Relationship of Helium and CO_2 to Other Gases in New Mexico Reservoirs*

Ronald F. Broadhead[1]

Search and Discovery Article #11095 (2018)**
Posted July 2, 2018

*Adapted from oral presentation at 2018 AAPG Annual Convention & Exhibition, Salt Lake City, Utah, May 20-23, 2018

[1]New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, NM (Ron.Broadhead@nmt.edu)

Abstract

Carbon dioxide is a common component of natural gases. In most New Mexico gases CO_2 is less than 1%, with either hydrocarbons or N_2 being the dominant components. In other less common gases, CO_2 is dominant and may constitute more than 99% of the gas. The major CO_2 reservoir in New Mexico is the Bravo Dome field in the northeast part of the state. This giant field with more than 10 TCF original reserves is formed by a combination structural-stratigraphic trap in the Yeso Formation (Lower Permian) and has produced 3.5 TCF CO_2. Gases that are mostly CO_2 are also present in the Las Vegas and Raton basins of north-central New Mexico and under Chupadera Mesa and in the Estancia Basin of central New Mexico and have also been encountered by exploratory wells drilled in west-central New Mexico. The main source of CO_2 appears to have been degassing of Tertiary-age magmas.

Commercial production of helium in New Mexico has been from 8 small oil and gas fields on the Four Corners Platform of northwest New Mexico. Almost 1 BCF He have been produced from reservoirs of Permian, Pennsylvanian, Mississippian and Devonian age. In southeast New Mexico gases with enhanced He content have been produced from Lower Permian Abo red beds with He content increasing in proximity to northeast-trending strike-slip faults. Gases with enhanced He content have been encountered in Lower Permian strata under Chupadera Mesa in central New Mexico and in Pennsylvanian strata in the Tucumcari Basin. Although most He in crustal reservoirs has probably been generated by radioactive decay of uranium in granitic rocks, isotopic analysis of Chupadera Mesa He indicates that a portion of the He was derived from juvenile sources in the mantle.

There is an inverse correlation between He content of gases and CO_2 content and hydrocarbon gas content. Most gases with CO_2 more than 5% have He less than 1%. All gases with CO_2 more than 20% have He less than 1%. He content also decreases with increasing BTU value of the gas, a proxy for hydrocarbon content. All gases with heating values more than 1,000 BTU/ft^3 have He substantially less than 1%. He increases with N_2 content, an indication of incomplete charge of reservoirs with either hydrocarbons or with CO_2. CO_2 and hydrocarbons appear to dilute the He that has migrated into the reservoirs from either granitic basement or via deep-seated faults that penetrate to the mantle.

References Cited

Oxburgh, E.R., R.K. O'Nions, and R.I. Hill, 1986, Helium isotopes in sedimentary basins: Nature, v. 324, p. 632-635.

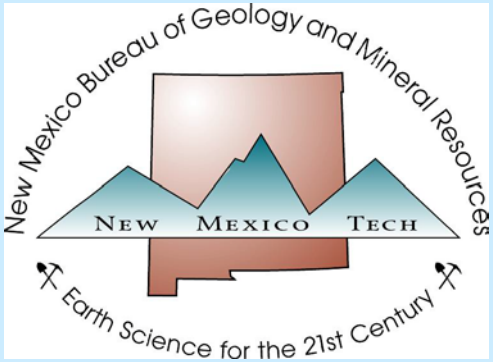
Staudacher, T., 1987, Upper mantle origin of Harding County well gases: Nature, v. 325, 605-607.

Relationship of Helium and CO_2 to other Gases in New Mexico Reservoirs

Ron Broadhead

New Mexico Bureau of Geology and Mineral Resources

A Division of New Mexico Tech



AAPG Annual Meeting, May 2018

Outline of Talk

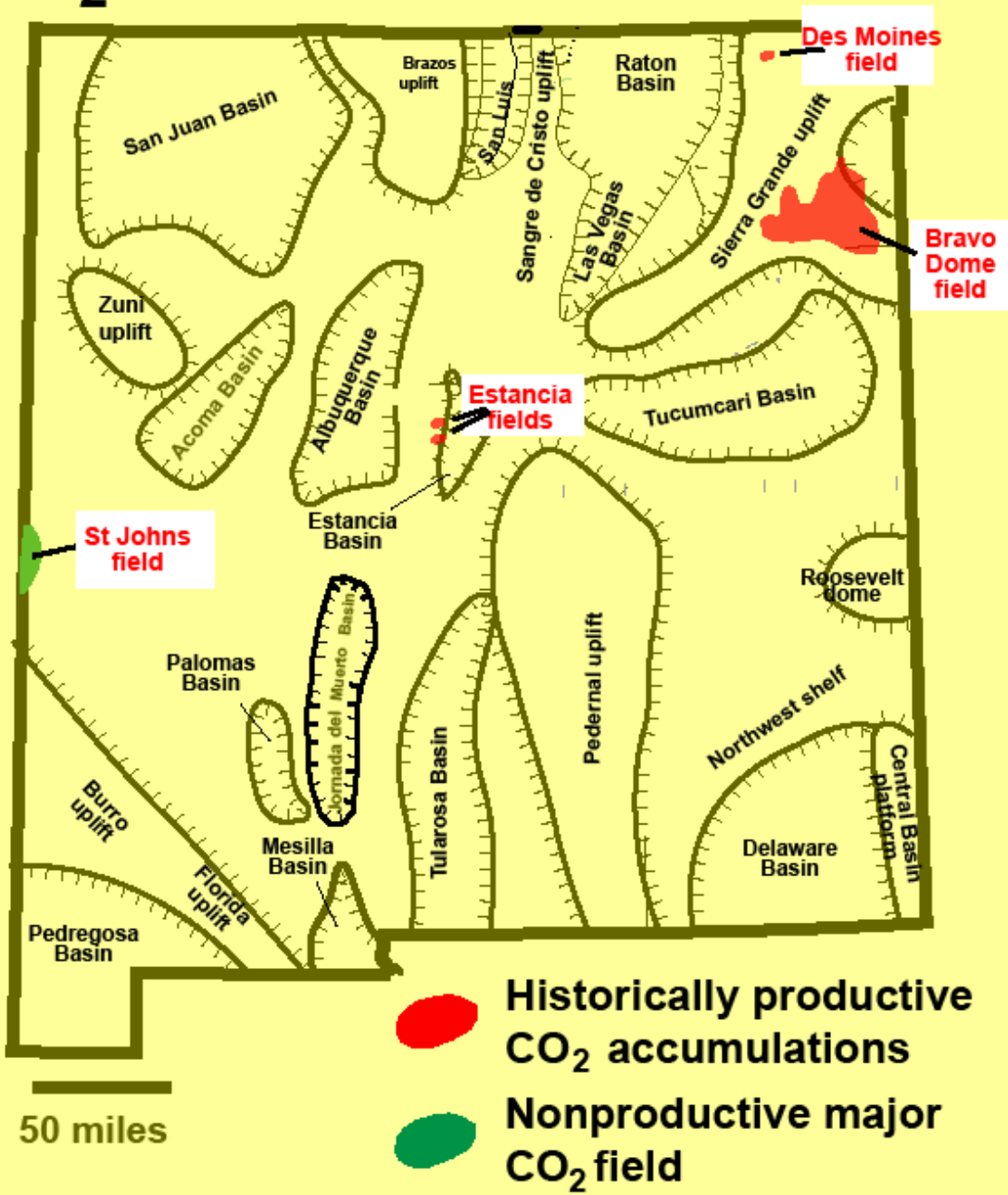
- Summary of sources of different gas types
- CO_2 -rich gases, distribution and geology
- He –rich gases, distribution and geology
- Relationships of CO_2 and He to hydrocarbons and N_2 in New Mexico reservoirs

Summary of gas sources and flux rates

Gas	Source (NM)	Flux Rate
Helium (^{4}He) (relatively common)	radioactive decay of **U** and **Th** in granitic basement	slow
Helium (^{3}He) (relatively rare)	migration from mantle along deep-seated extensional faults	slow-medium?
CO_2	exsolution from rising magmas	fast (geologic burp)
Hydrocarbon gases	source-rock maturation	medium
Nitrogen (major)	degassing of basement	slow
Nitrogen (minor)	early-stage maturation of woody kerogen	medium

CO_2-rich gases in New Mexico

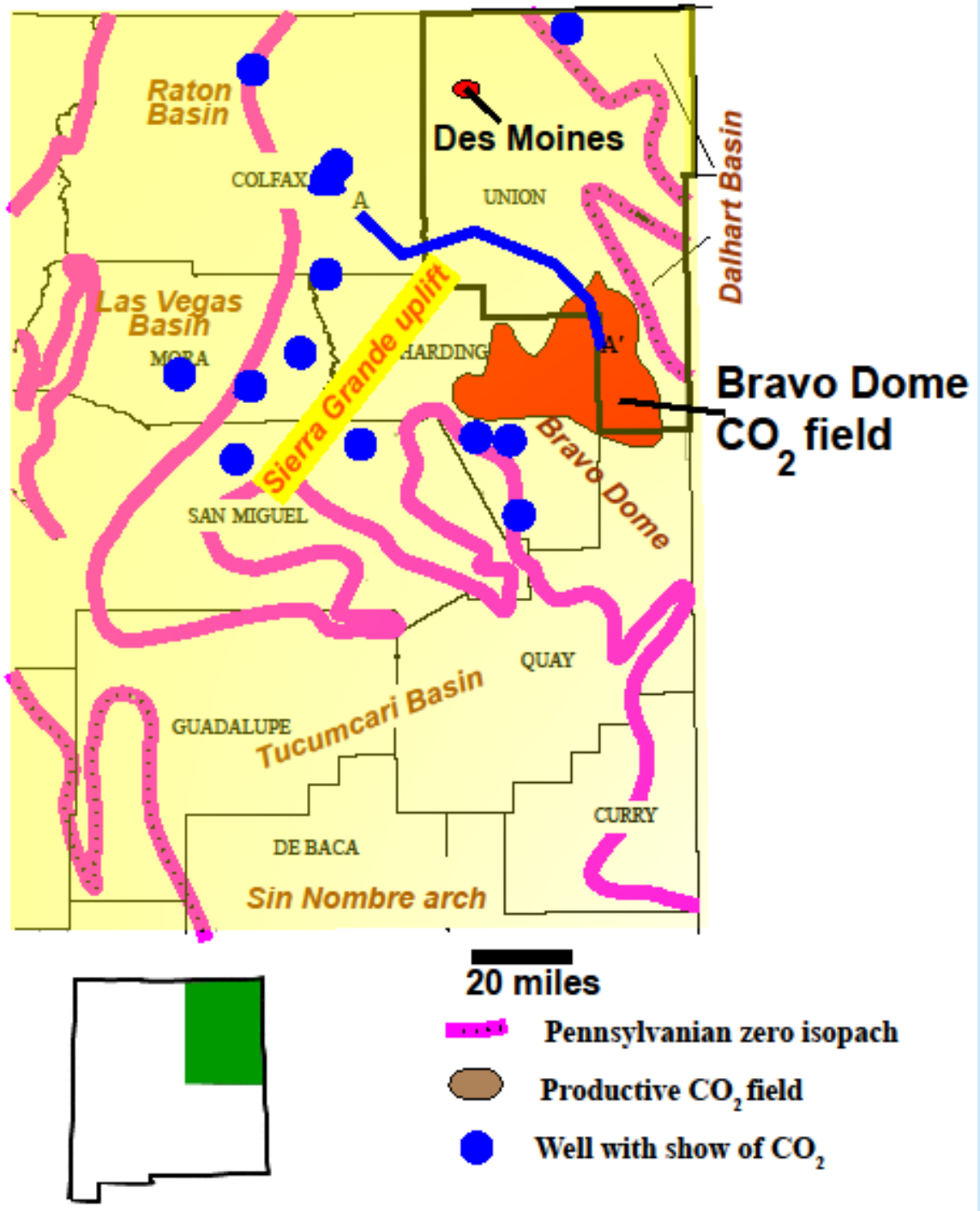
CO_2 Fields in New Mexico

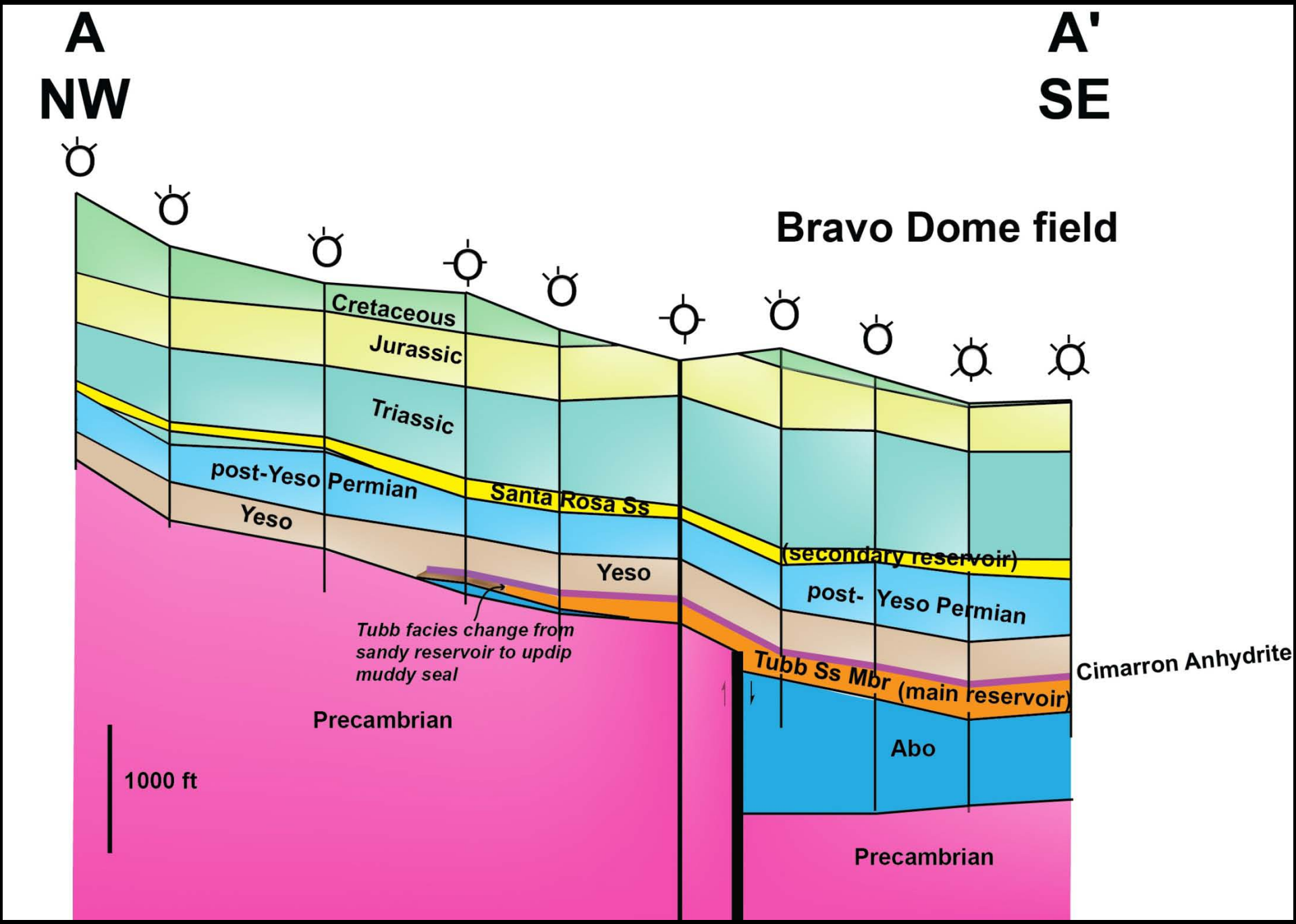


Bravo Dome CO_2 field

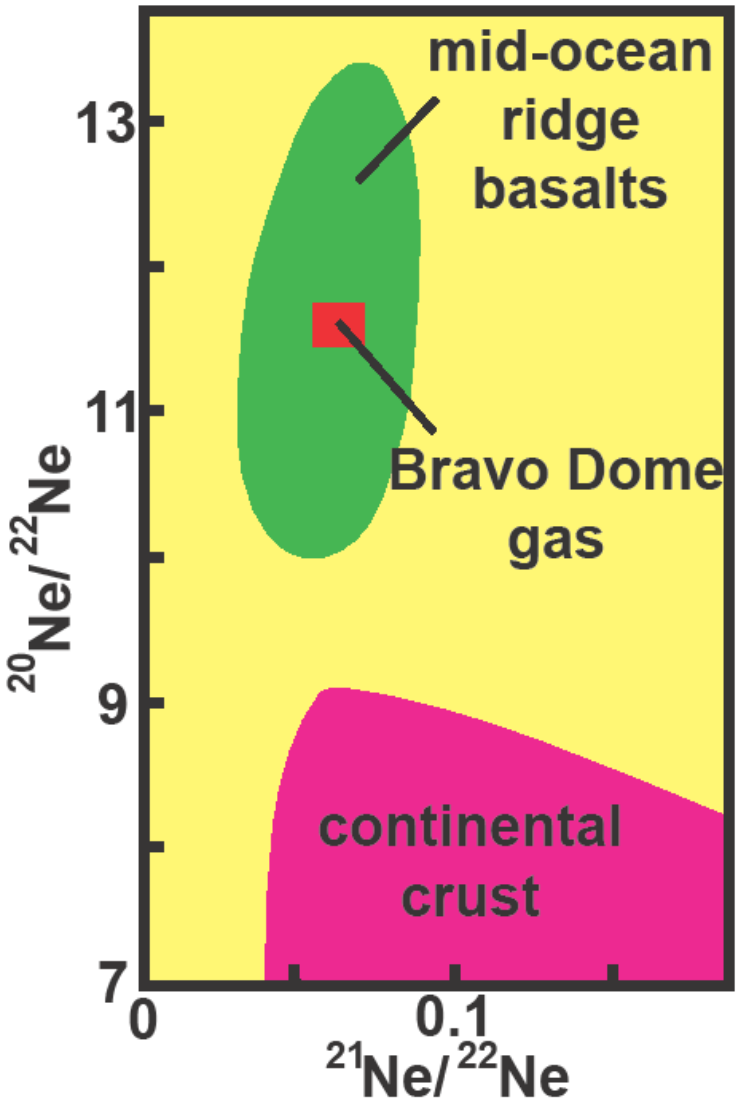
3.5 TCF production,

- **99% CO_2;**
- **Tr – 0.1% He**




A
NW
A'
SE
Bravo Dome field
Cretaceous
Jurassic
Triassic
post-Yeso Permian
Yeso
Santa Rosa Ss
Yeso
(secondary reservoir)
post- Yeso Permian
Tubb facies change from sandy reservoir to updip muddy seal
Tubb Ss Mbr (main reservoir)
Cimarron Anhydrite
Abo
Precambrian
Precambrian
1000 ft

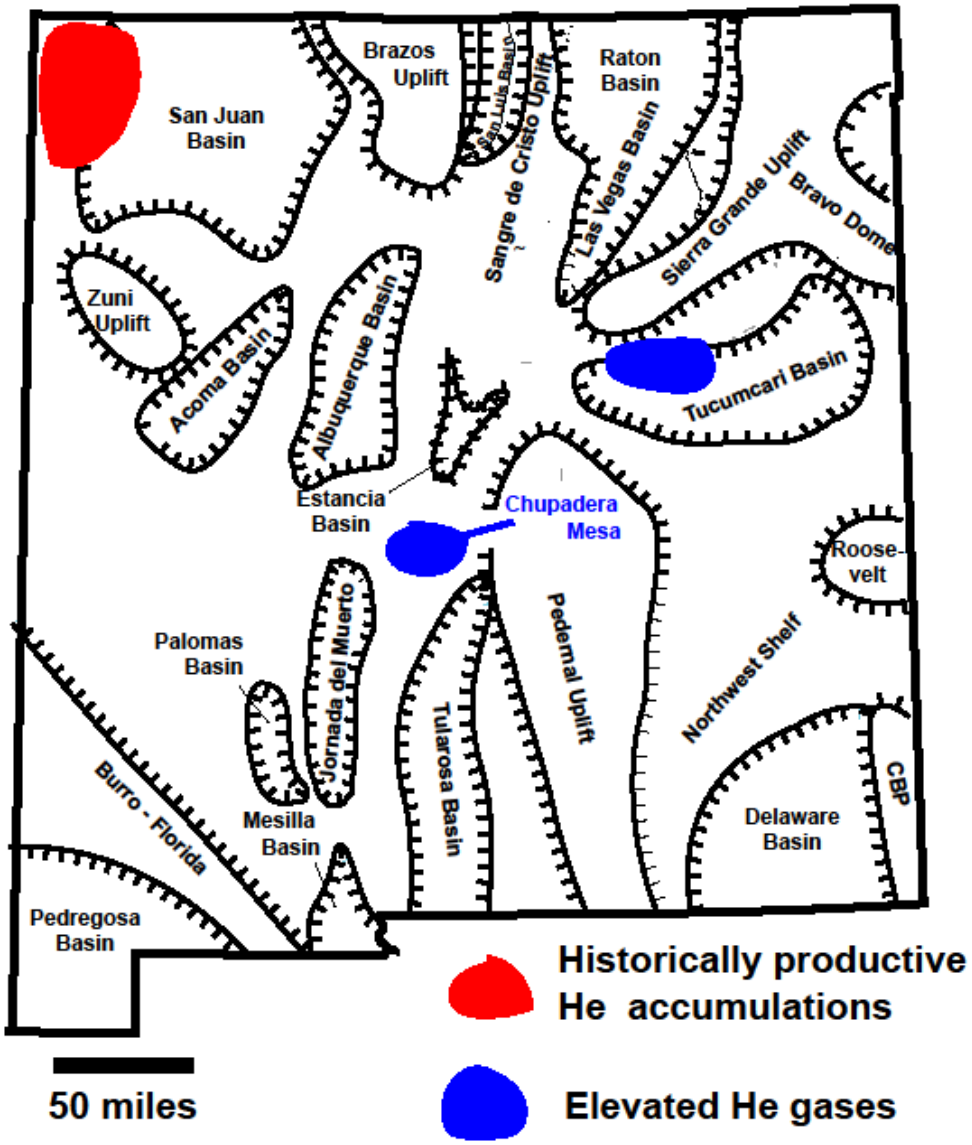
Noble gases in Bravo Dome CO_2

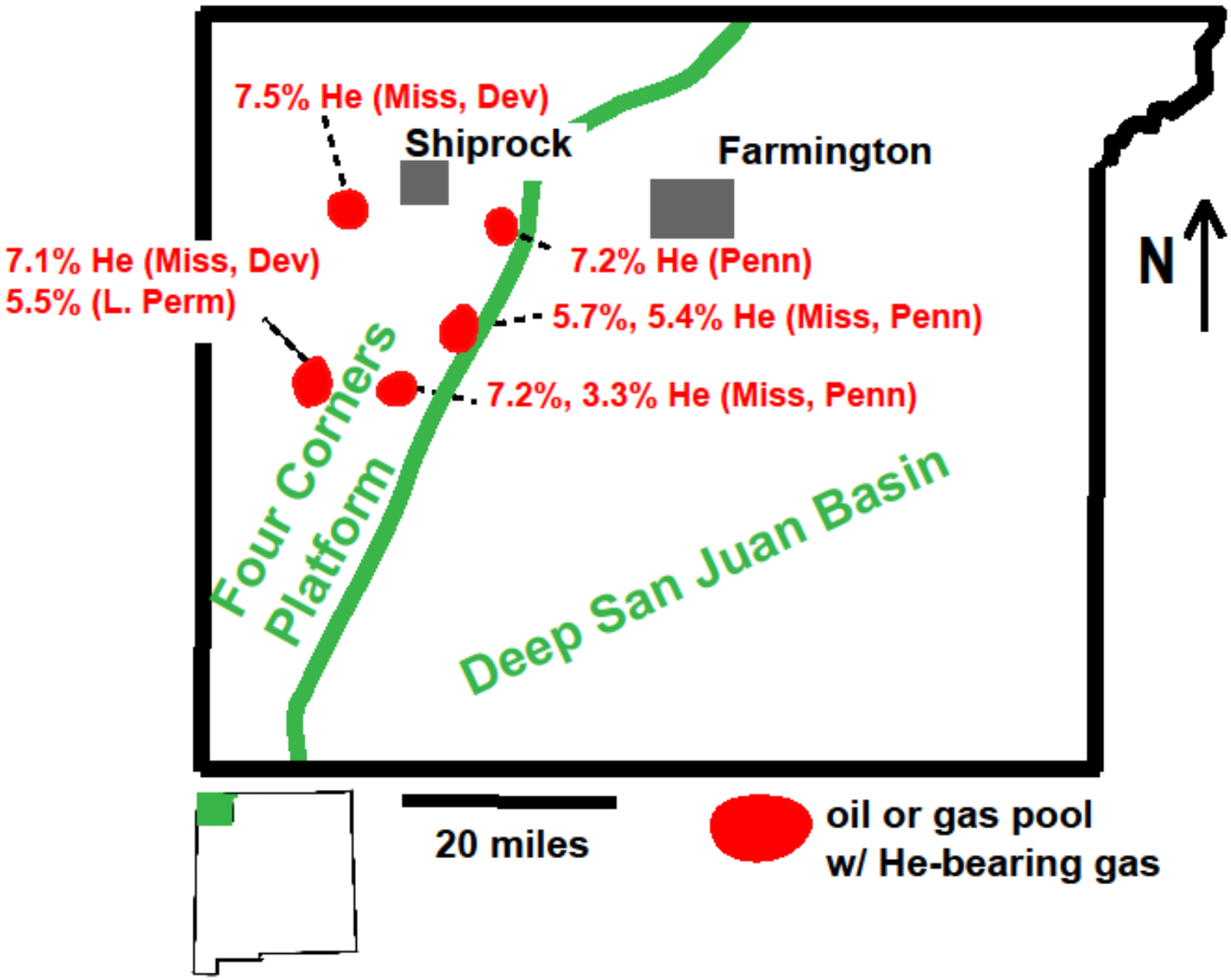


After Staudacher (1987)

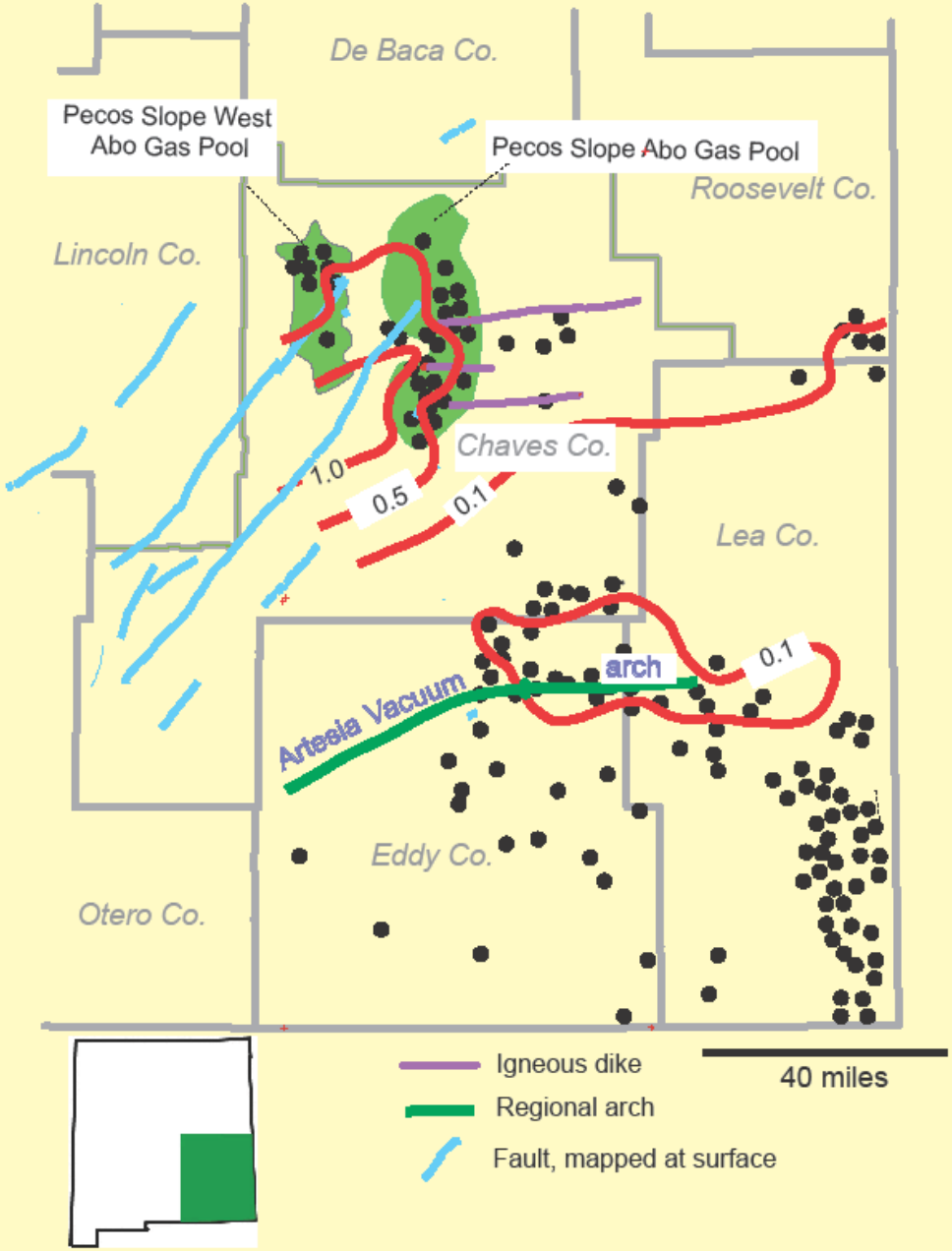
Helium-rich gases in New Mexico

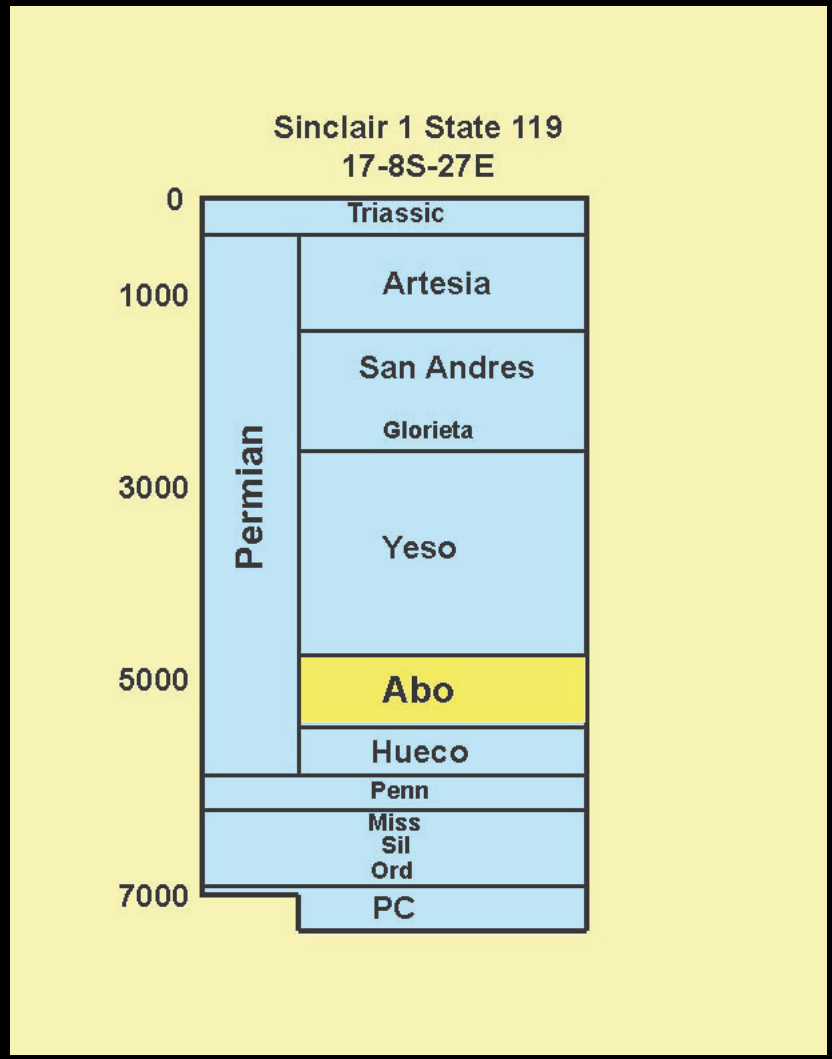
Helium in New Mexico



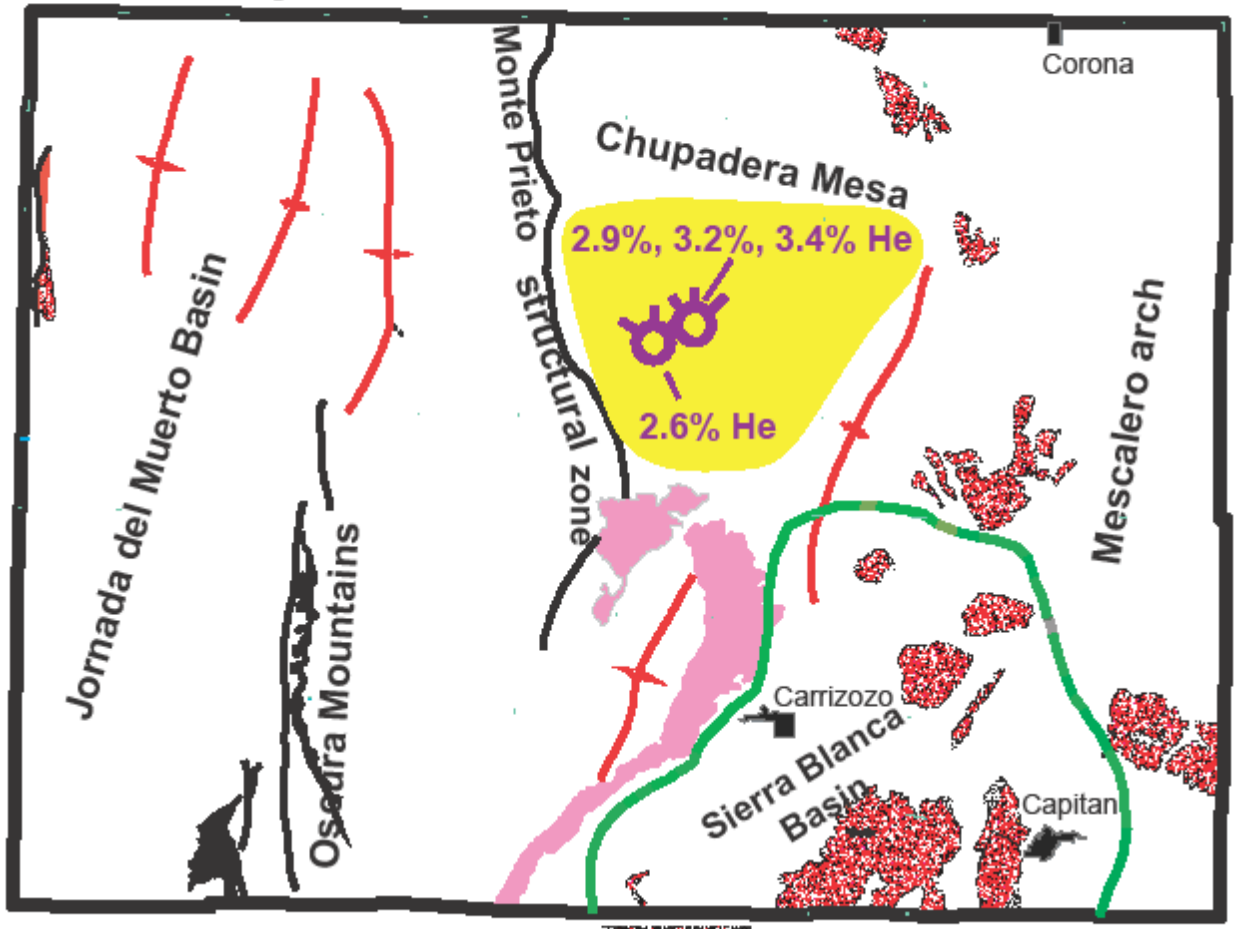

7.5% He (Miss, Dev)
Shiprock
Farmington
7.1% He (Miss, Dev)
5.5% (L. Perm)
7.2% He (Penn)
5.7%, 5.4% He (Miss, Penn)
7.2%, 3.3% He (Miss, Penn)
Four Corners Platform
Deep San Juan Basin
N
20 miles
oil or gas pool
w/ He-bearing gas

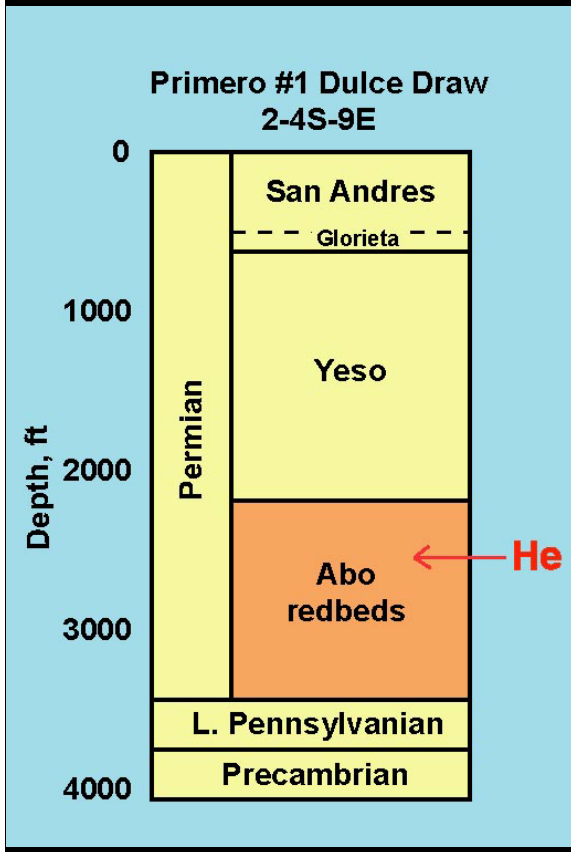
He in Permian, southeast New Mexico





Chupadera Mesa He Occurrences





Helium isotopes Chupadera Mesa

R = ratio of $^{3}He/^{4}He$ normalized to air (1.39×10^{-6})

$R_{chupadera} = 0.515$

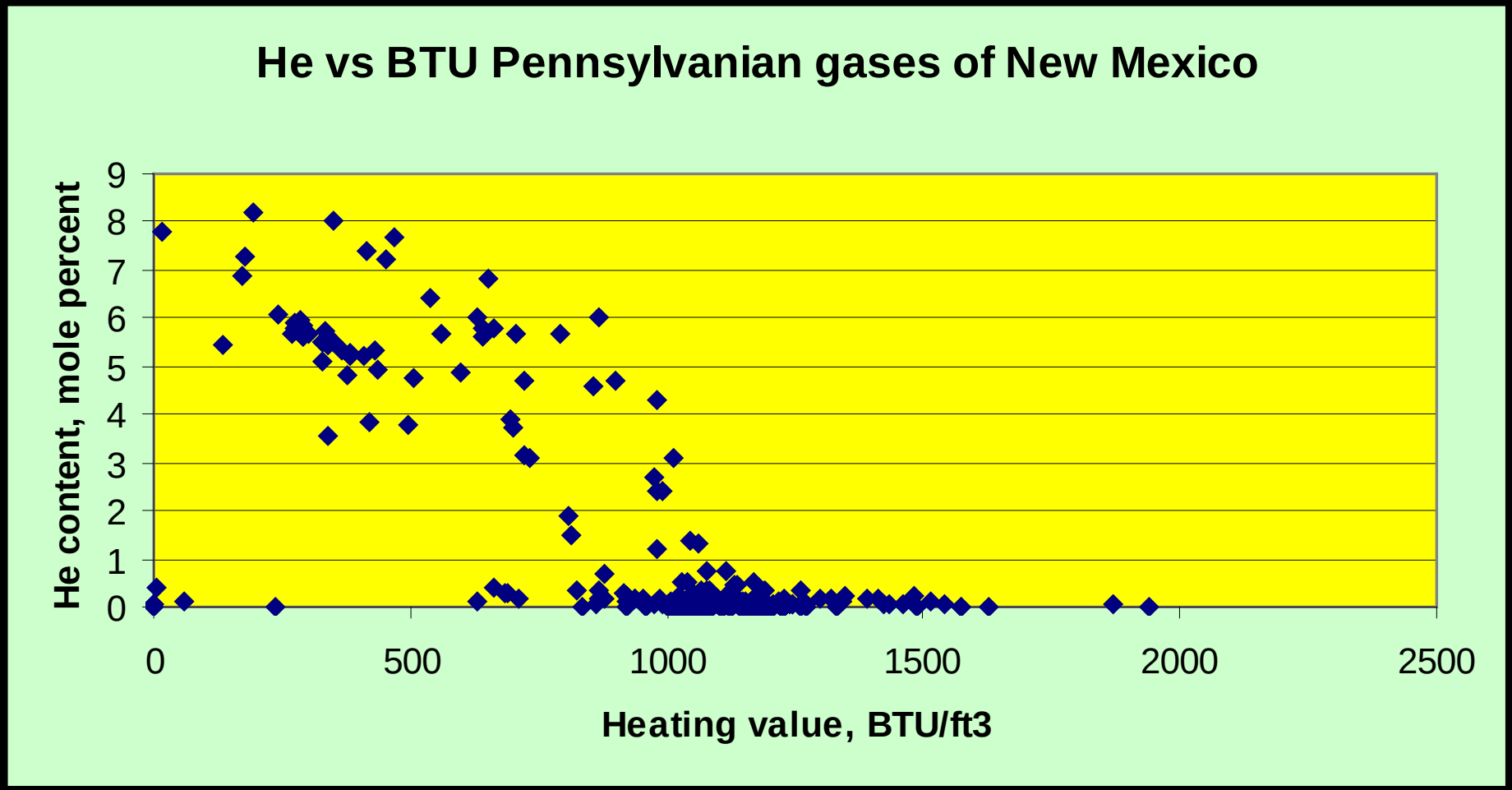
For mantle He $6 < R < 10$ (Oxburgh et al, 1986)

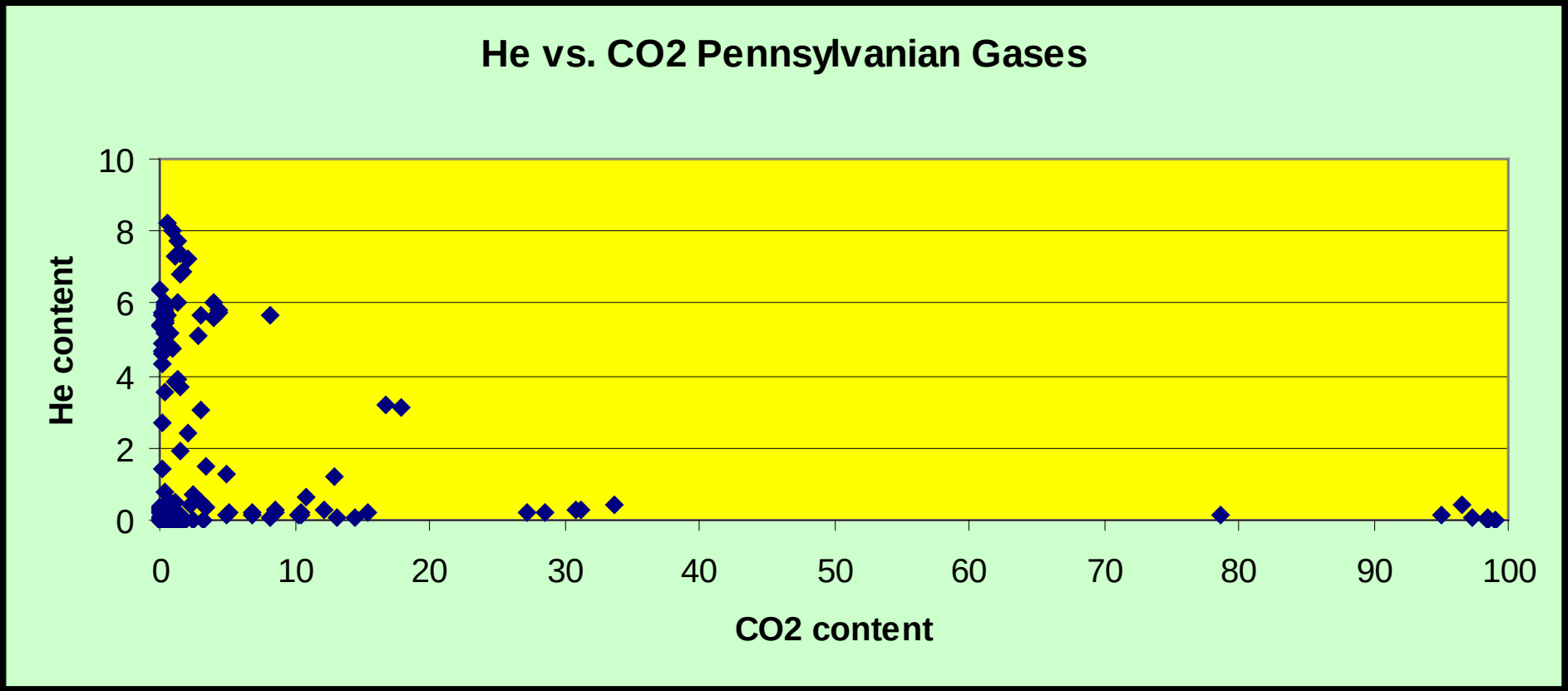
For most crustal He $R < 0.08$ (Oxburgh et al, 1986)

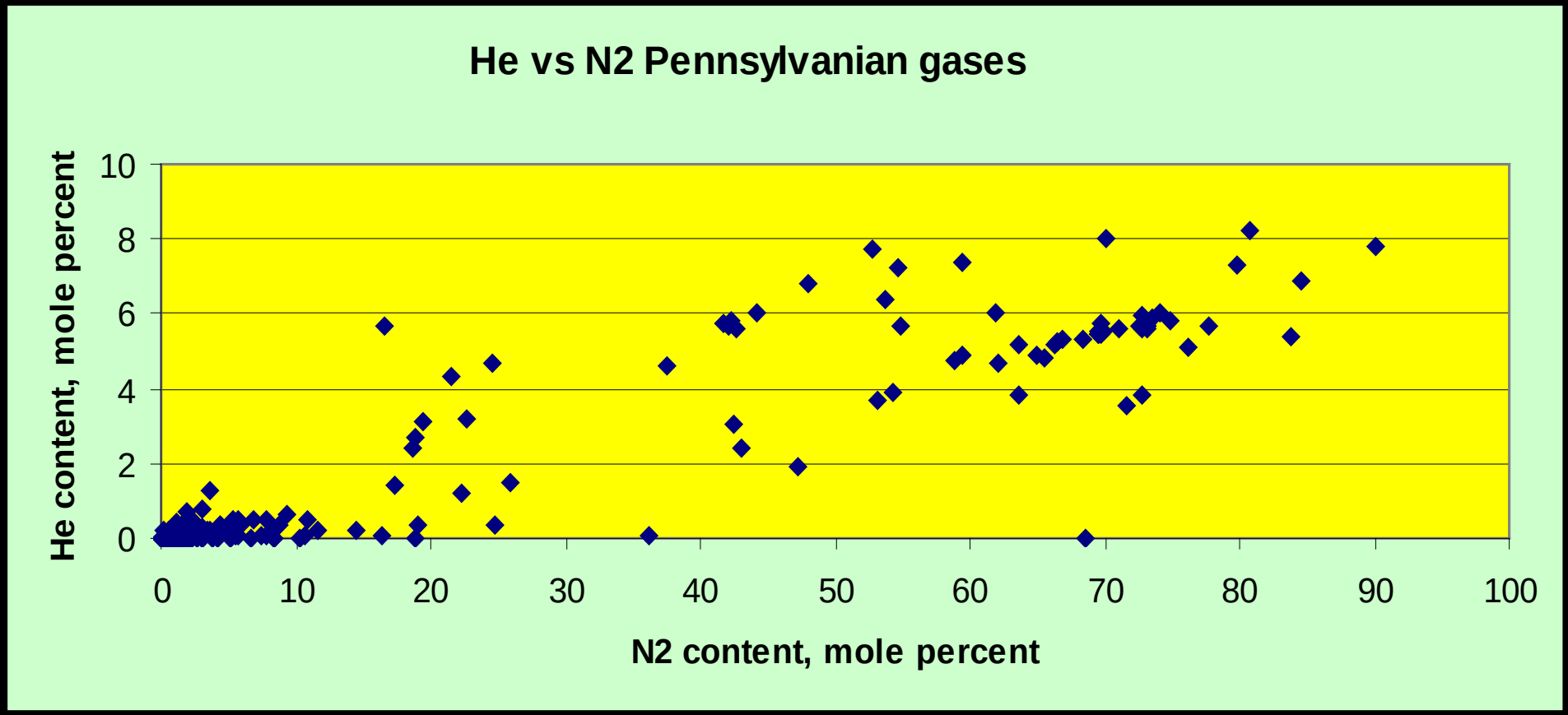
Strongly suggestive that part (6.2%) of Chupadera He is mantle-derived.

Remainder of Chupadera He is crustal.

Relationships of CO_2 & He to hydrocarbons and N_2


He vs BTU Pennsylvanian gases of New Mexico
He content, mole percent
0
1
2
3
4
5
6
7
8
9
0
500
1000
1500
2000
2500
Heating value, BTU/ft3


He vs. CO2 Pennsylvanian Gases
He content
10
8
6
4
2
0
0
10
20
30
40
50
60
70
80
90
100
CO2 content


He vs N2 Pennsylvanian gases
He content, mole percent
10
8
6
4
2
0
0
10
20
30
40
50
60
70
80
90
100
N2 content, mole percent

Summary

- **Gases that contain >99% CO_2 have been produced from the Bravo Dome field, where the main reservoir is a Lower Permian sandstone. Trap is combination structural-stratigraphic. Production is 3.5 TCF.**
- **The CO_2 is juvenile, derived from degassing of rising magmas.**
- **Commercial production of helium in New Mexico has been from 8 small oil & gas reservoirs on the Four Corners Platform. Cumulative production has been 1 BCF He.**
- **^{4}He is dominant and is sourced by radioactive decay in the crust, chiefly from granitic rocks.**
- **^{3}He is juvenile, derived from the mantle**
- **In Lower Permian reservoirs in southeast New Mexico, He percentage increases with increasing proximity to strike-slip faults which presumably acted as migration pathways from the basement.**

Summary (cont'd)

- **Lower Permian sandstone reservoirs under Chupadera Mesa contain gases with up to 3.4% He, the highest concentrations in New Mexico outside of the Four Corners Platform**
- **He isotope analyses suggest that part of the Chupadera He is crustally derived and part is juvenile, from the mantle.**
- **He content of gases decreases with increasing hydrocarbon content, suggesting that migrating hydrocarbons dilute the He in the reservoirs.**
- **He content > 1% is uncommon in reservoirs with CO_2 > 5%, suggesting that volcanic CO_2 charging dilutes crustal or mantle-derived He.**
- **He content of gases increases with increasing N_2 content, suggesting that incomplete reservoir charge with HC's or CO_2 may be necessary for high He gases.**