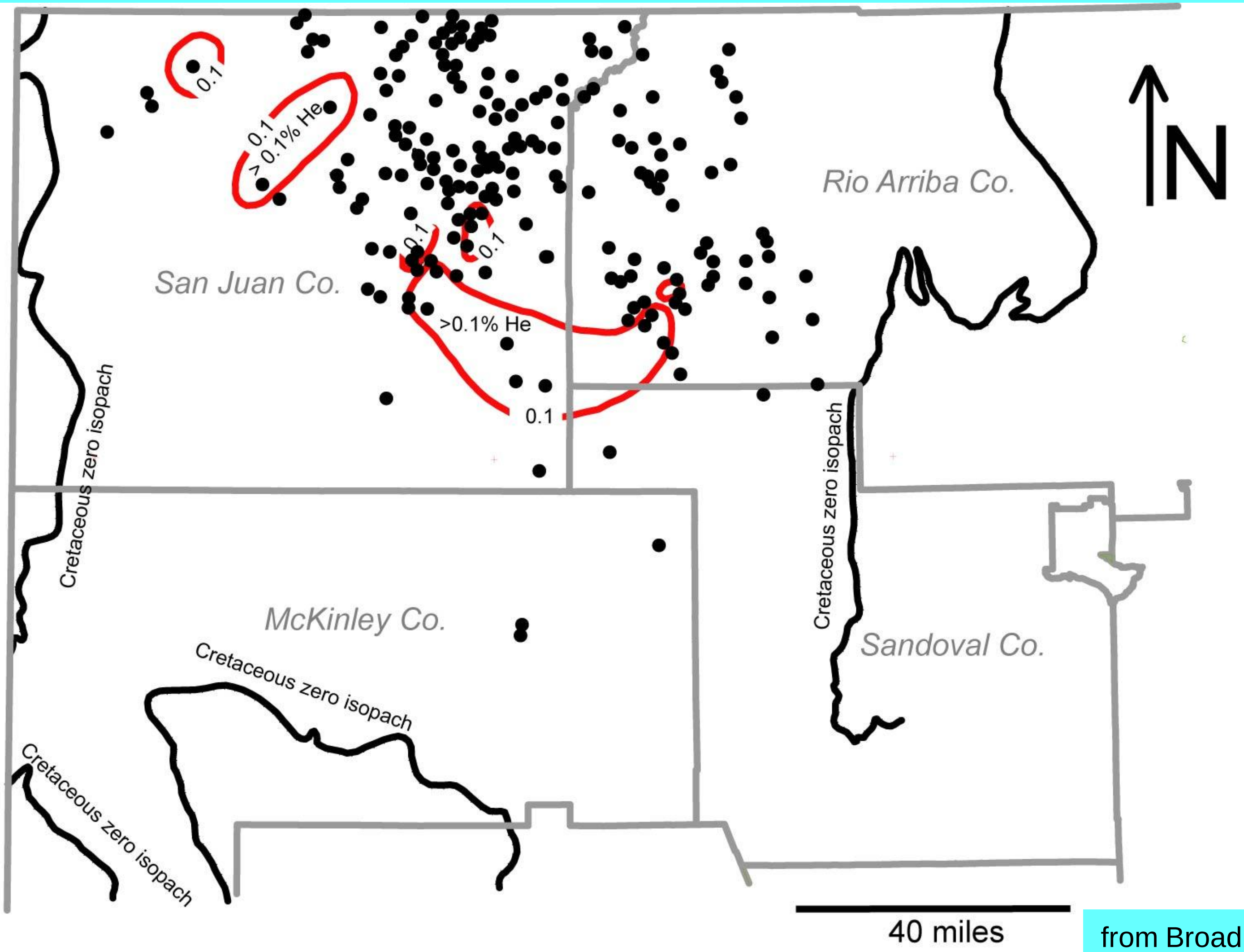
from Broadhead and Gillard (2004)

He in Permian gases
San Juan Basin



from Broadhead and Gillard (2004)

He in Cretaceous gases
San Juan Basin



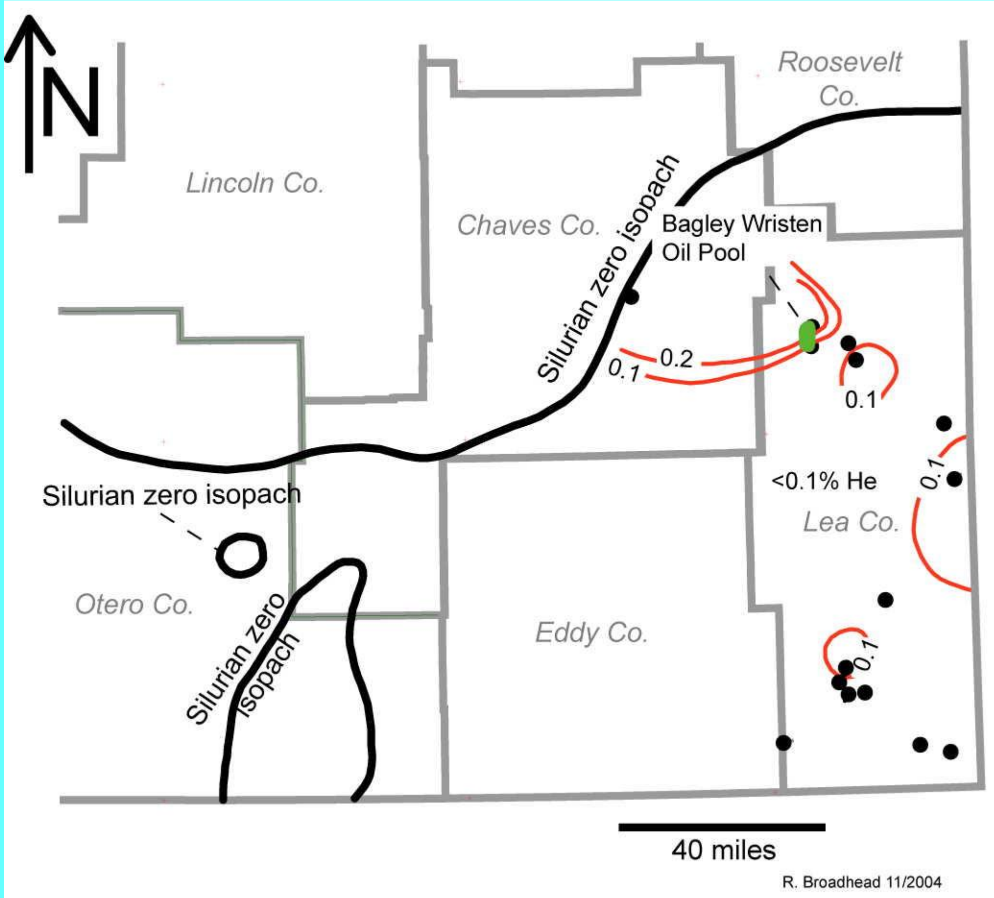
from Broadhead and Gillard (2004)

He in Permian Basin Southeastern New Mexico

Geologic system	He content of gases	He produced commercially (estimated)
Quaternary	no data	0
Tertiary	no data	0
Cretaceous	only erosional remnants of Cretaceous preserved	0
Jurassic	Jurassic strata not present	0
Triassic	no data	0
Permian	Tr-0.974%	0
Pennsylvanian	Tr-0.348%	0
Mississippian	0.03% (1 sample)	0
Devonian	no data	0
Silurian	Tr-0.29%	0
Ordovician	0.07-0.233%	0
Cambrian	no data	0
Precambrian	no data	0

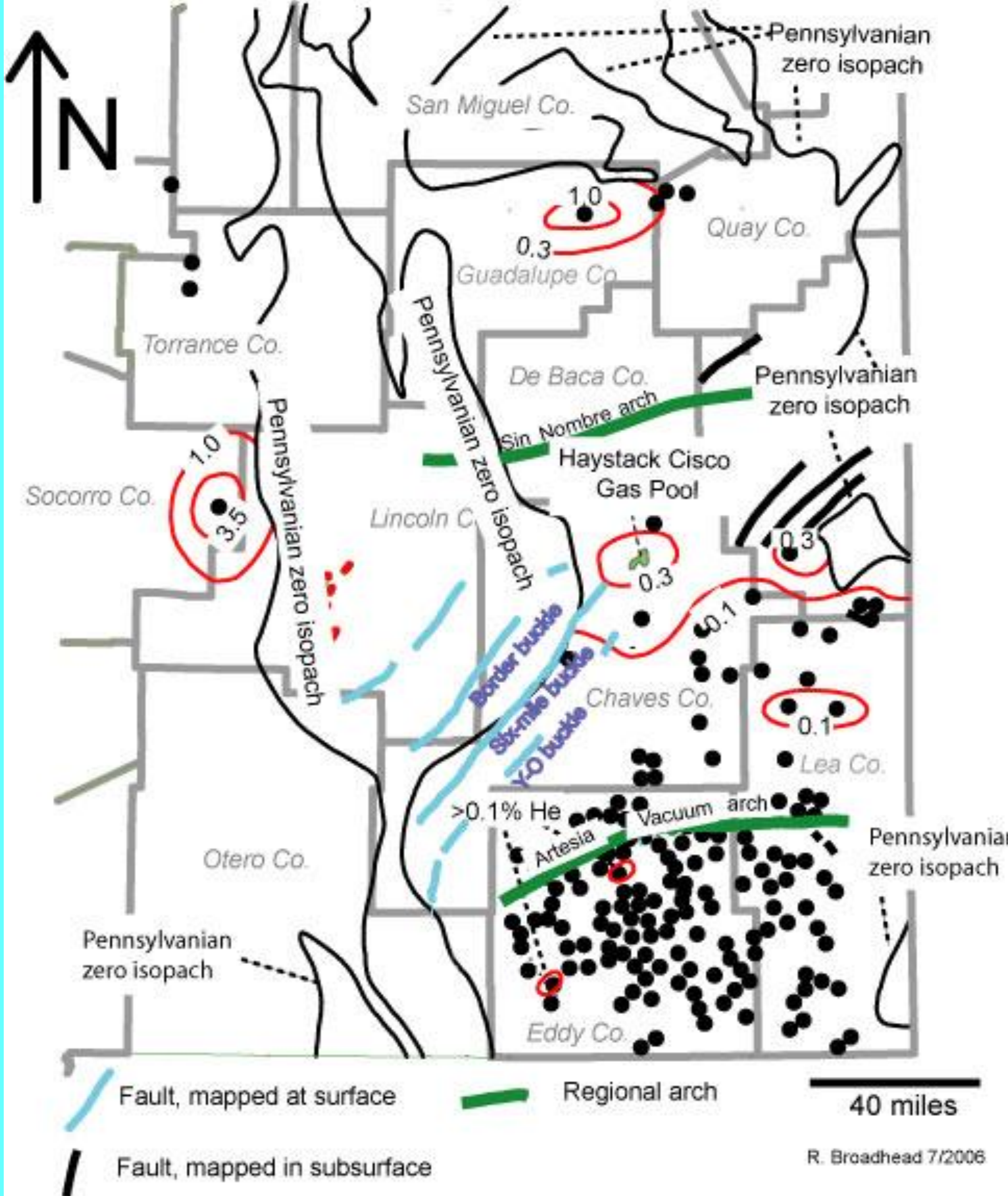
from Broadhead and Gillard (2004)

He in Silurian gases
Permian Basin



from Broadhead and Gillard (2004)

He in Pennsylvanian reservoirs Permian Basin



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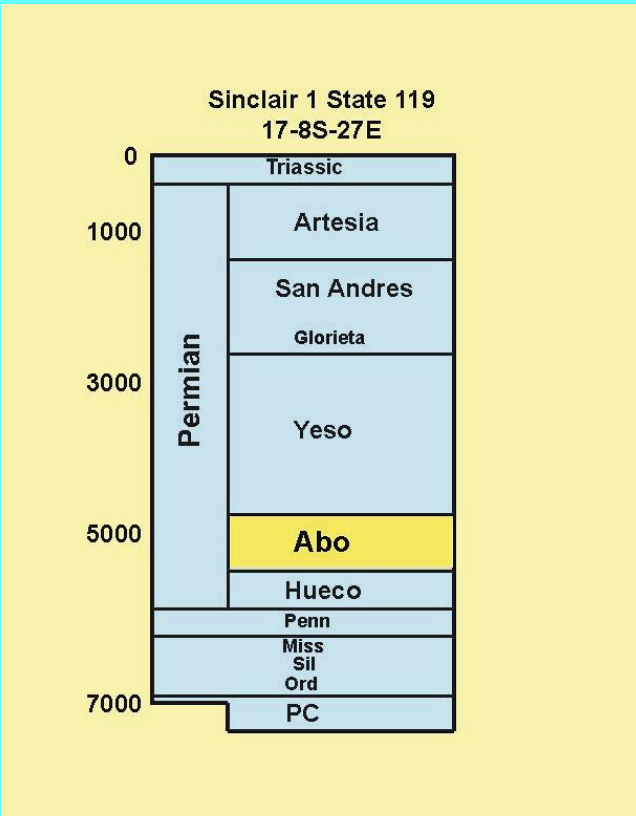
He in Permian reservoirs Permian Basin



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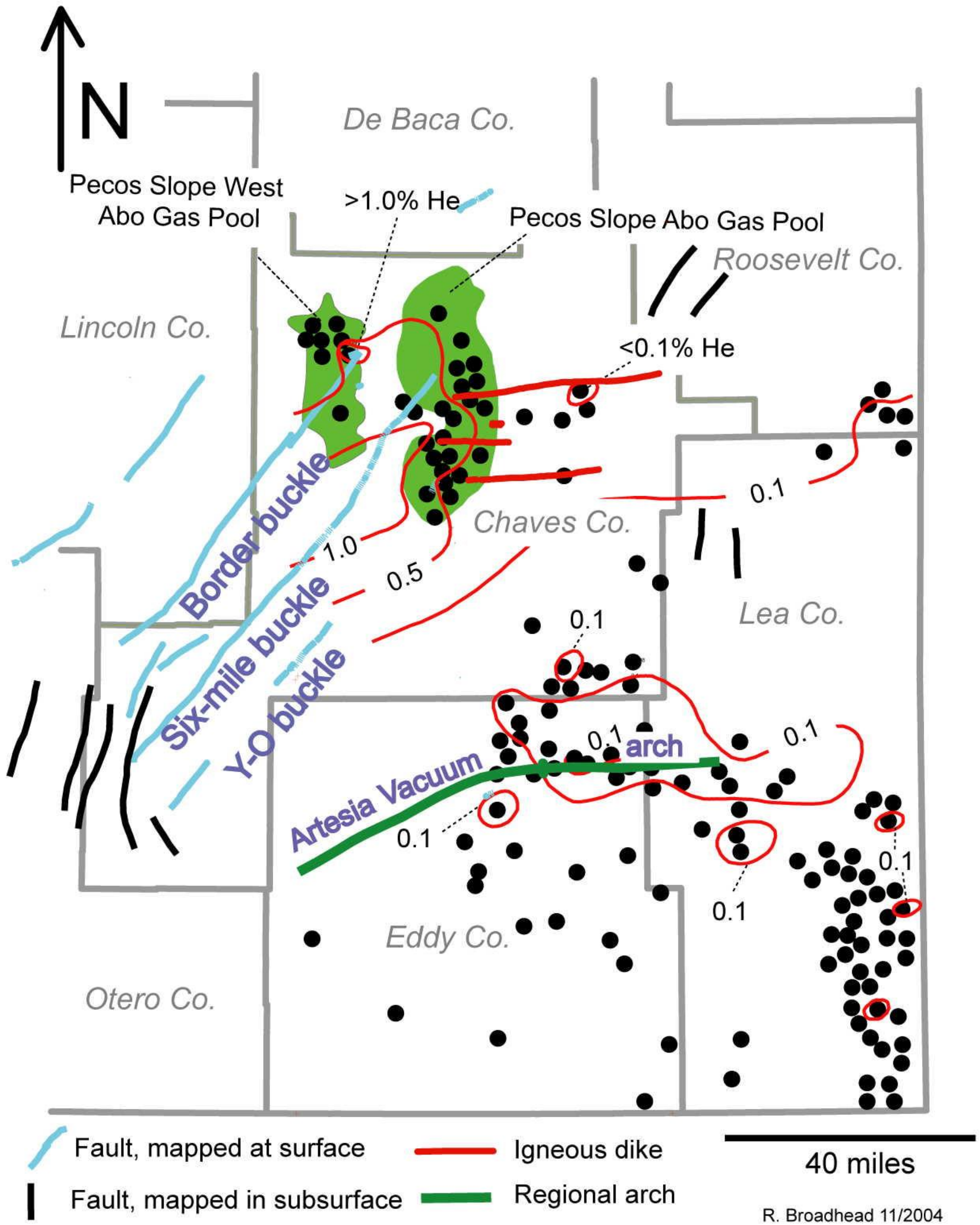
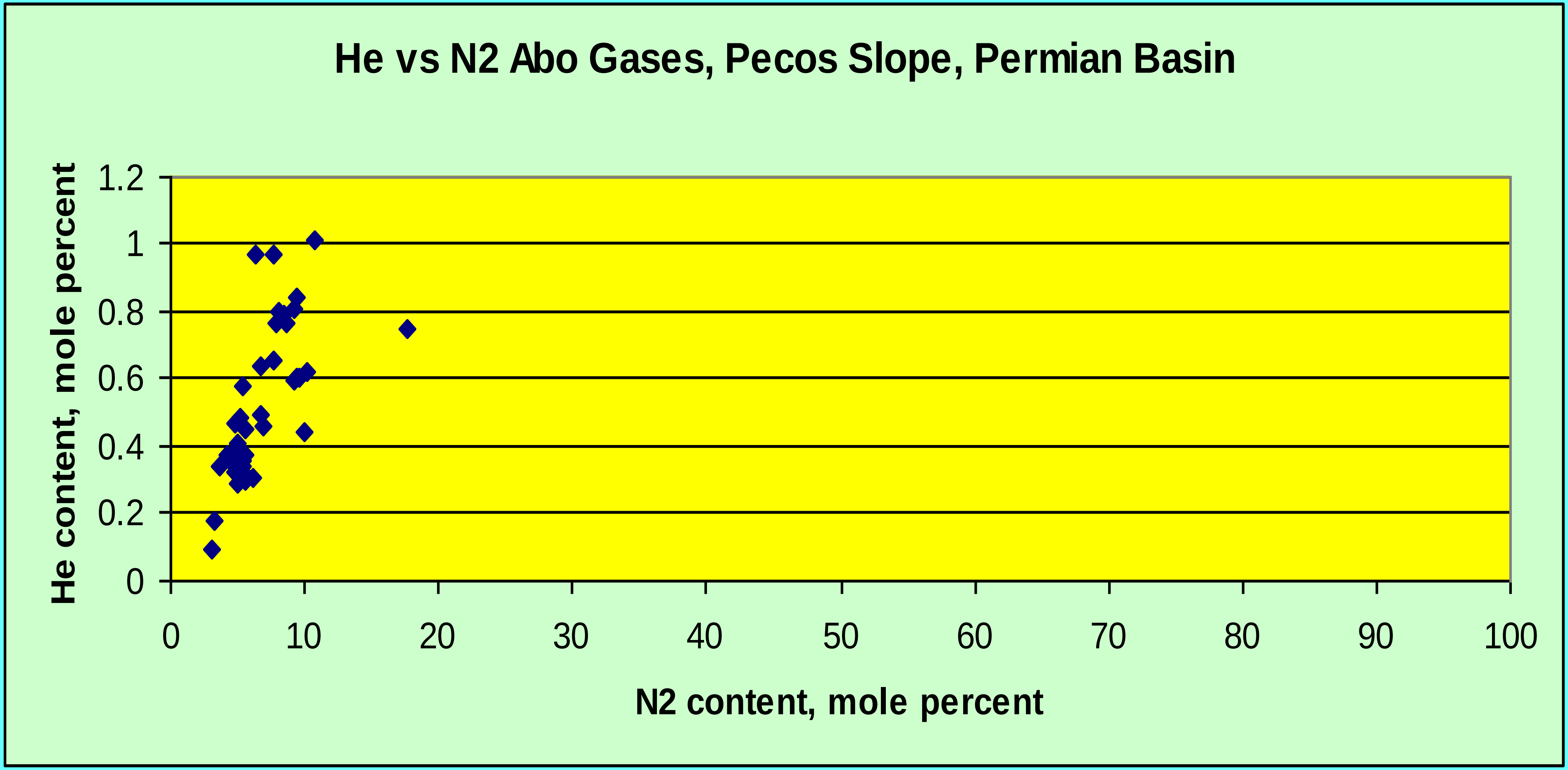
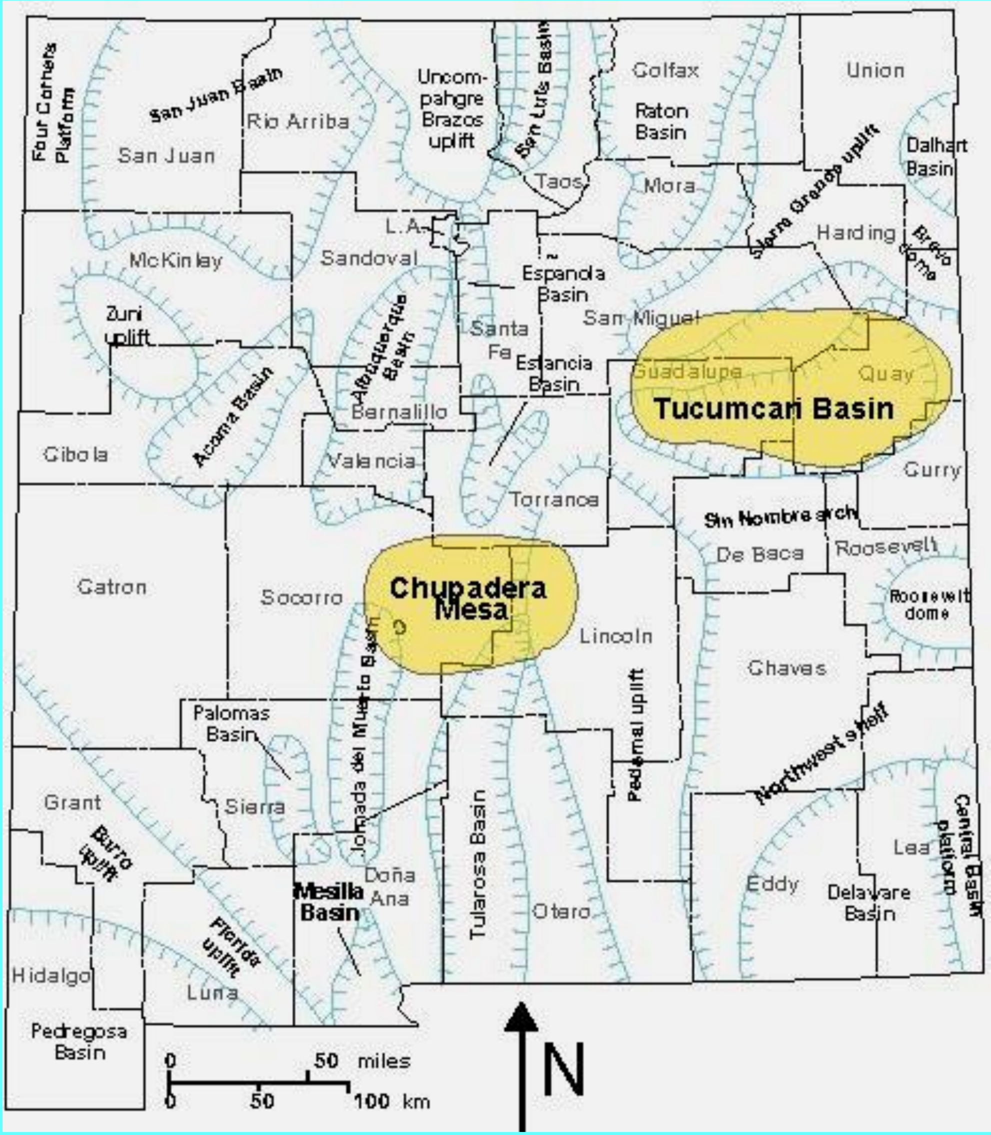


He and N_2 contents of Pecos Slope gases



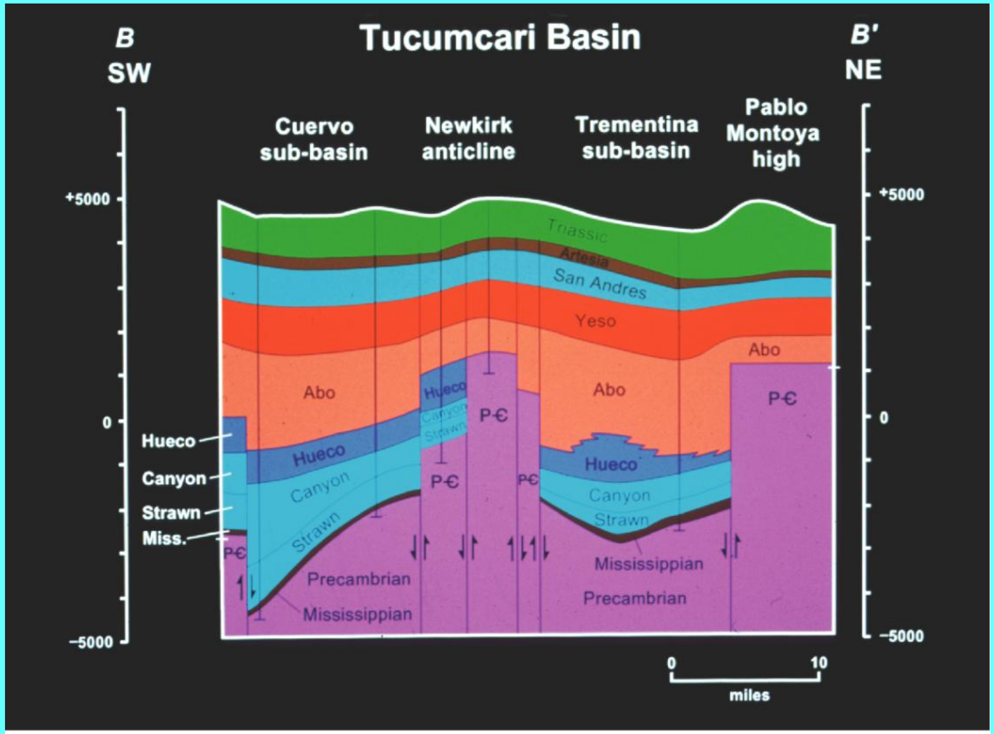
from Broadhead and Gillard (2004)

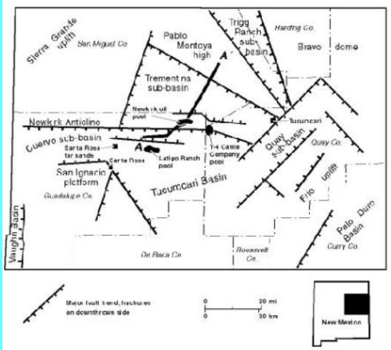
Helium in Frontier Areas



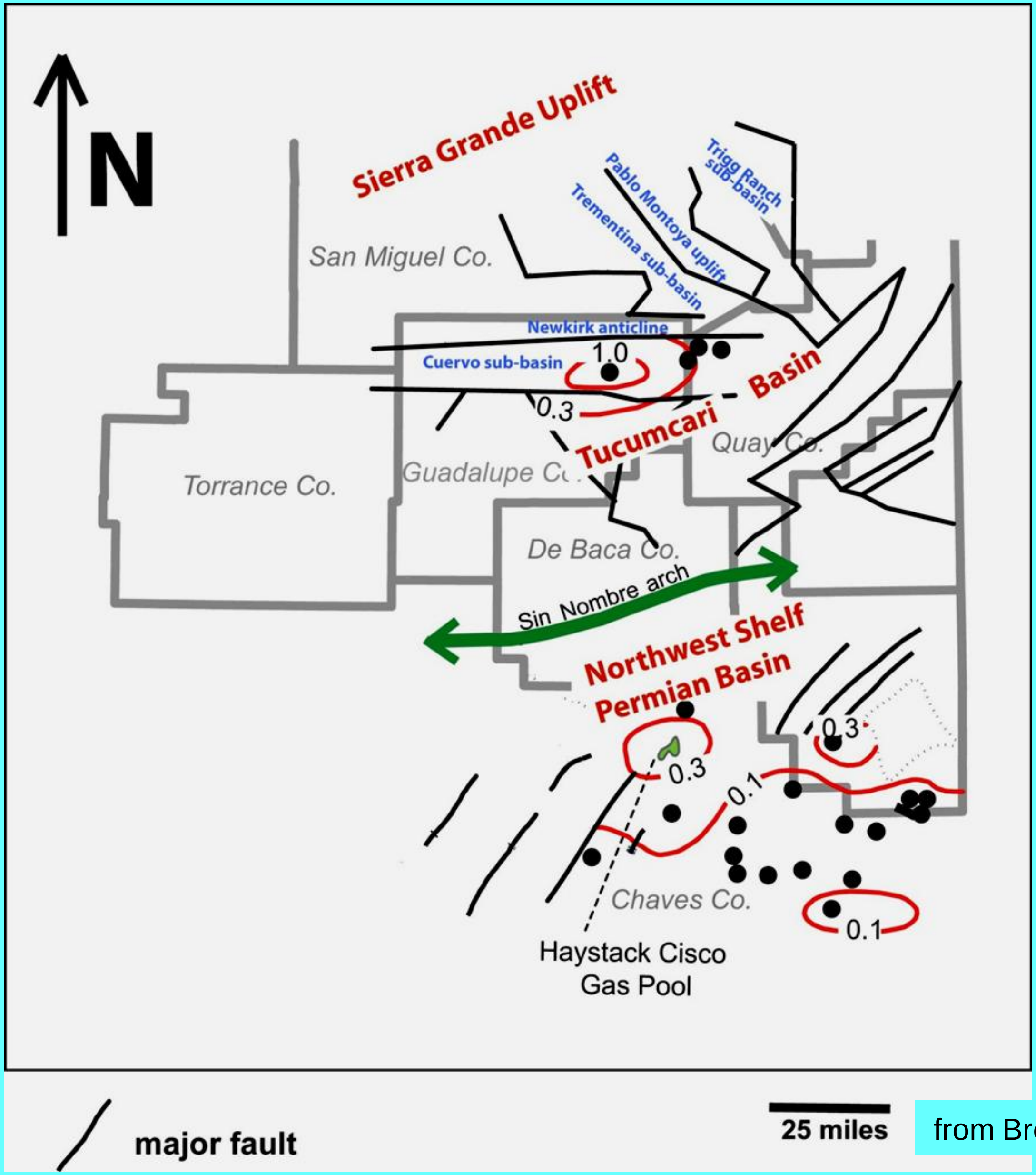
Tucumcari Basin

Pennsylvanian sandstone reservoirs



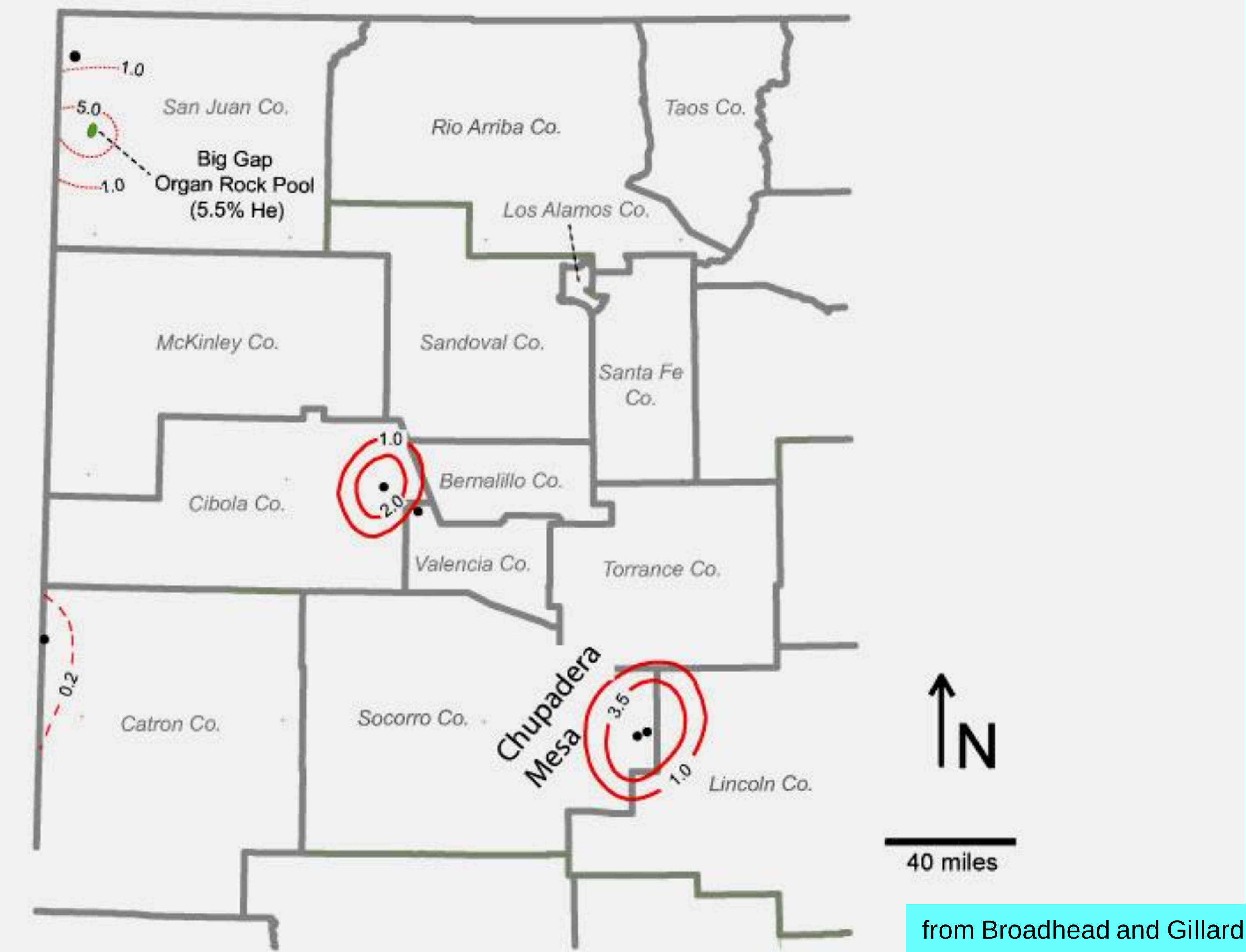


Tucumcari Basin



from Broadhead and Gillard (2004)

Central New Mexico
Permian reservoirs



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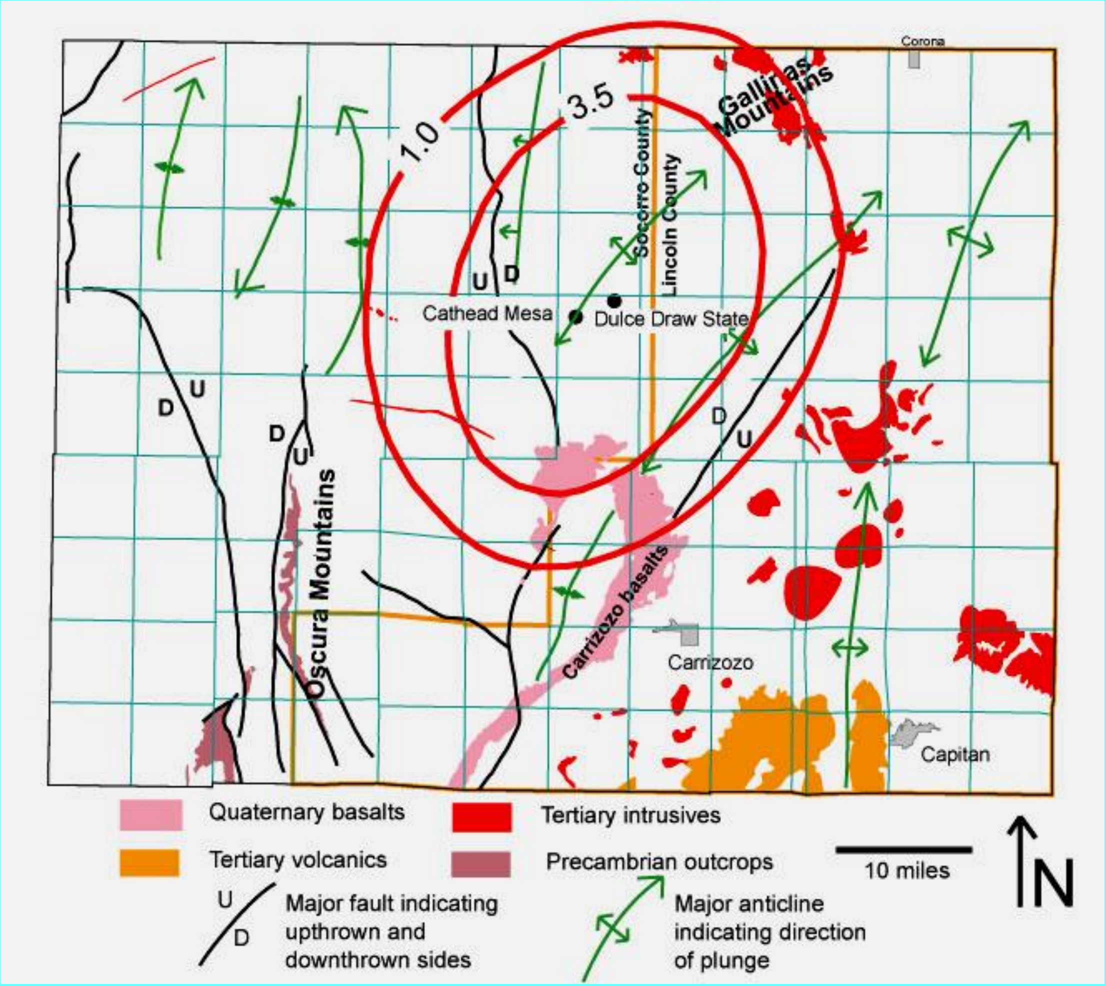
Chupadera Mesa, Central New Mexico
Lower Permian sandstones



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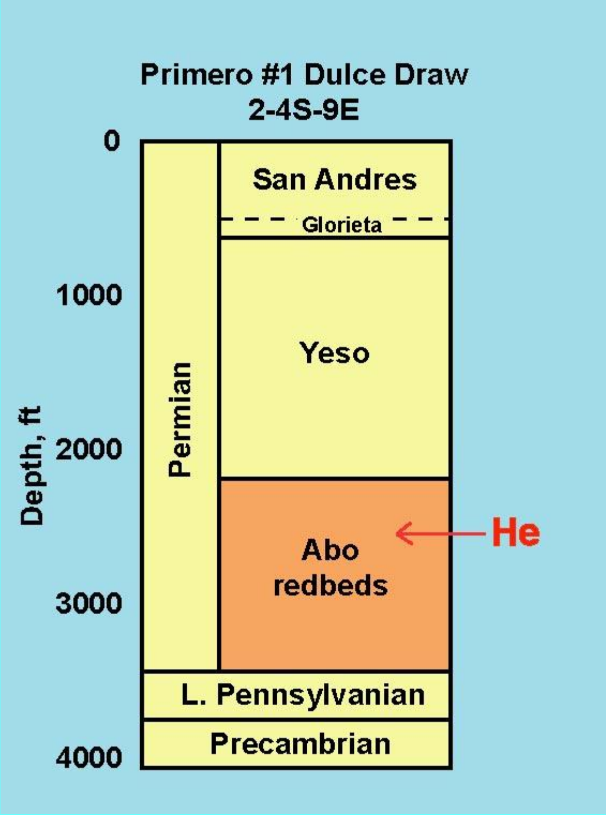
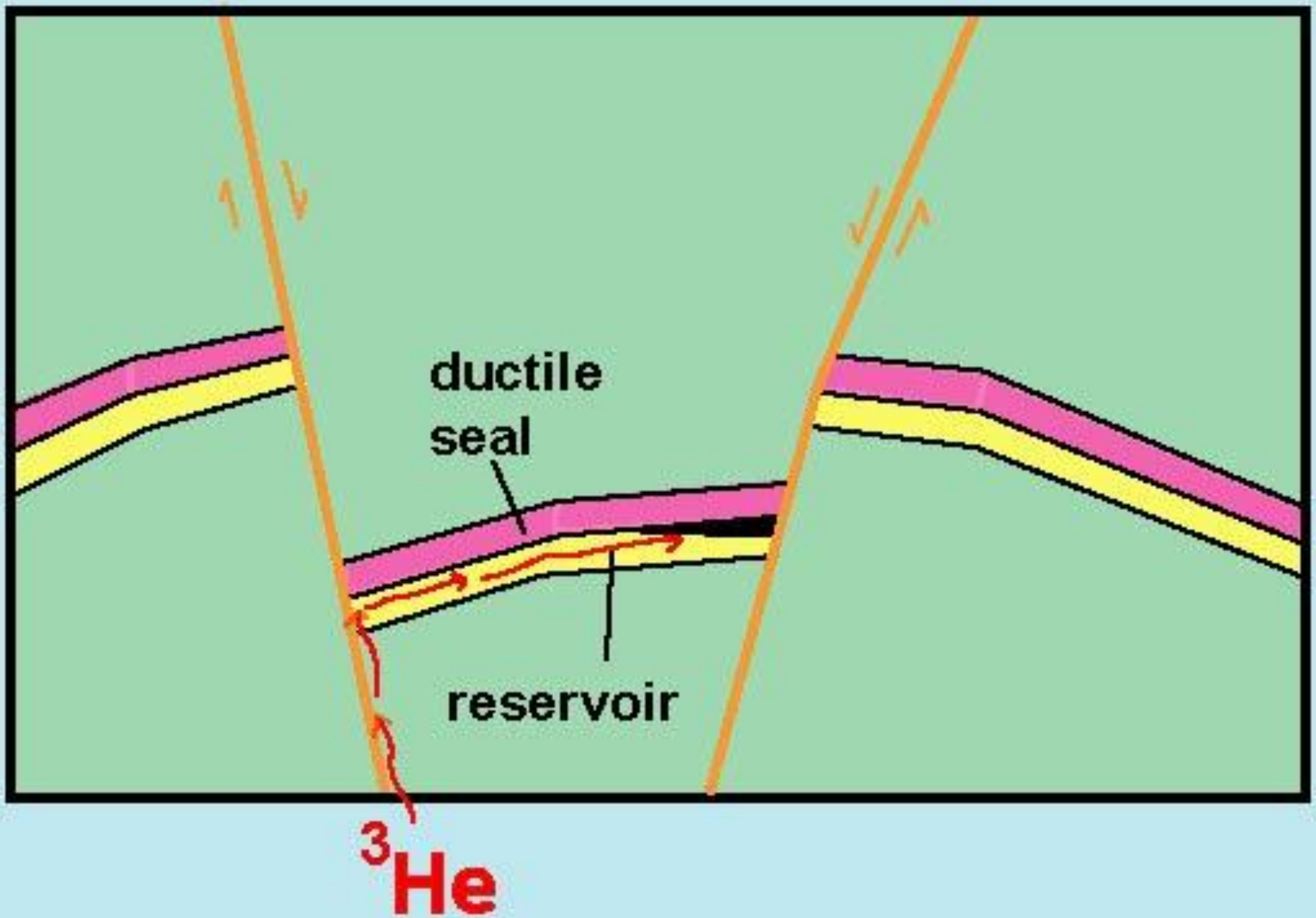


Highest known He concentrations in NM gases outside of the depleted fields in the Four Corners area

Helium isotopes Chupadera Mesa

- R = ratio of $^3He/^4He$ normalized to air (1.39×10^{-6})
- $R_{chupadera} = 0.515$
- For mantle He $6 < R < 10$ (Oxburgh et al, 1986)
- For most crustal He $R < 0.08$ (Oxburgh et al, 1986)
- Strongly suggestive that part of Chupadera He is mantle derived
- Remainder of Chupadera He is crustal

He exploration model #2
migration along deep-seated extensional faults
Cenozoic terrains



CONCLUSIONS

- **Almost 1 BCF of helium has been produced from 8 oil & gas pools on the Four Corners Platform in San Juan County since 1943.**
- **In the San Juan Basin, productive He accumulations are located over orthogonal systems of high-angle faults that acted as migration pathways for He generated in granitic Precambrian rocks.**
- **Although no He has been produced from deep San Juan Basin, potential in Devonian, Mississippian and Pennsylvanian reservoirs is indicated by elevated He concentrations.**
- **In the Permian Basin, gases with He contents from 0.35% to almost 1% have been produced from reservoirs along the northwest flank of the basin. NE-SW-trending faults define exploration fairways.**

CONCLUSIONS (continued)

- **Frontier exploration areas characterized by He-rich gases in Pennsylvanian and Permian reservoirs include the Tucumcari Basin, the Chupadera Mesa area and a wide region across Catron and Cibola counties. These areas are of exploratory interest and have attracted helium explorationists and drilling.**
- **New sources of helium must be discovered, developed, and produced in order to maintain access to advanced technologies that enhance our lives. The market provides incentives for exploration.**
- ***At sufficient concentrations and at sufficient helium prices, methane becomes the byproduct of helium production***

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