Helium in New Mexico:
Geologic Distribution and Exploration Possibilities

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New Mexico Bureau of Geology and Mineral Resources
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Earth Science for the 21st Century

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Organization of talk

- **What is He? - properties, origin**
- **Simple exploration model**
- **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 –269^{o}C (*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?

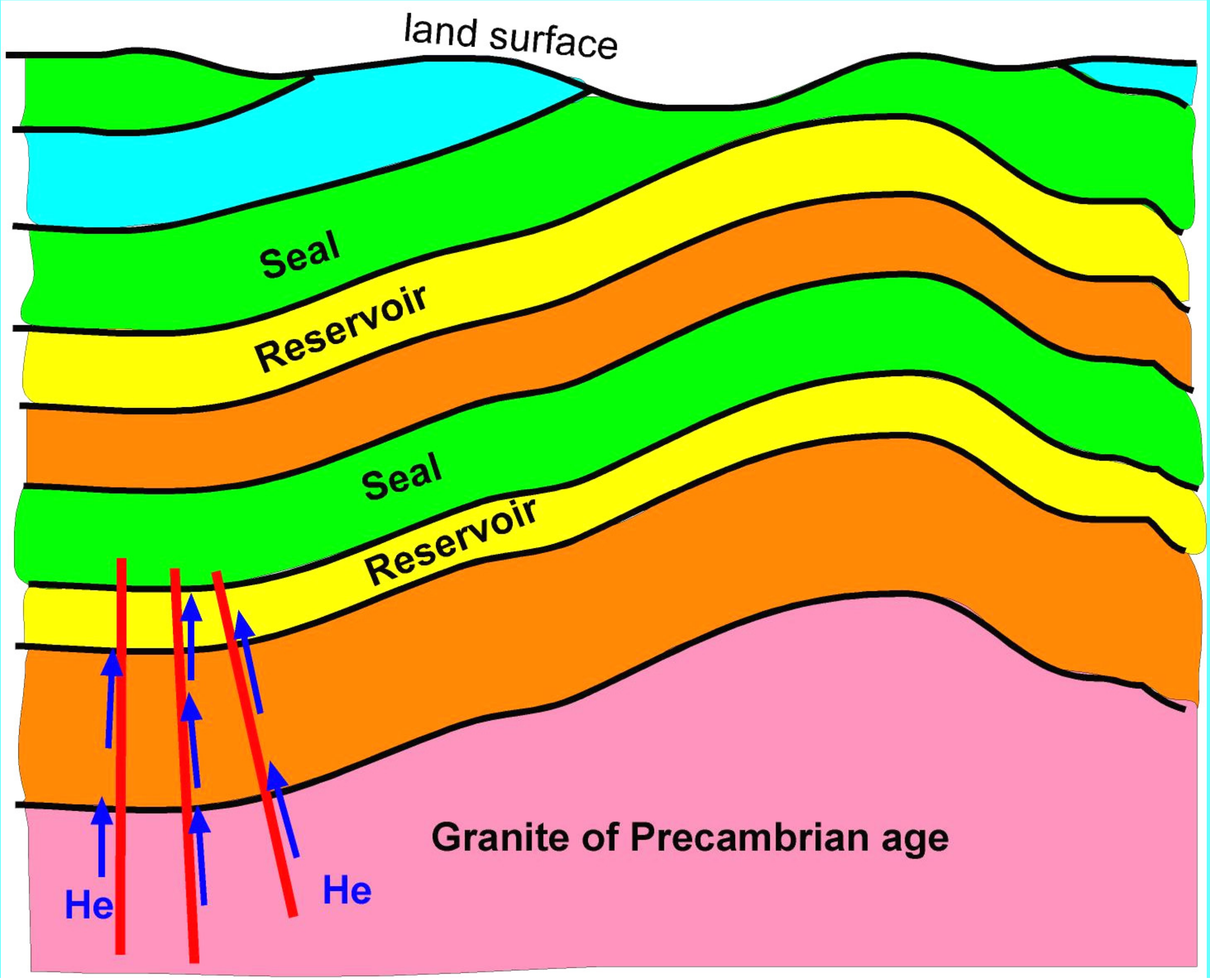
- ^{4}He originates from radiogenic decay of uranium and thorium in crustal rocks (mostly granites)
- ^{3}He is mostly primordial and is derived from the mantle
- A very minor amount of ^{3}He may be derived from neutron capture by ^{3}H in crustal reservoirs; clays rich in ^{6}Li
- Some helium in atmosphere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

Helium has two isotopes, He^3 and He^4. Each has a different mode of origin.

Isotope	Relative abundance in crustal reservoirs	Origin	Migration mechanisms
^3He	Relatively rare	Dominantly primordial (*Derived from the mantle. Some may be produced in crustal reservoirs through neutron capture by* ^3H *in lithium-rich sediments*).	1) Devolatilization of rising magmas. 2) Vertical migration through deep-seated fractures in post-Cretaceous extensional domains.
^4He	Relatively common	Radiogenic (*Derived from radiogenic decay of uranium and thorium in basement rocks or in sedimentary ore bodies*).	Dominant migration is out of impermeable basement via fractures and faults. Enhanced levels of He in gases and groundwater are associated with proximity to faults and fractures.

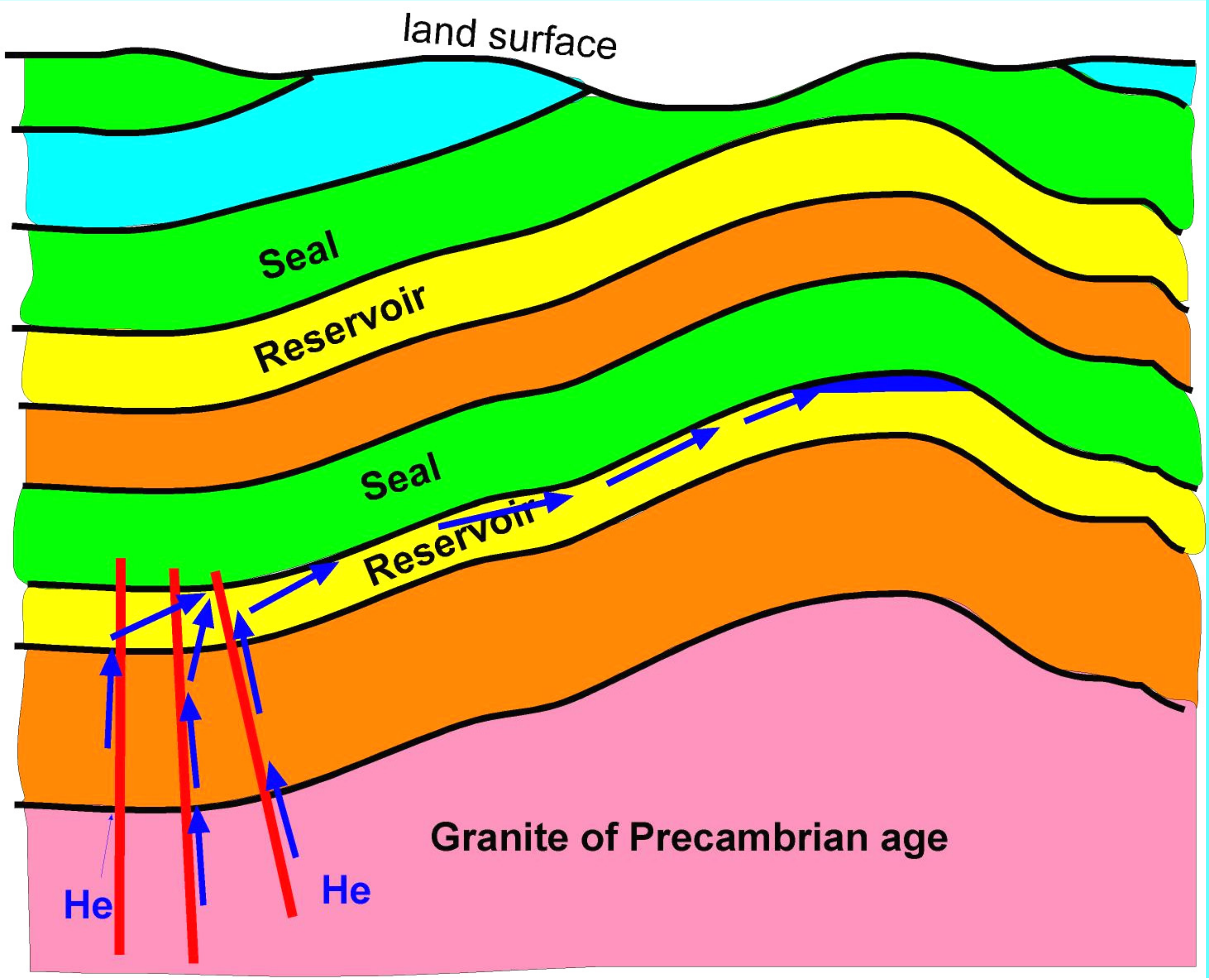
$^3He/He^4 = 10^{-5}$ to 10^{-8}

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

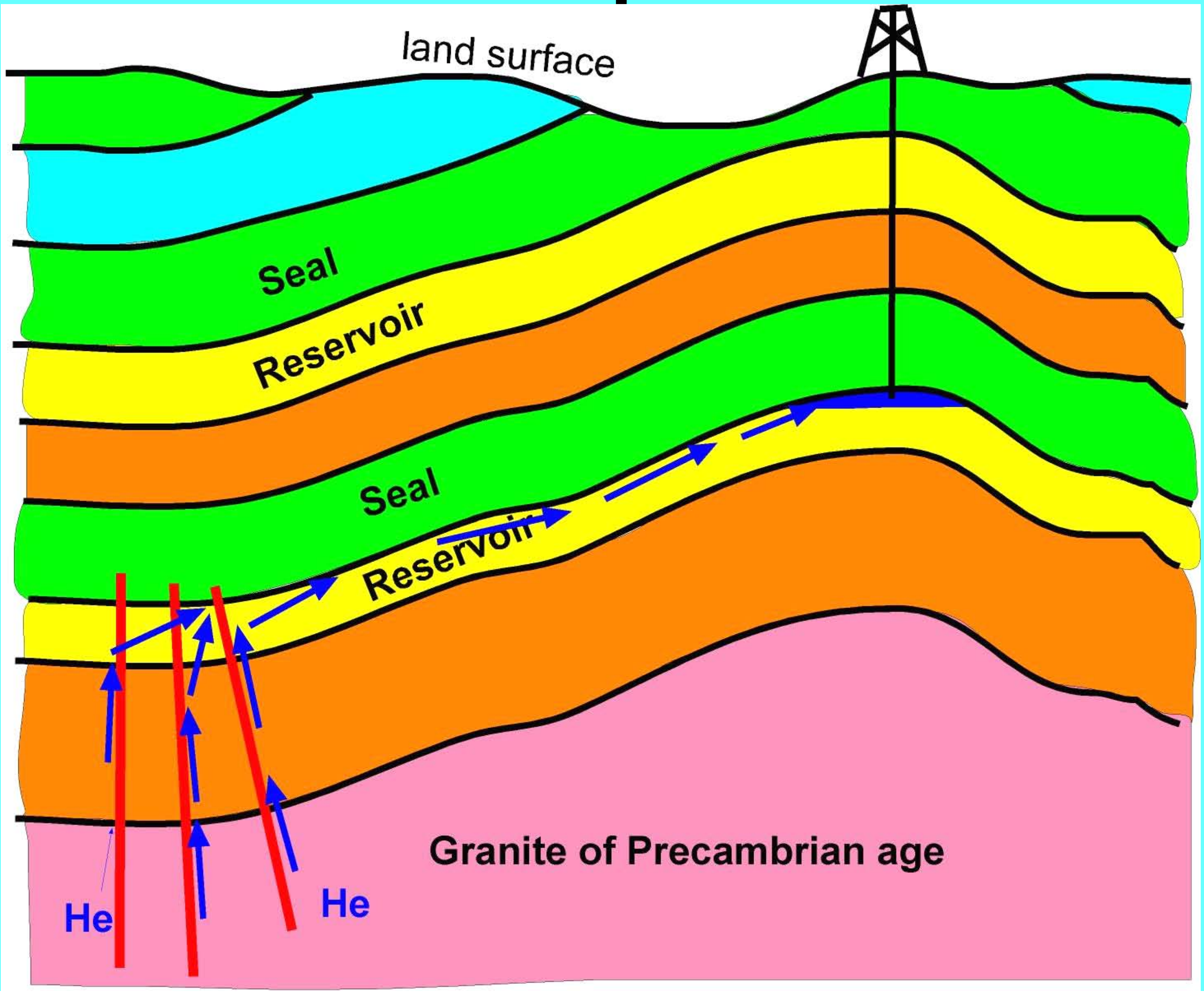


- For ^{4}He derived from granite, the granite is impermeable so the He migrates out of the granite along fault/fracture faces
- For juvenile ^{3}He that comes from the mantle, the He can migrate upward into the crust along extensional faults of Tertiary and Quaternary age

What does it do once it gets into crustal reservoirs?



How do we find it?
Most simple case



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)
- Pressurizing and purging
- Cooling medium for nuclear reactors
- Welding
- Leak detection
- Synthetic breathing mixtures
- Lifting (blimps)

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 4.3 BCF in 2004, an increase of 8%
- Domestic production has fallen from 4 BCF in 1998 to 3 BCF in 2004 as production from established fields on KS, TX, OK has declined
- Shortfall in production filled by withdrawing He from underground storage
- 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

$$ Helium economics (continued) $$

- Prices have risen as production has fallen below demand.
- Private industry price for He in 2000 was $42 to $50 per MCF
- Price in 2003 was $60 to $65 per MCF, with some producers adding a surcharge to these prices

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%

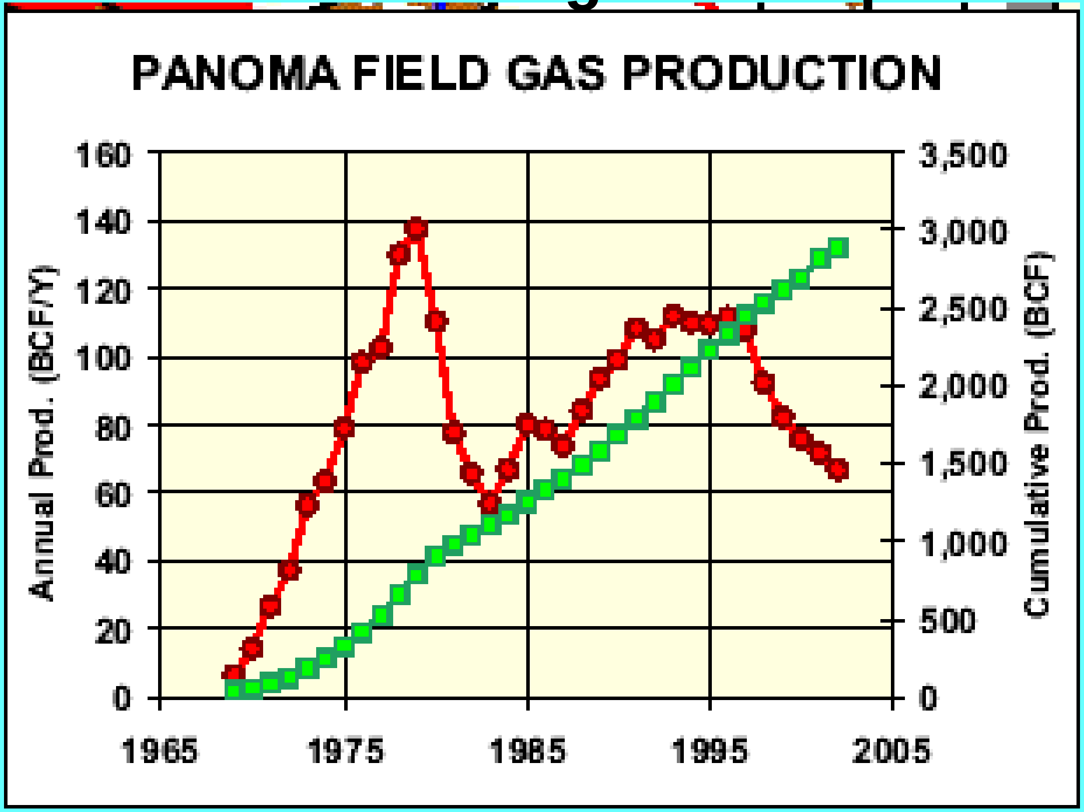
Tongish (1980, U.S. Bureau of Mines)

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. Panoma field in Kansas),
***hence* a shortage develops.**



Red = annual production
Green = cumulative production

From Dubois et al. (2002)

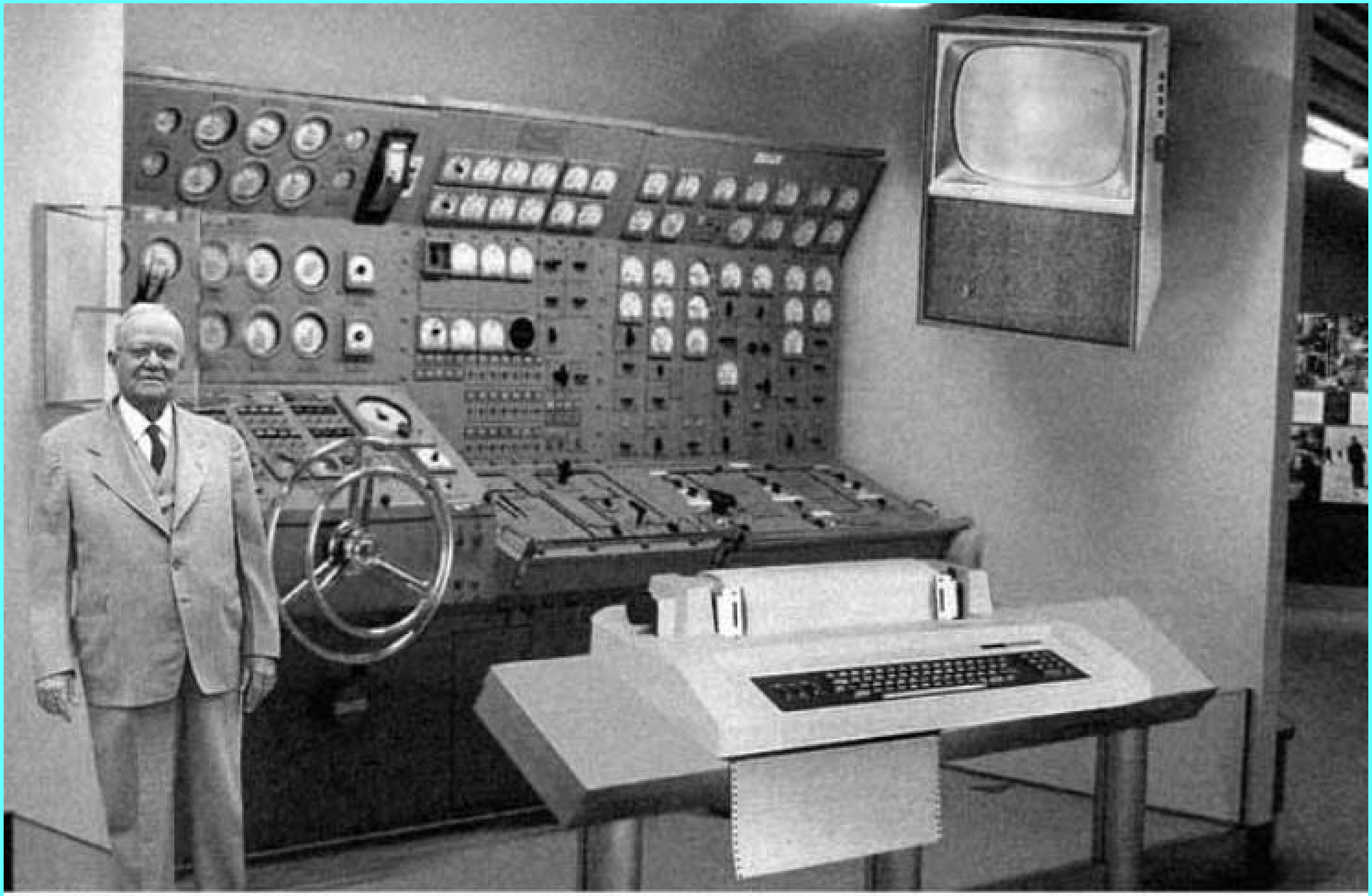
No helium?

Then no MRI's?

No helium?

**Then what happens to
the manufacture of computer chips?**

Without helium, will this be the PC of the future?

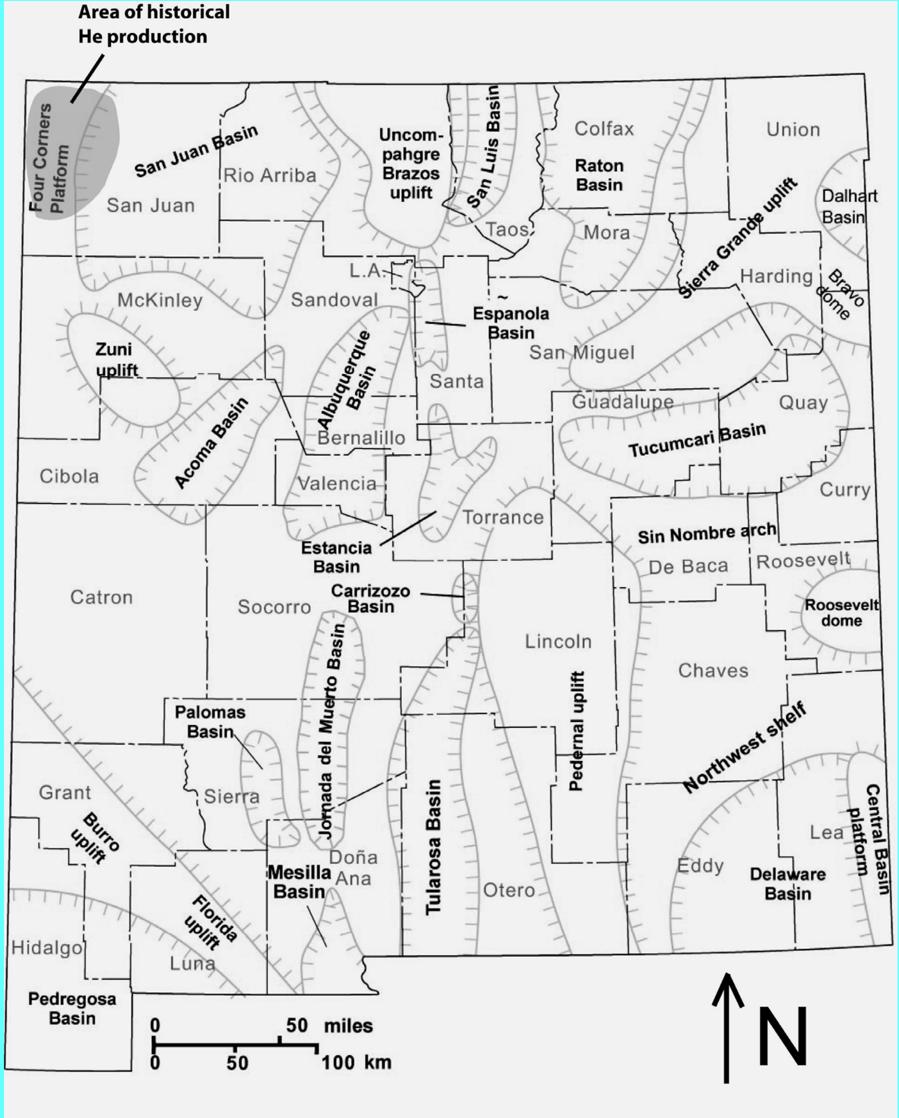


Scientists from the RAND Corporation have created this model to illustrate how a "home computer" could look like in the year 2004. However the needed technology will not be economically feasible for the average home. Also the scientists readily admit that the computer will require not yet invented technology to actually work, but 50 years from now scientific progress is expected to solve these problems. With teletype interface and the Fortran language, the computer will be easy to use.

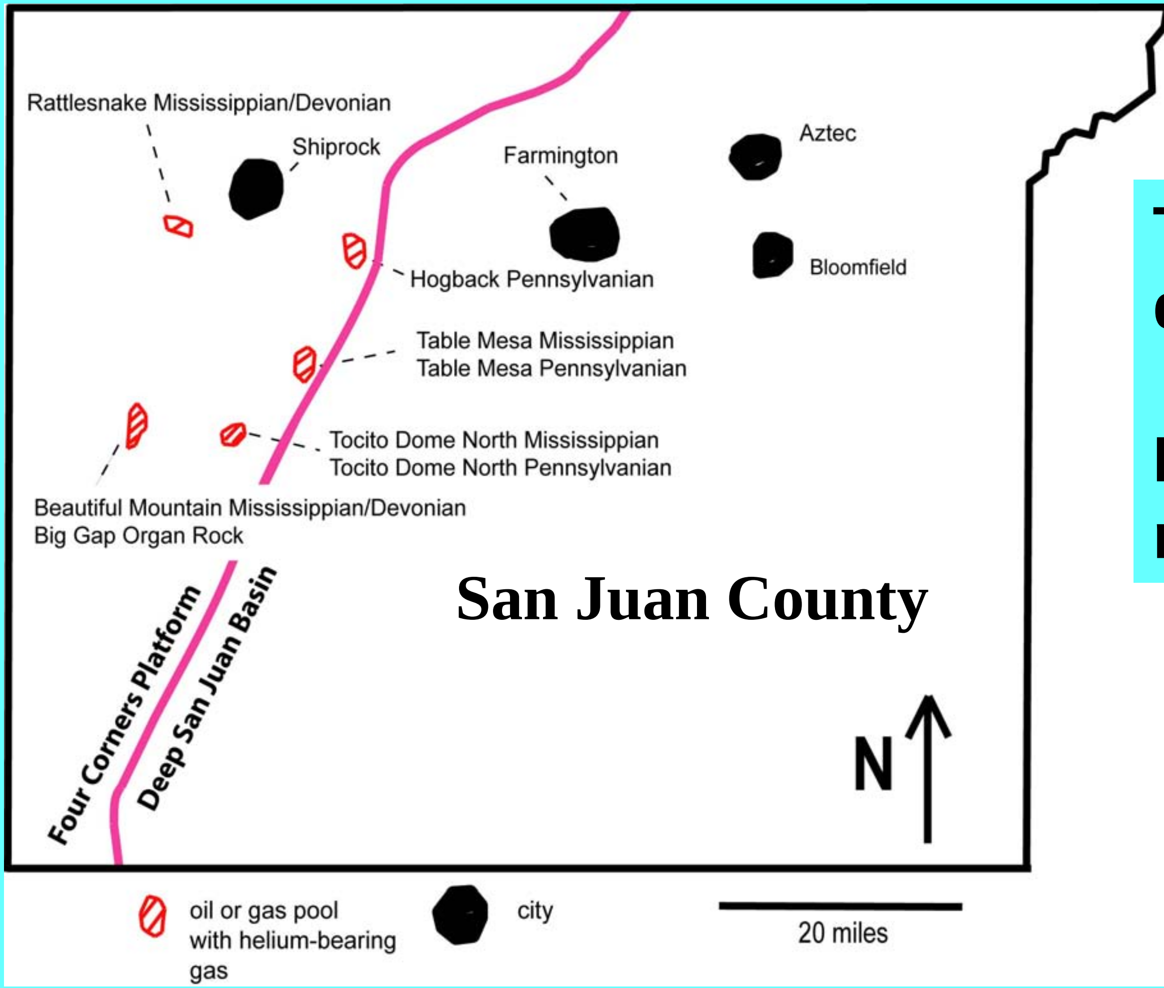
Helium in New Mexico

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

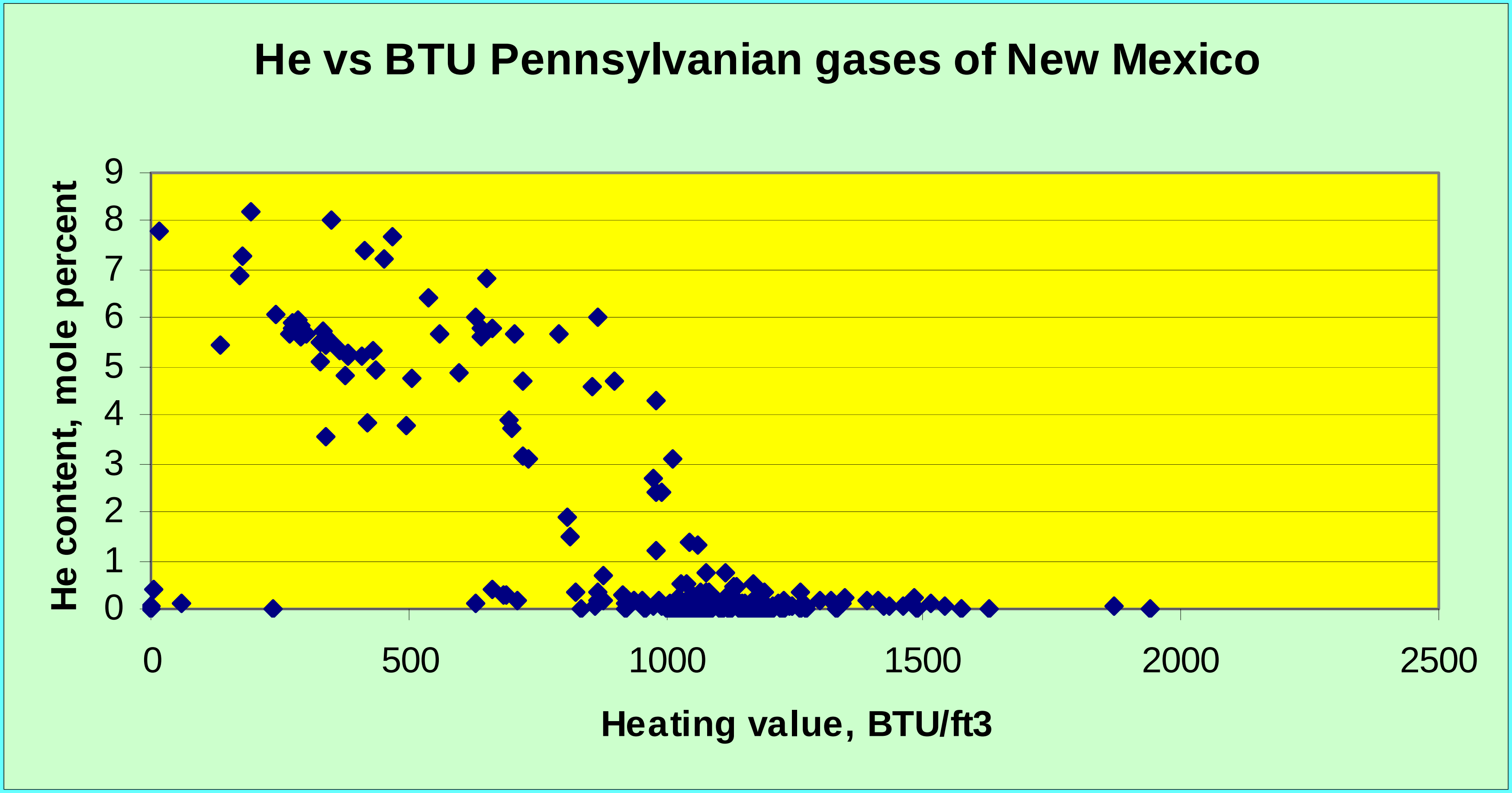


Total production to date is almost 1 BCF

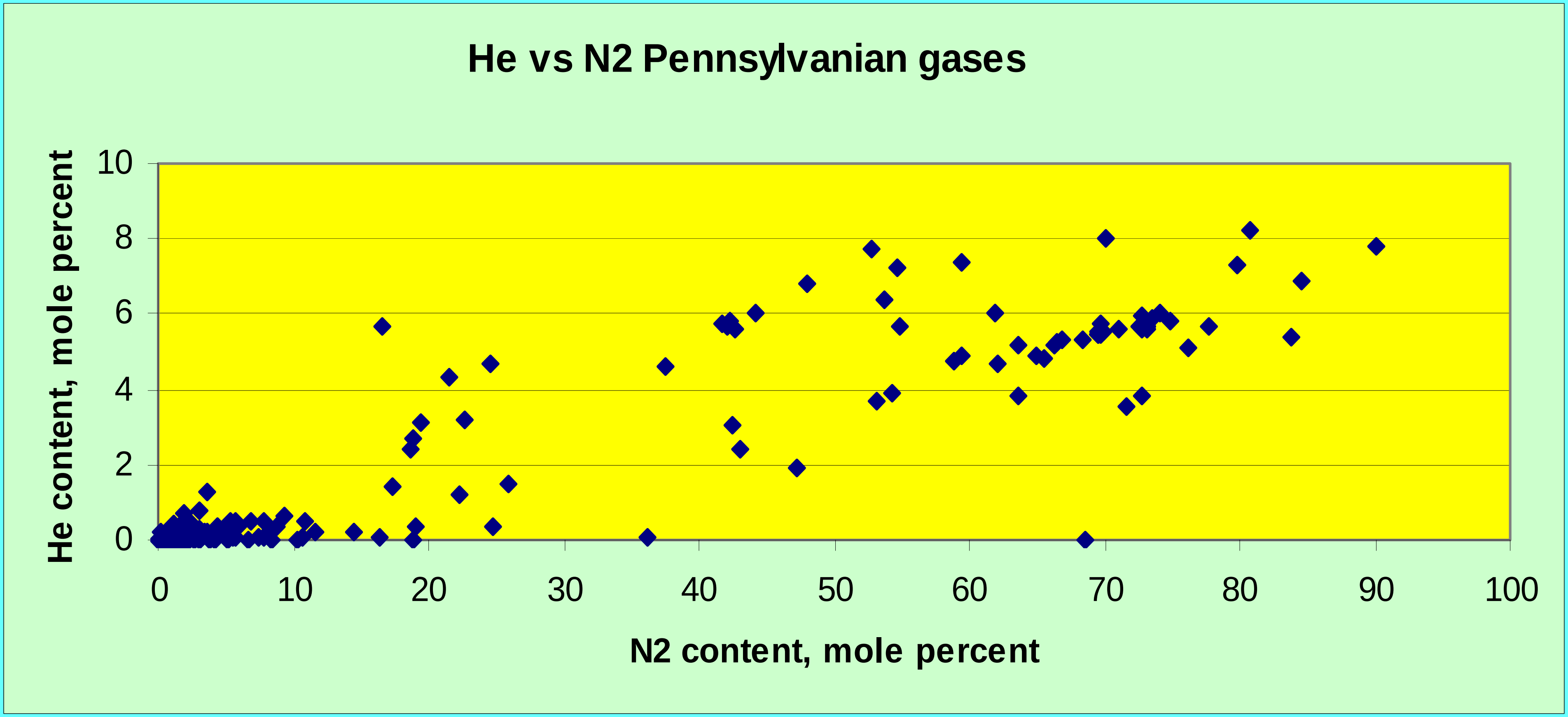
He contents of gases range from 3.2 to 7.5%

Only Big Gap & Beautiful Mountain are currently productive

Relationships of He to other gases in the reservoir



Pennsylvanian gases of New Mexico



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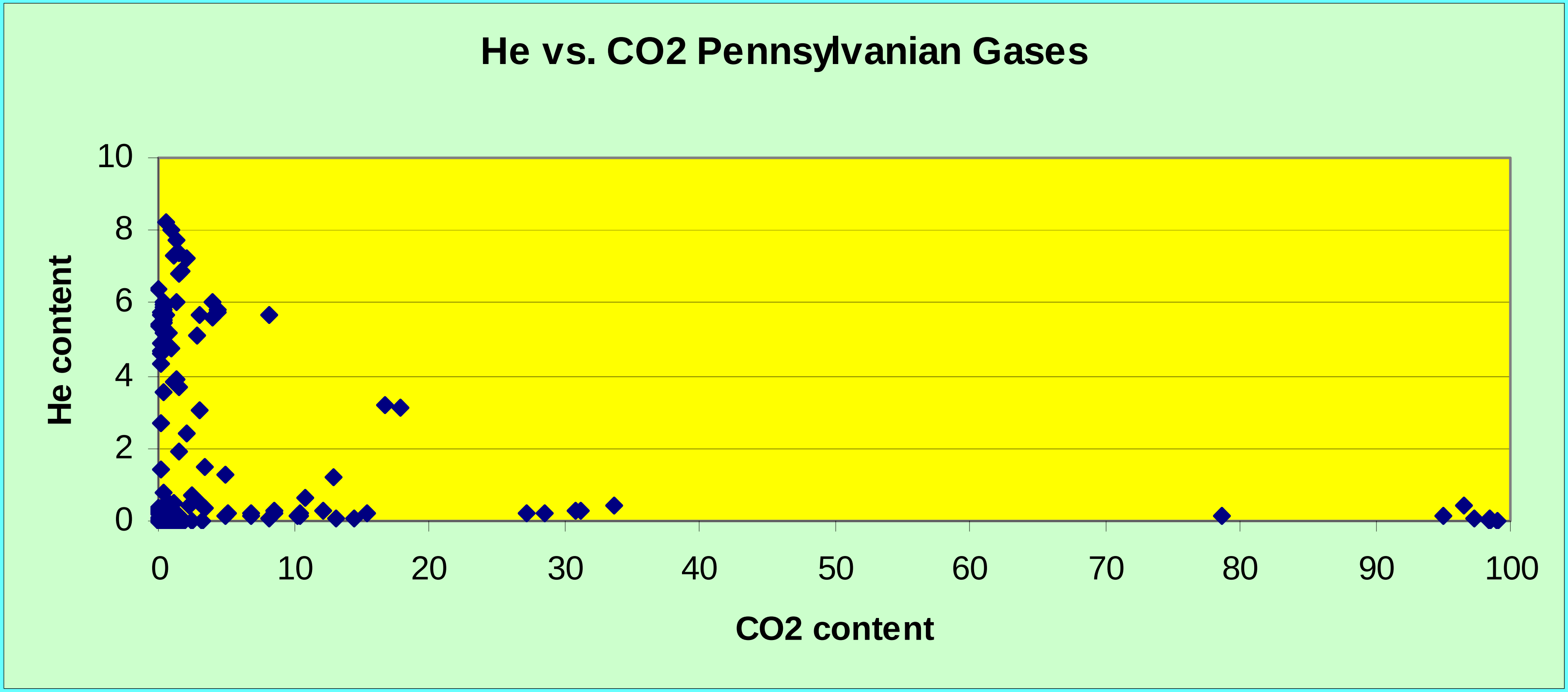
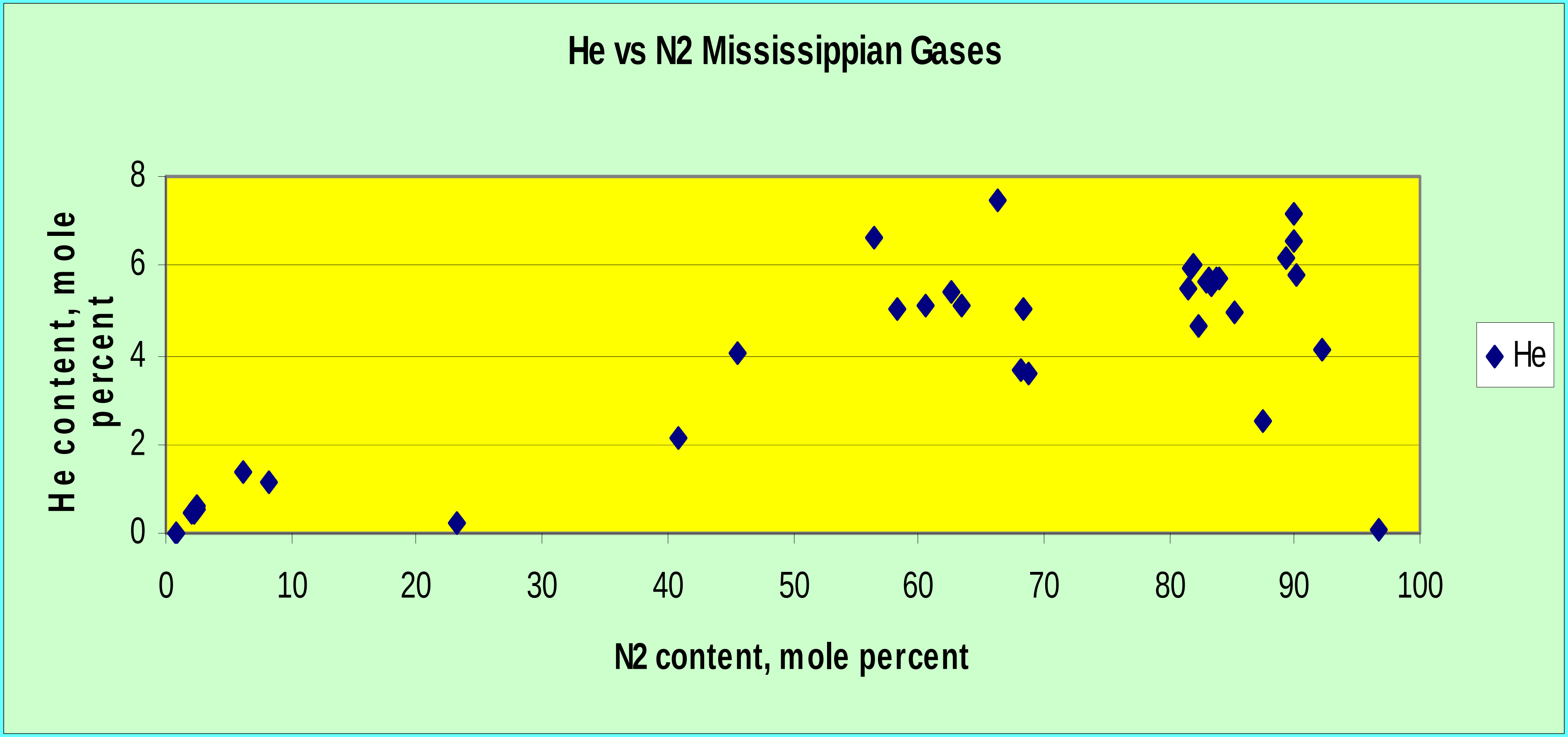
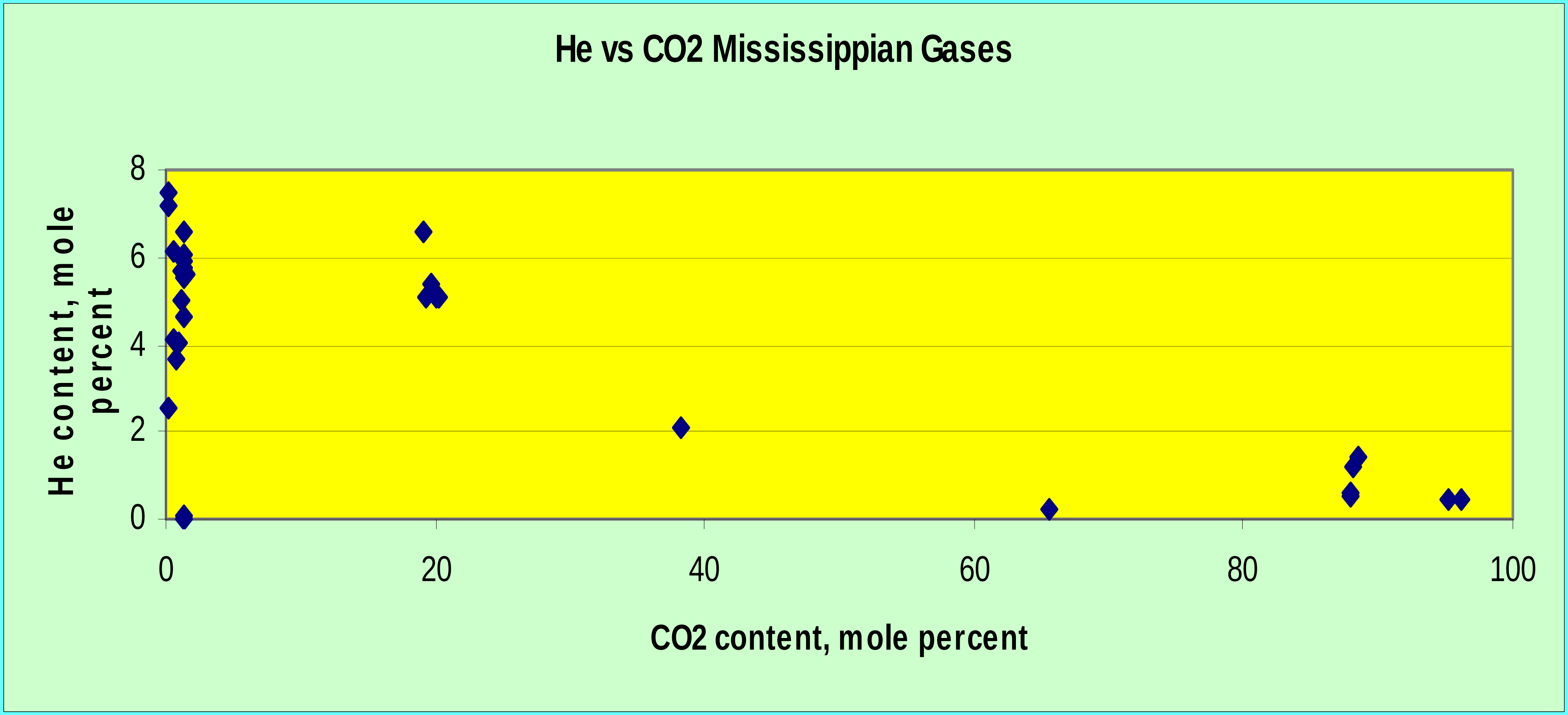


Mississippian gases of New Mexico



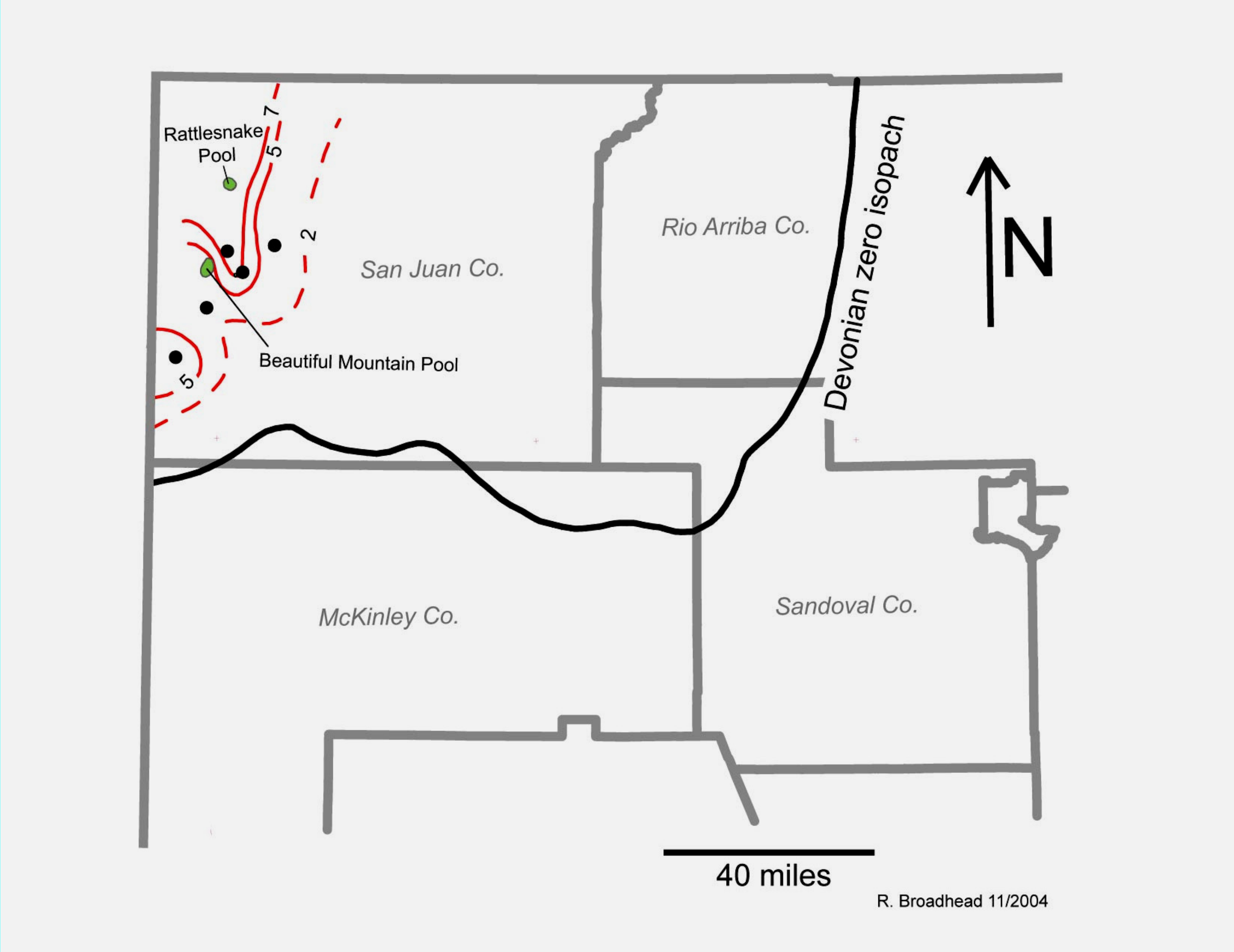
Mississippian gases of New Mexico



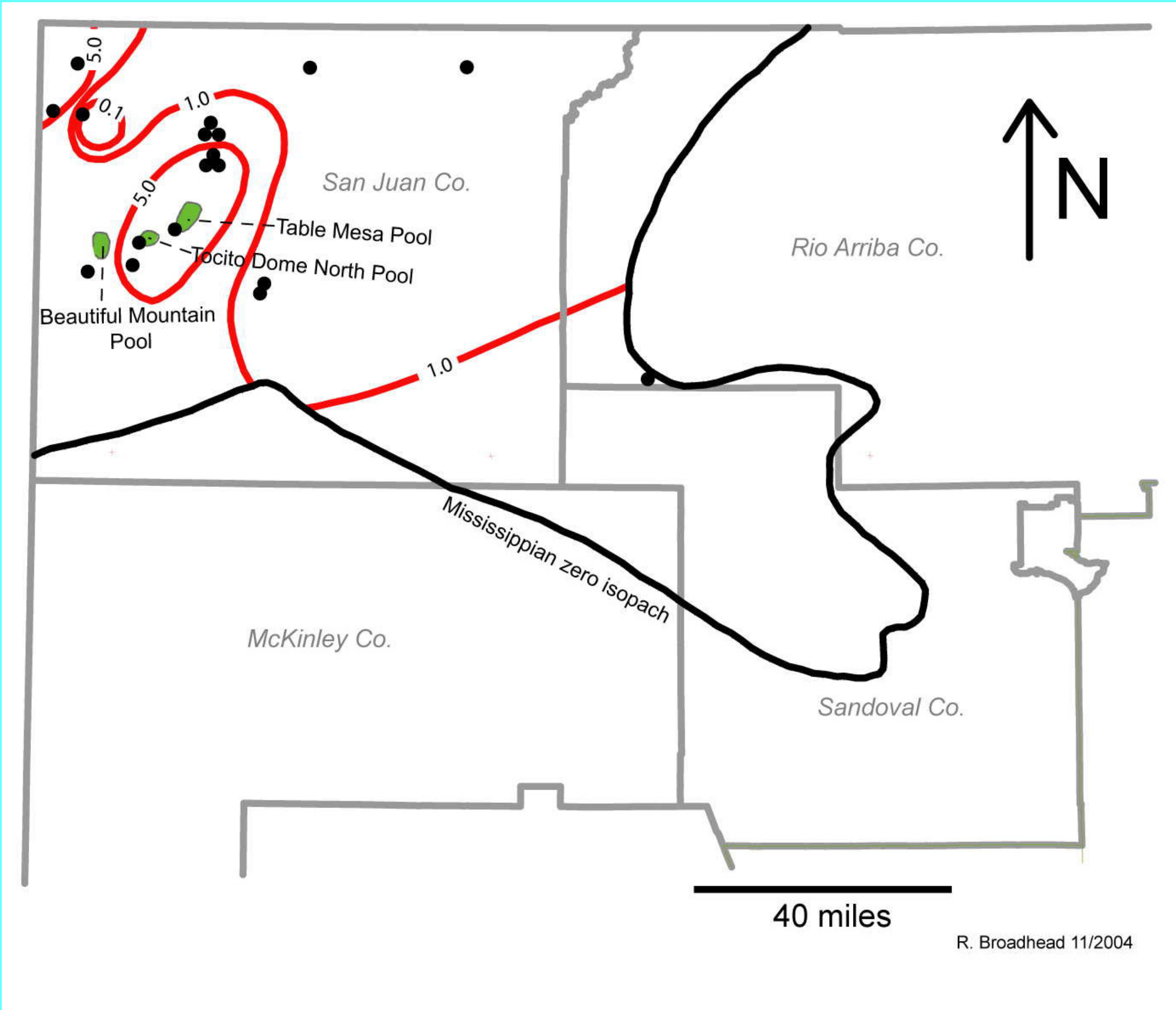
He in San Juan Basin Northwestern New Mexico

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

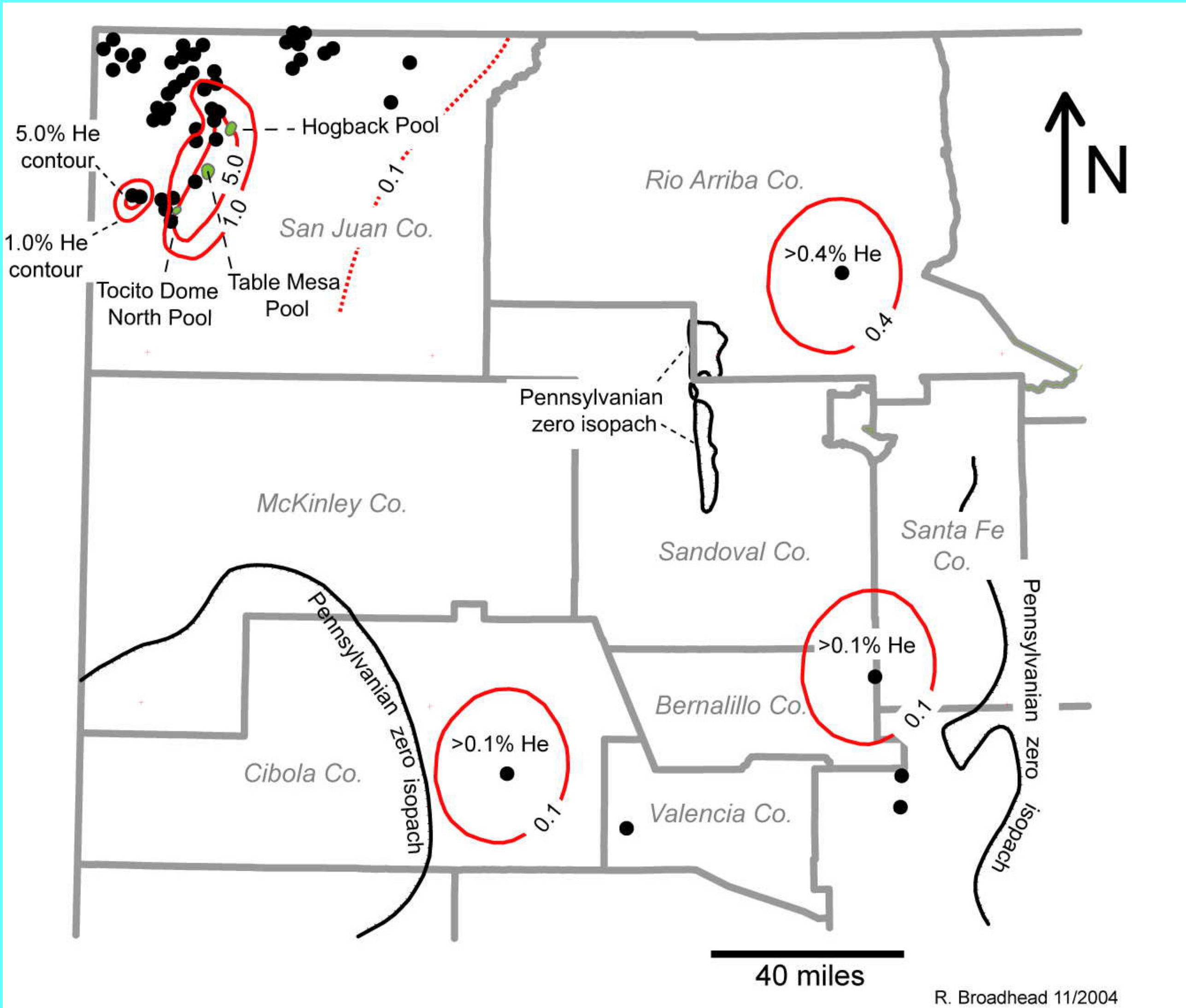
He in Devonian gases
San Juan Basin



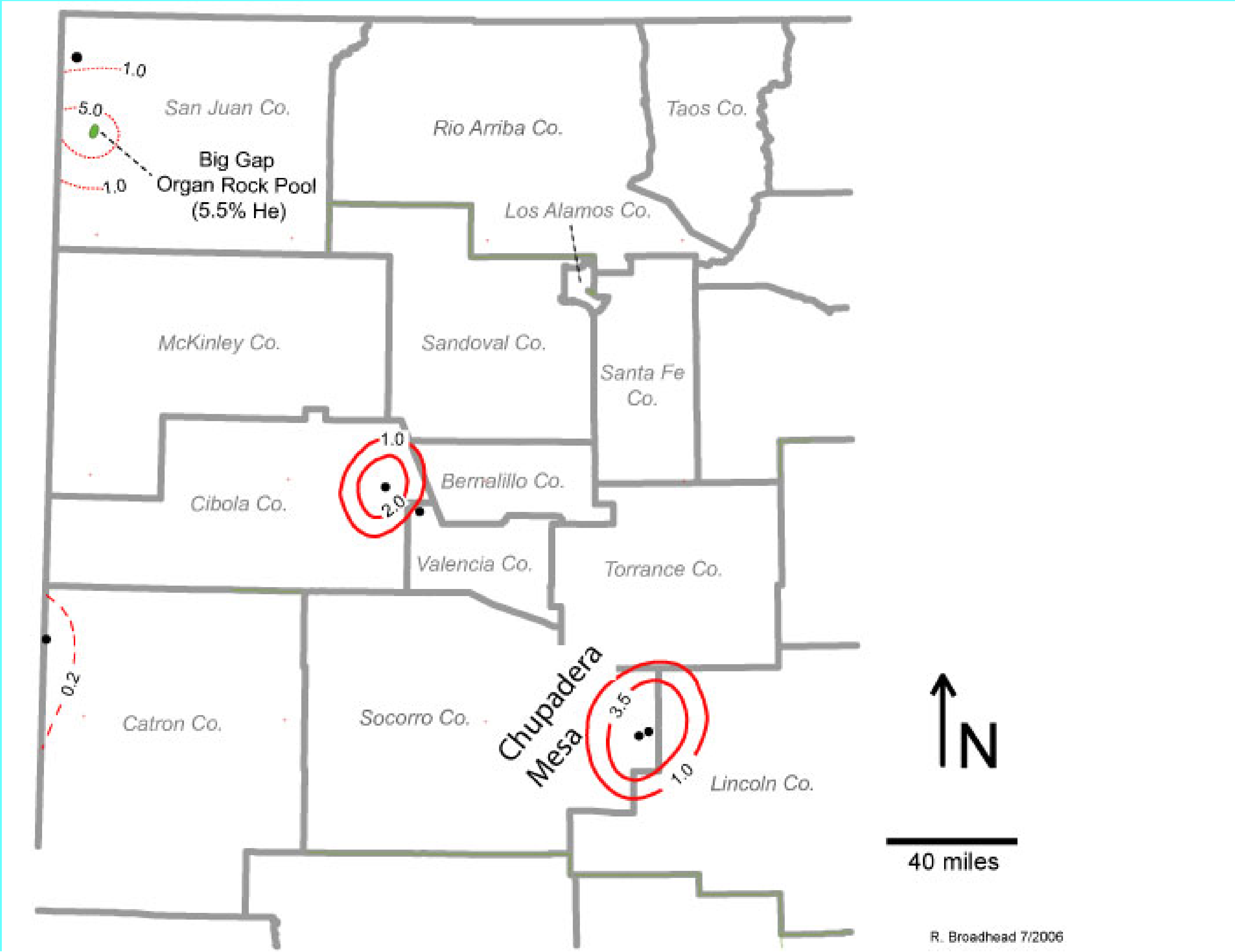
He in Mississippian gases San Juan Basin



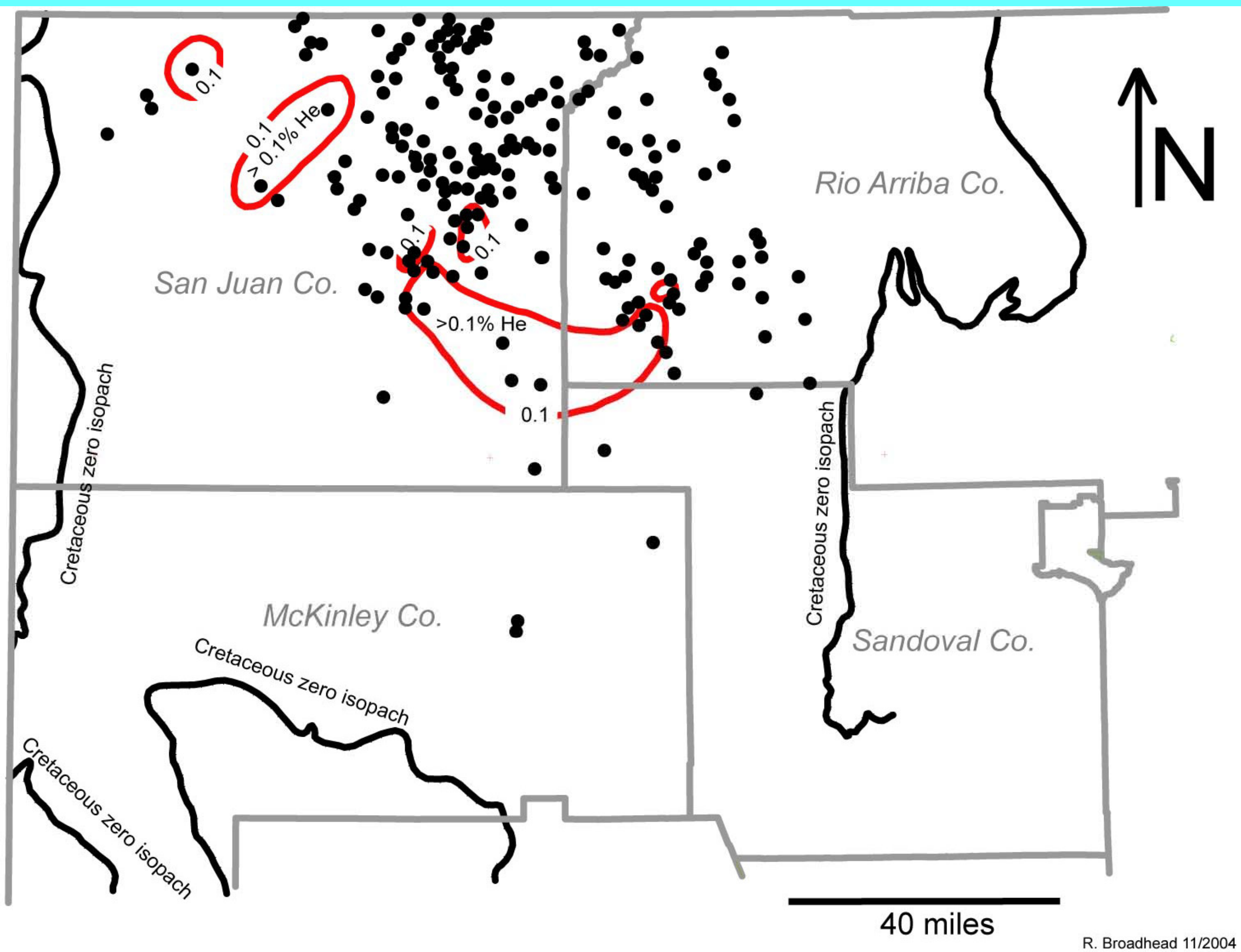
He in Pennsylvanian gases
San Juan Basin



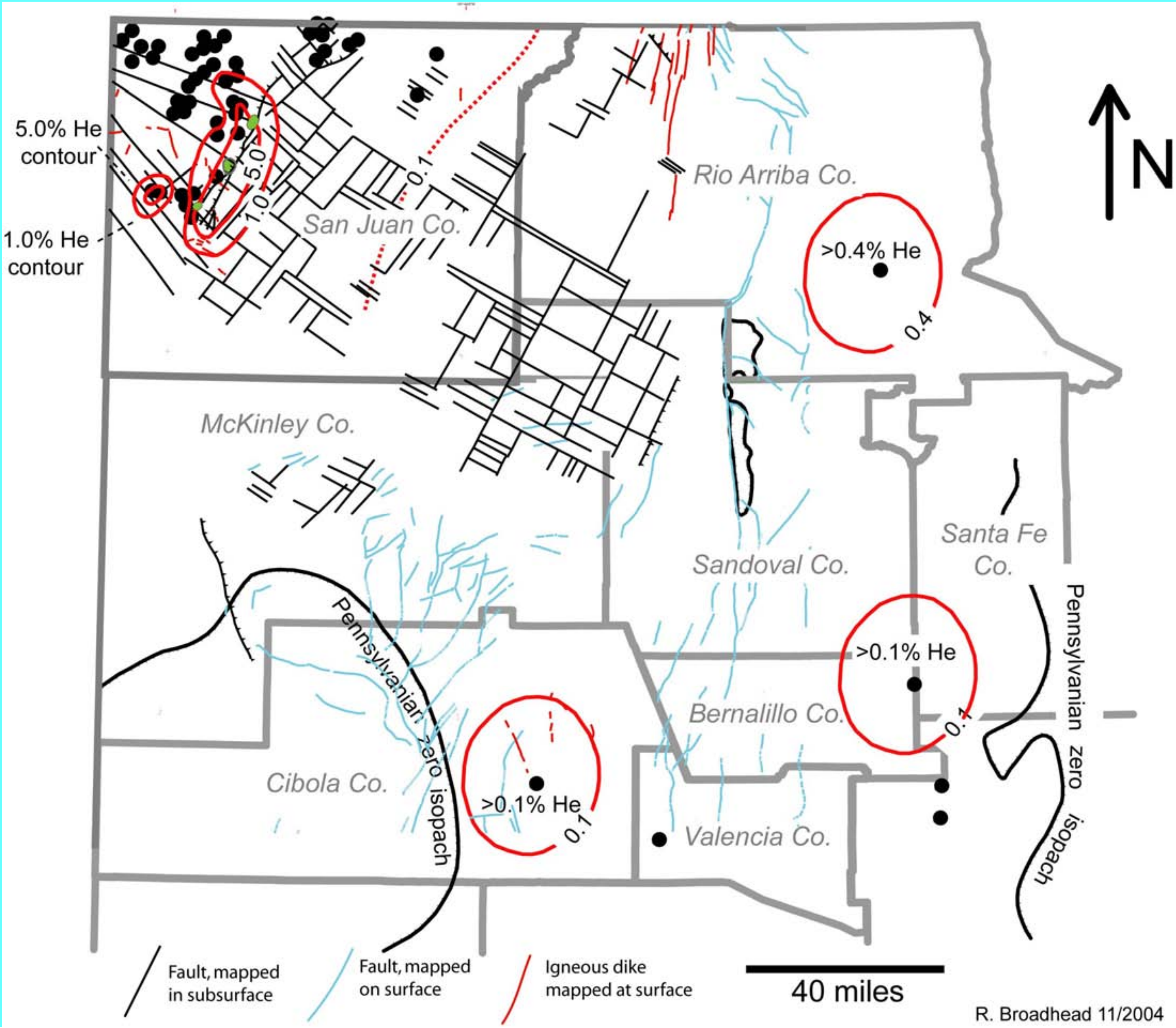
He in Permian gases



He in Cretaceous gases
San Juan Basin



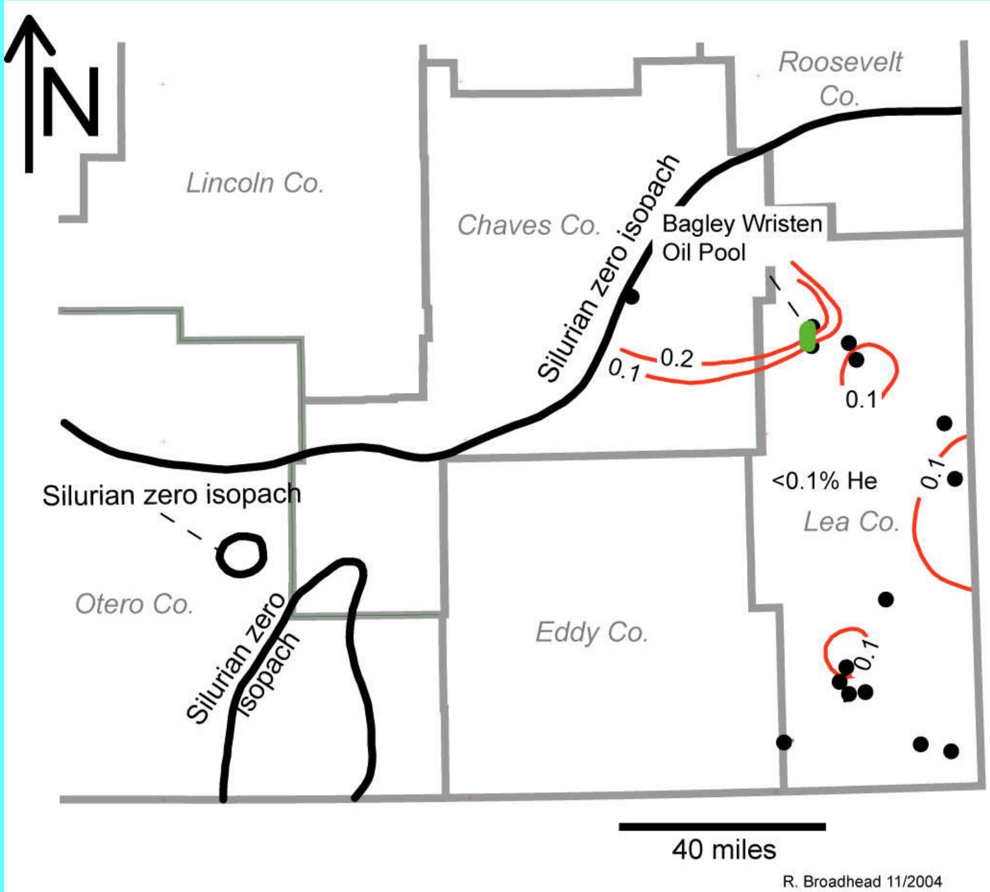
Faults and He in Pennsylvanian reservoirs
San Juan Basin



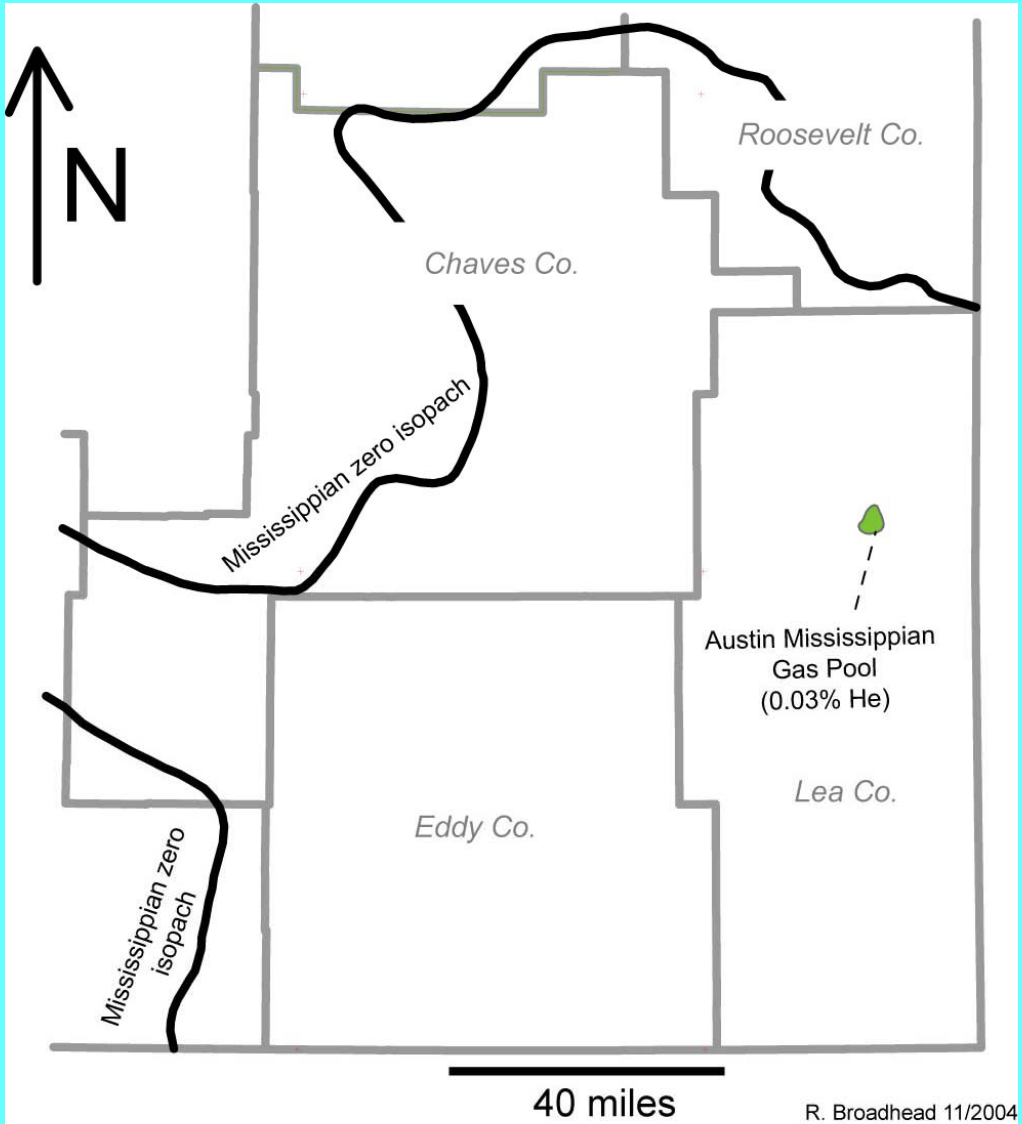
He in Permian Basin Southeastern New Mexico

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

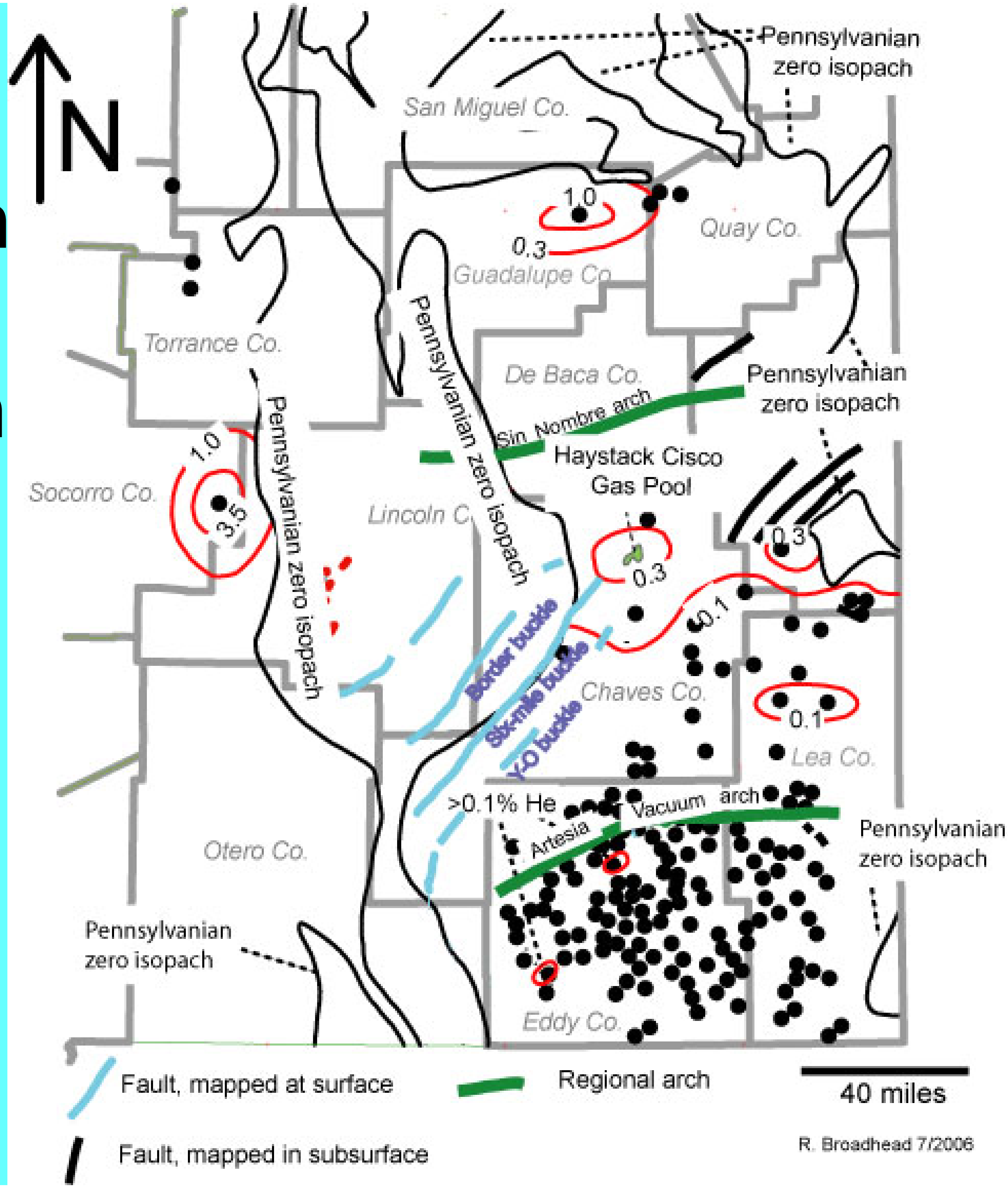
He in Silurian gases Permian Basin



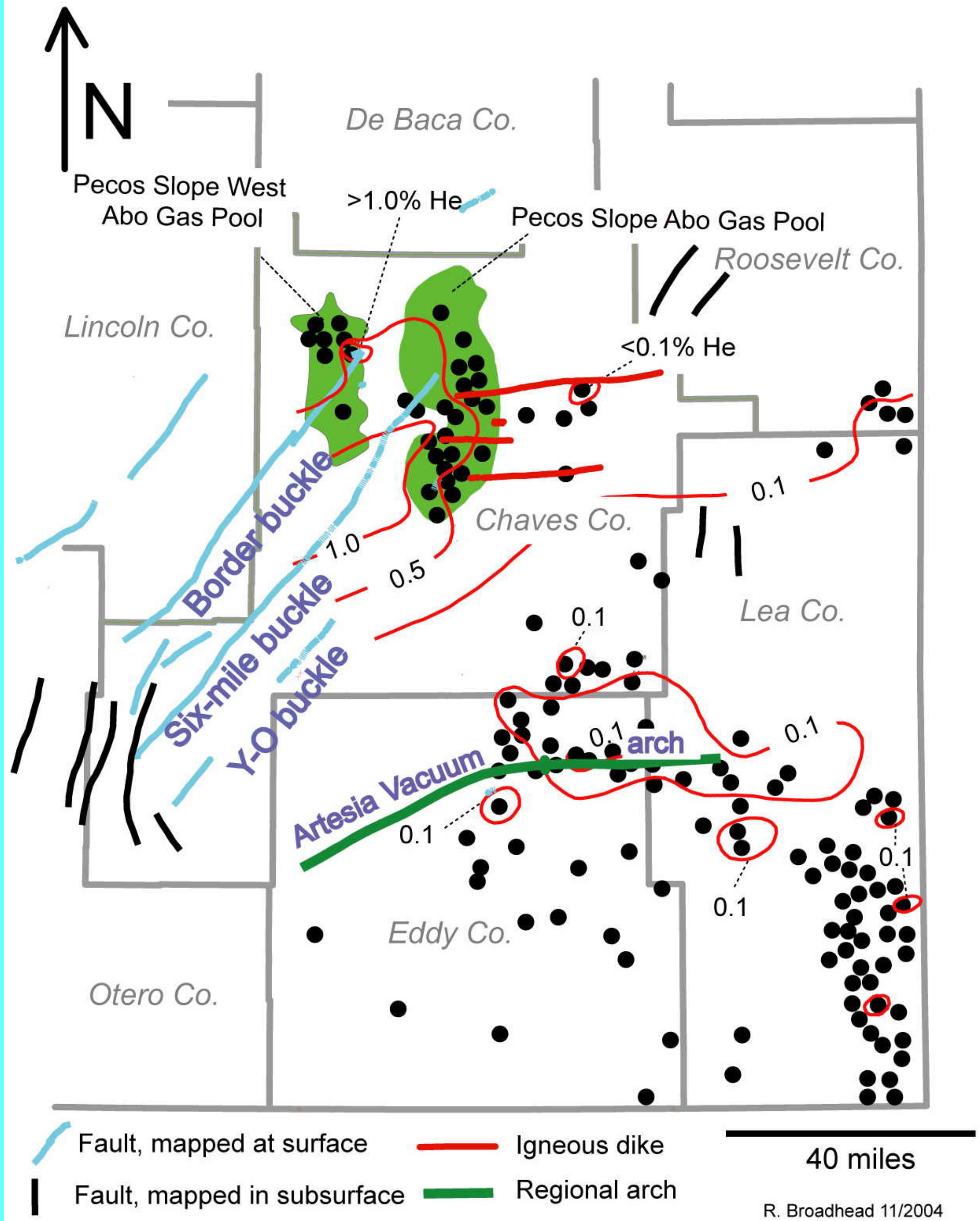
He in Mississippian gases
Permian Basin



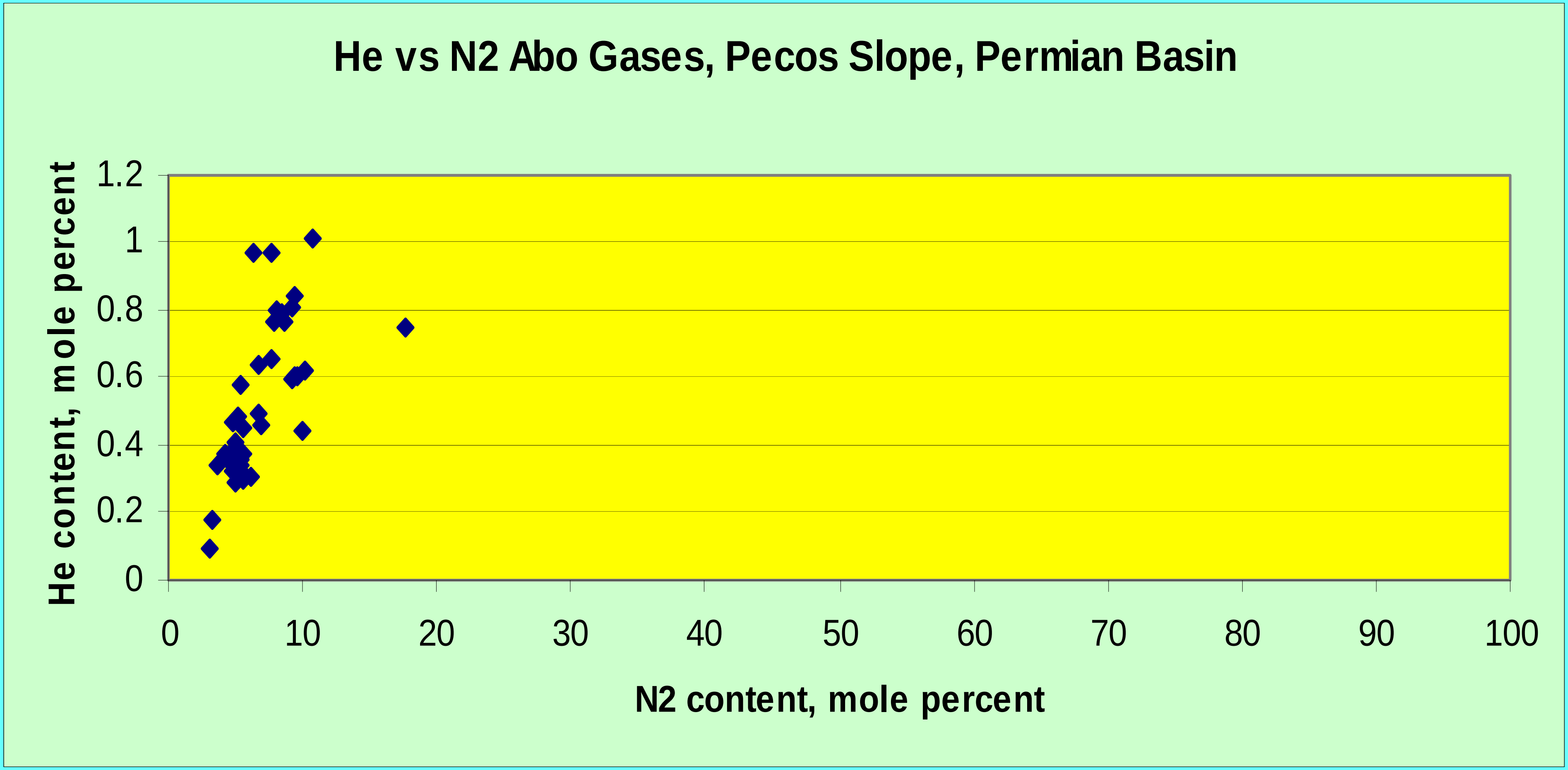
He in Pennsylvanian reservoirs Permian Basin



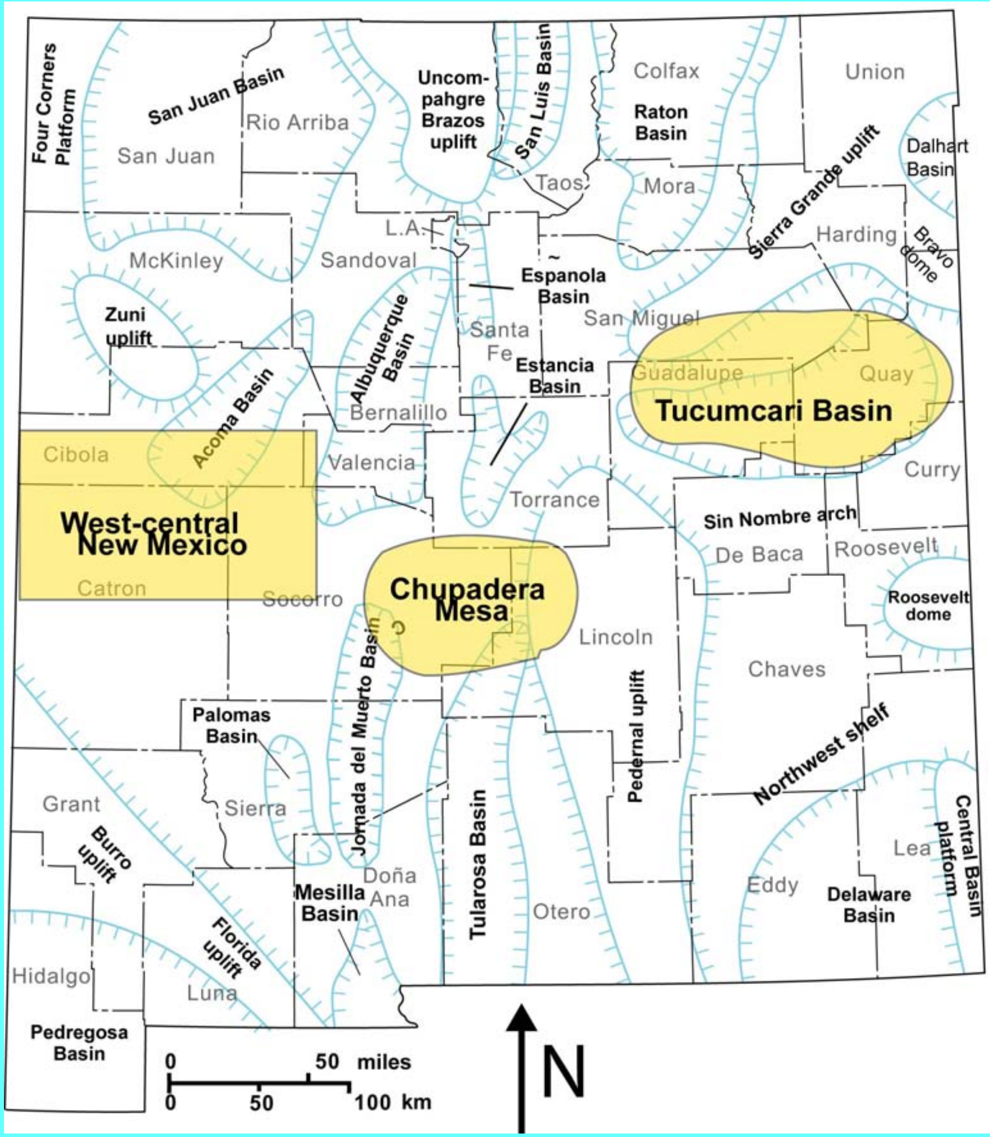
He in Permian Reservoirs Permian Basin



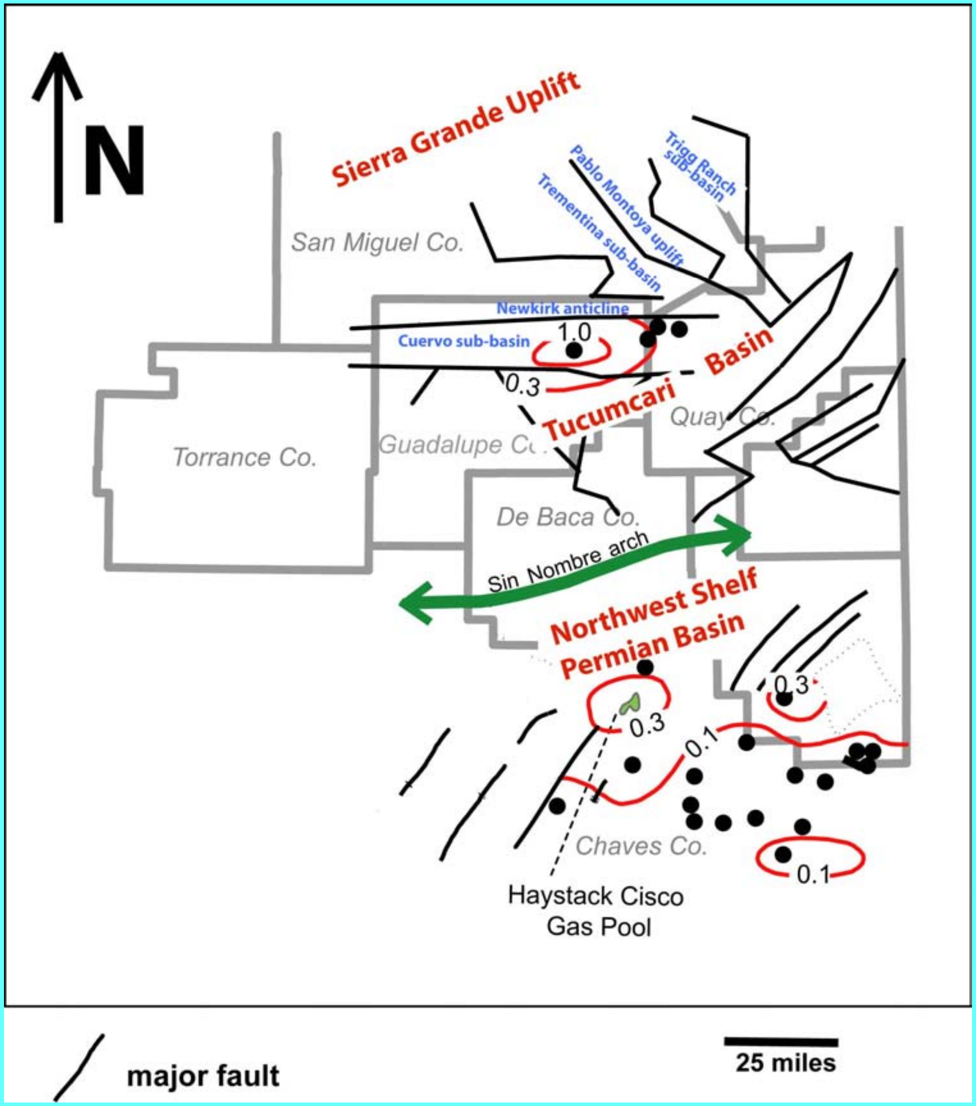
He and N_2 contents of Pecos Slope gases



Helium in Frontier Areas

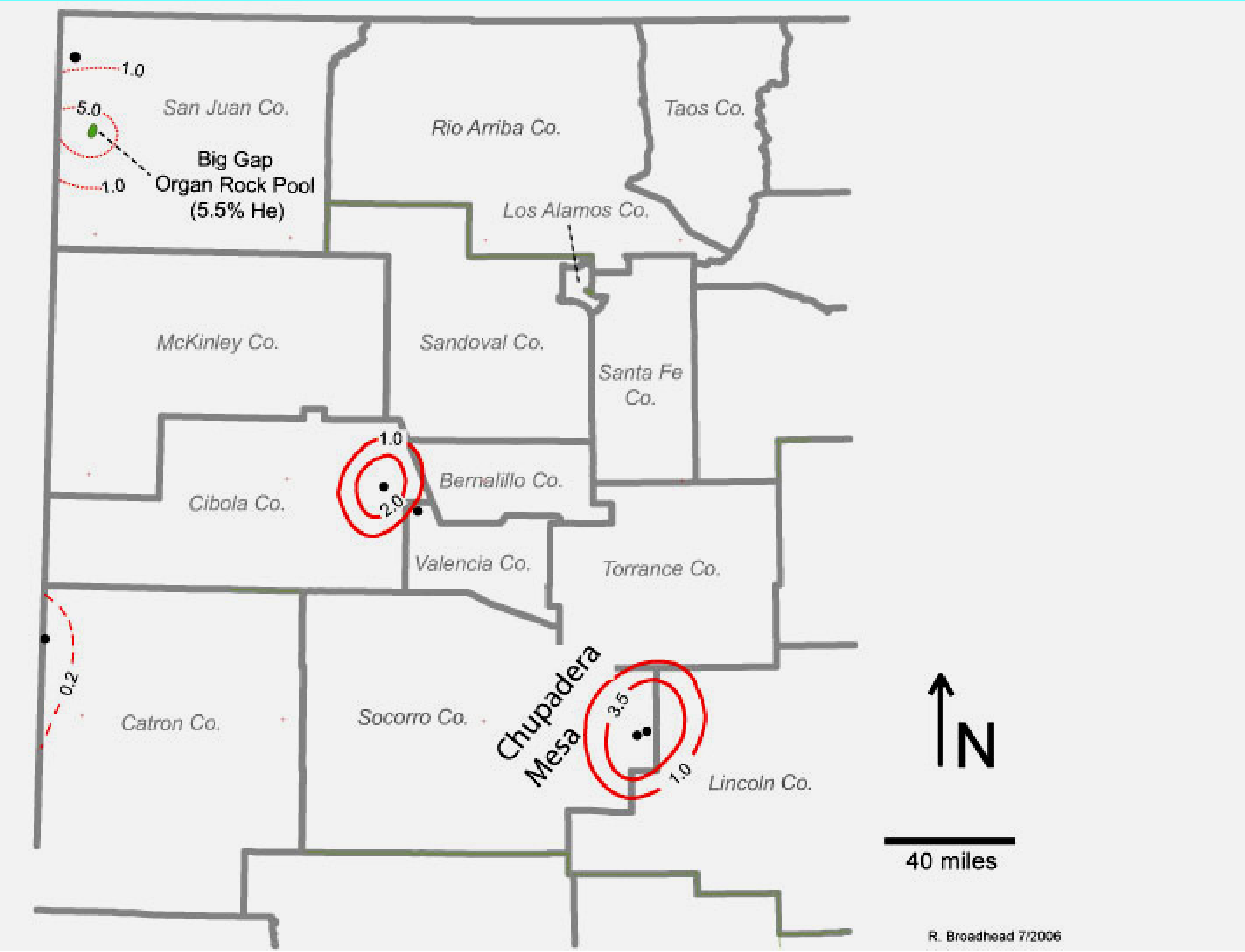


Tucumcari Basin
Pennsylvanian sandstone reservoirs



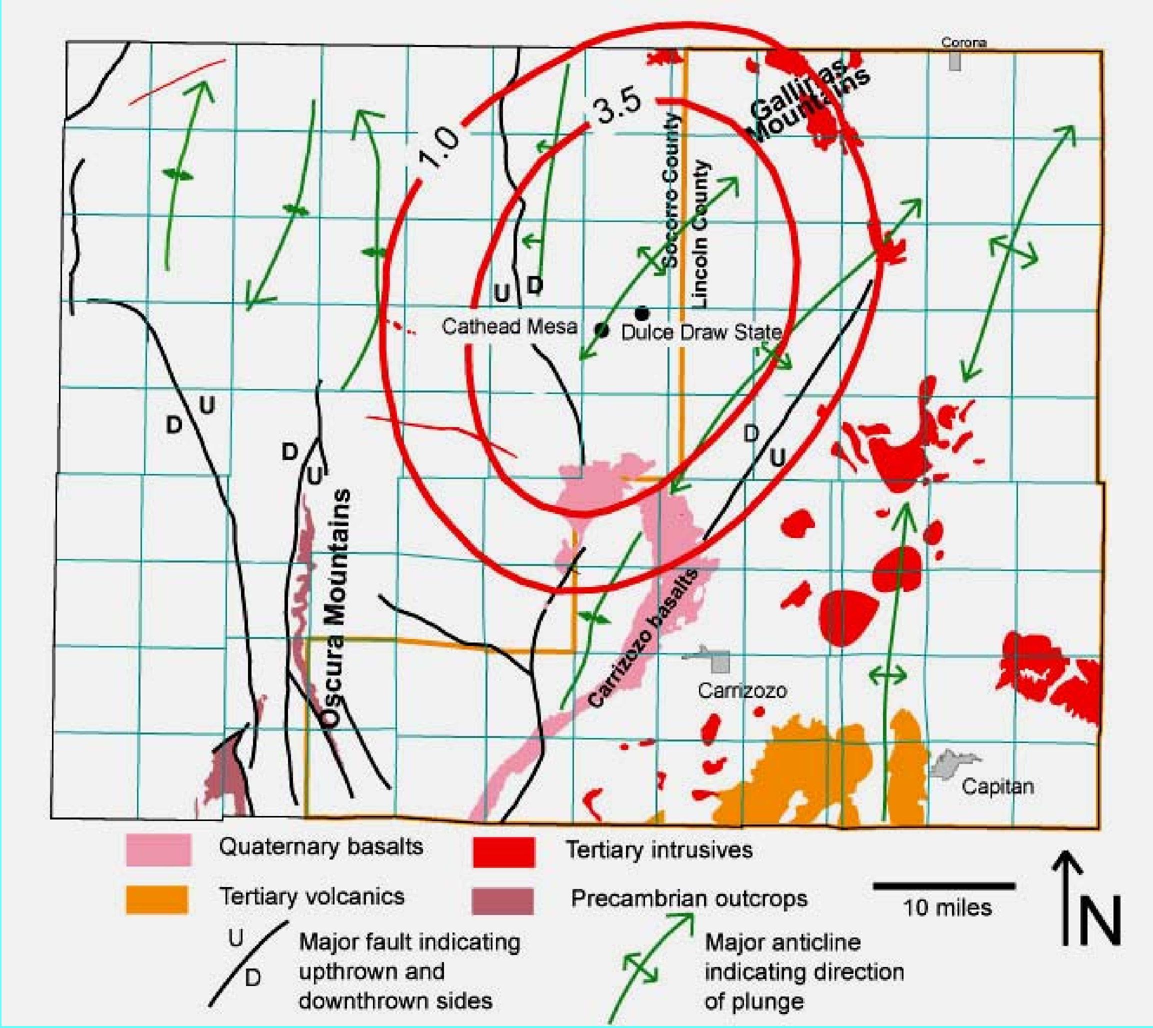
West-central New Mexico

Permian reservoirs



Chupadera Mesa

Lower Permian sandstones



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

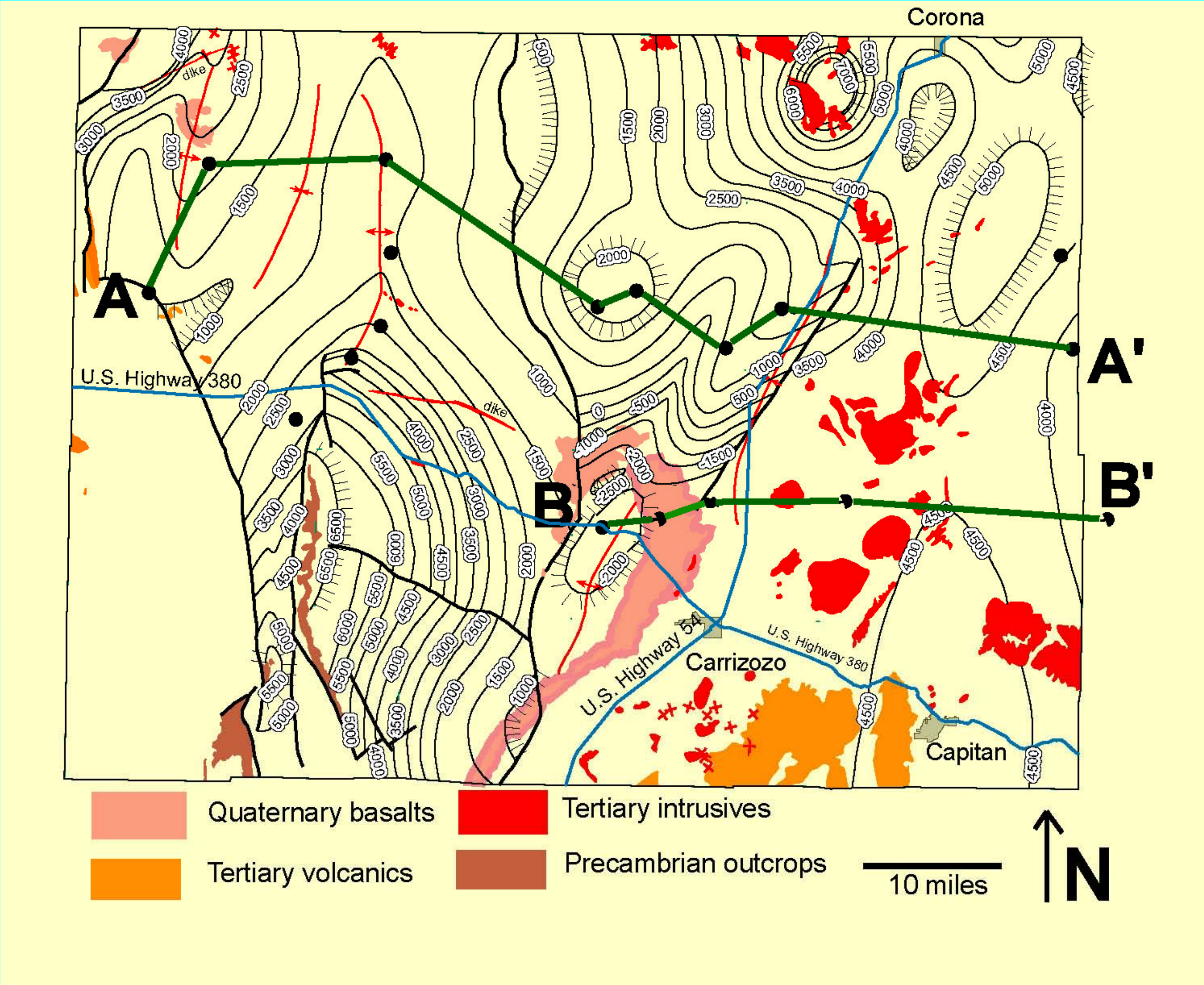
	AGE	ROCK UNITS	THICKNESS (feet)	DESCRIPTION
Permian	Leonardian	San Andres	0-500	limestone, dark gray, finely crystalline, dolostone, dark gray finely crystalline; anhydrite
		Glorieta	300	sandstone, very fine to coarse grained, white to light gray, quartzose
		Yeso	1300-2000	sandstone, orange to white, marine to marginal marine; orange shale; limestone; dolostone; gypsum; anhydrite; salt
	Wolfcampian	Abo	230-1700	shales, red, nonmarine; sandstones, red, very fine to coarse grained, arkosic, fluvial
Pennsylvanian	Virgilian	Madera	0-500	shale, gray to black; limestone, marine, lime mudstones and bioclastic wackestones; sandstone, fine to medium grained, quartzose to arkosic
	Missourian			
	Des Moinesian			
	Atokan	Sandia		sandstone, arkosic to lithic to quartzose, fine to coarse grained; shale, gray to black
	Morrowan	absent	0	
Precambrian				granodiorite,diorite,diabase, monzonite, meta-quartzite, schist, meta-arkose, meta-rhyolite

← 3.5 % He Abo

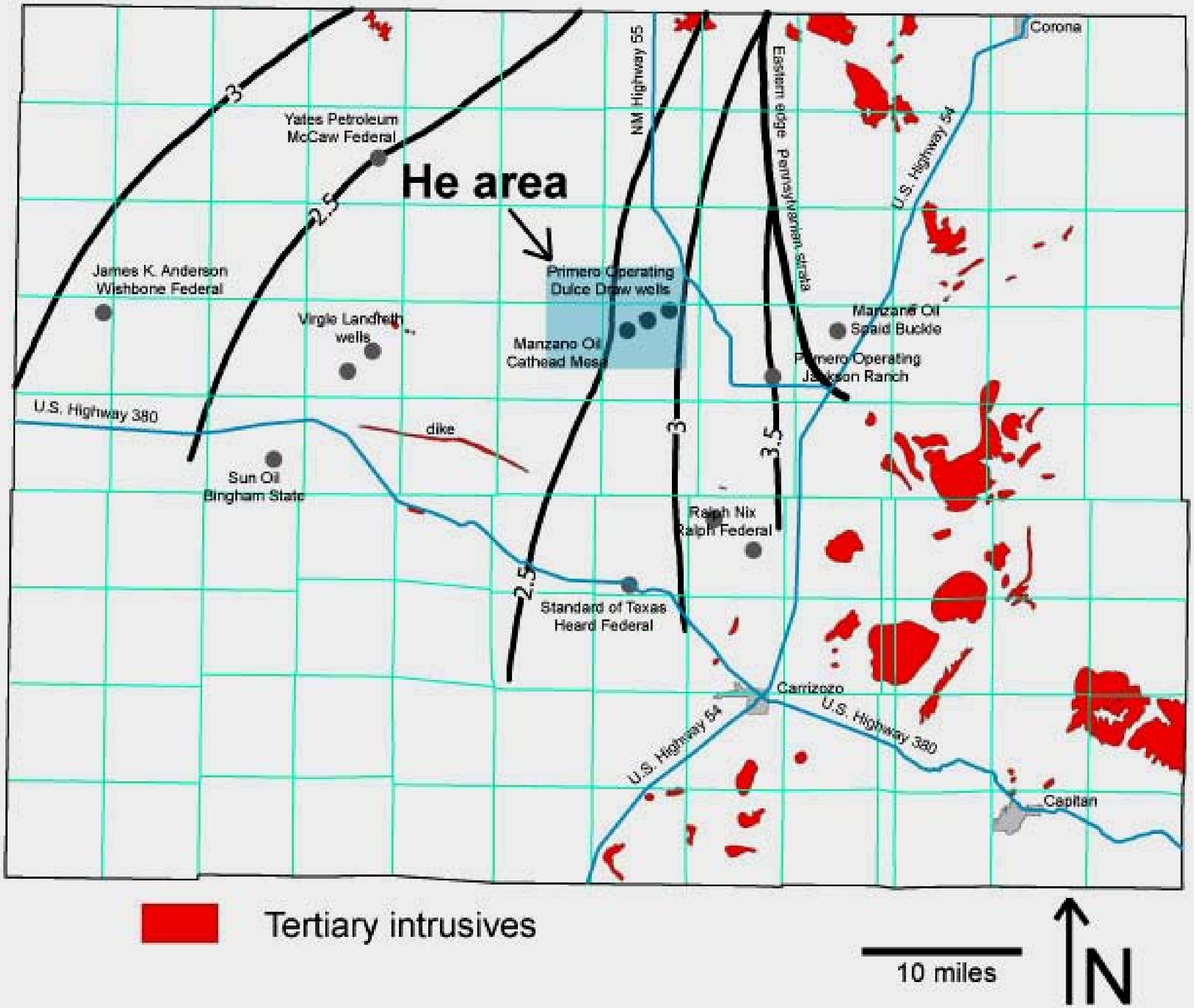
Helium isotopes Chupadera Mesa

- 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

Migration Pathways – Precambrian Structure



Pennsylvanian Source Rocks Thermal Maturity (TAI)



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.