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Farnham Dome and Grassy Trails Fields, Utah

CO_2 accumulation sources and migration paths

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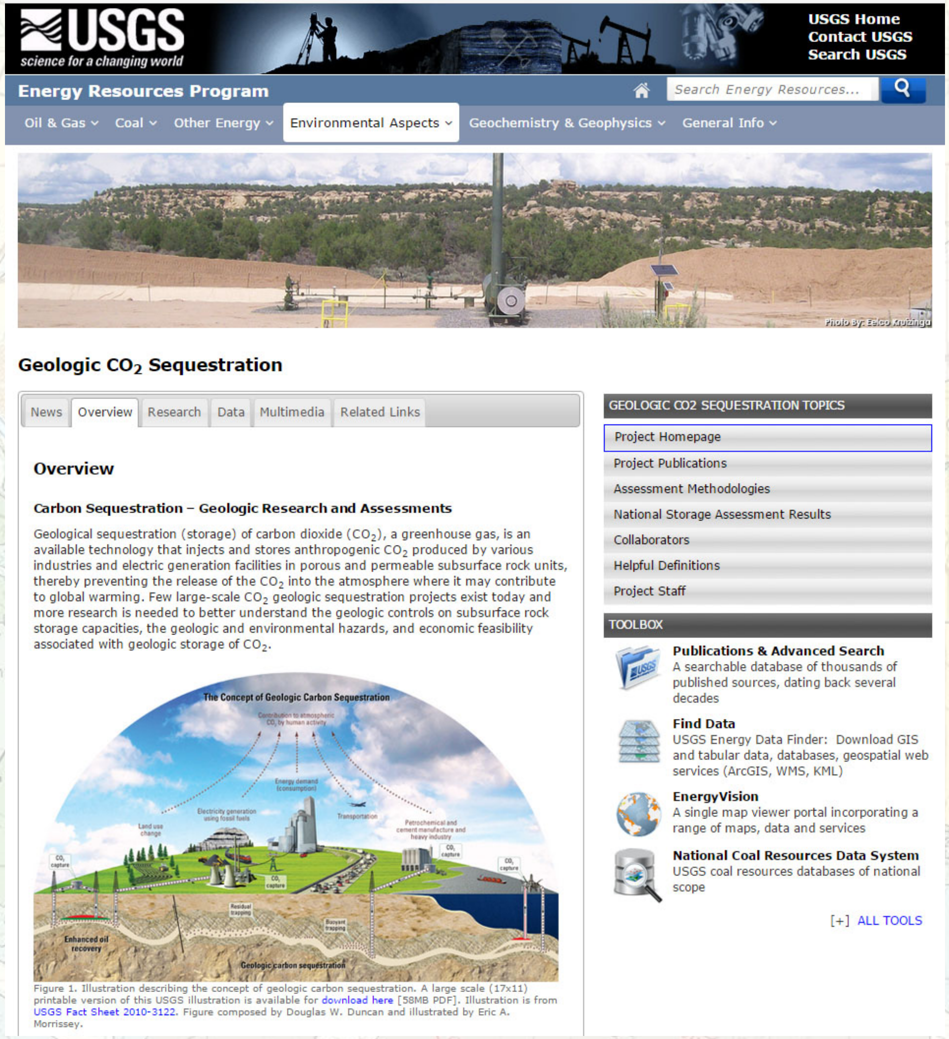
USGS - Natural CO_2 and Helium

Reservoirs and analogues for anthropogenic CO_2 storage

- Energy Independence and Security Act of 2007
- Helium Stewardship Act of 2013
- USGS Energy Resources program
  - with support from the USGS Climate and Land Use Change mission area



Why?

- The source of the CO_2 at these fields is unknown. Increased CO_2- enhanced oil recovery (EOR) in the Rocky Mountain region has led to growing interest in local CO_2 supplies.

- Use this study as a test of the Total Carbon Dioxide Systems (TCDS) concept.
  - Research framework for natural accumulations of CO_2 from which geologically grounded, organized, scale-able, and comparable investigations can be conducted.

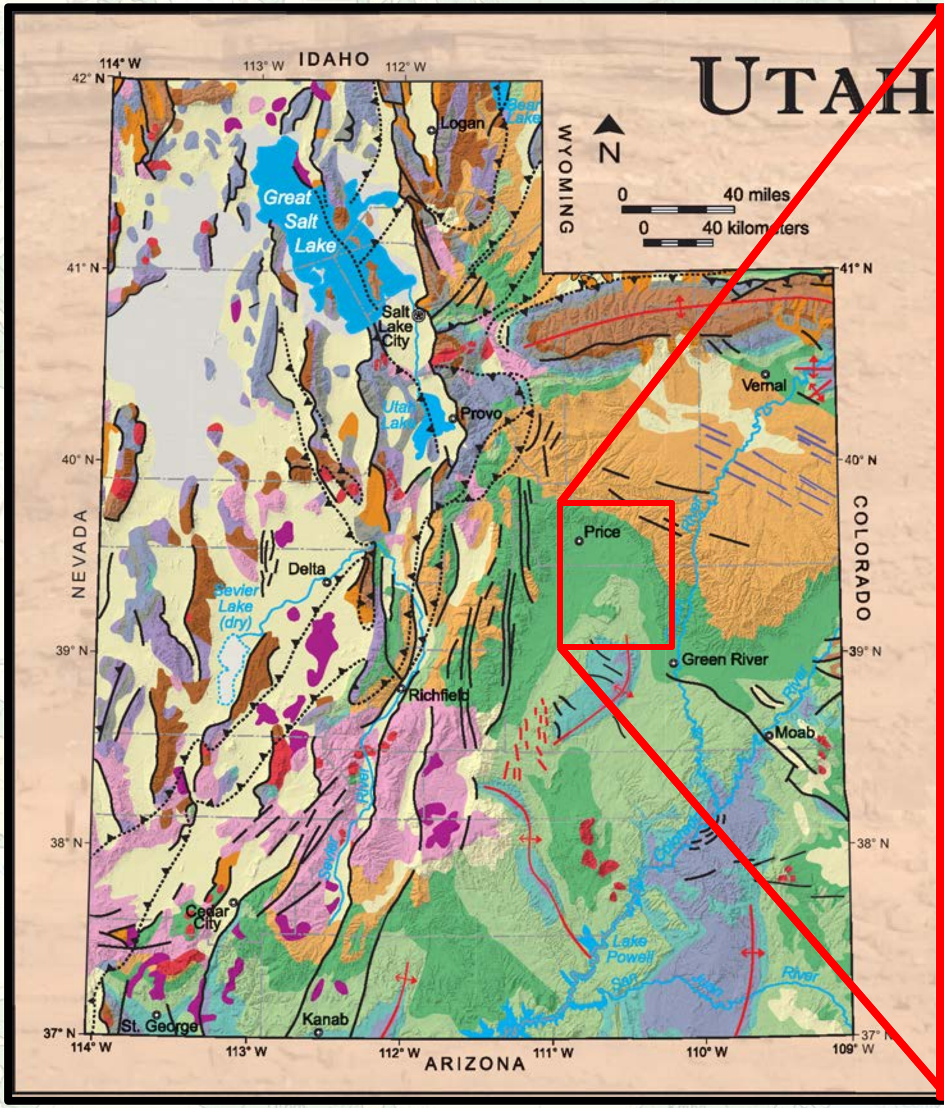
Goal

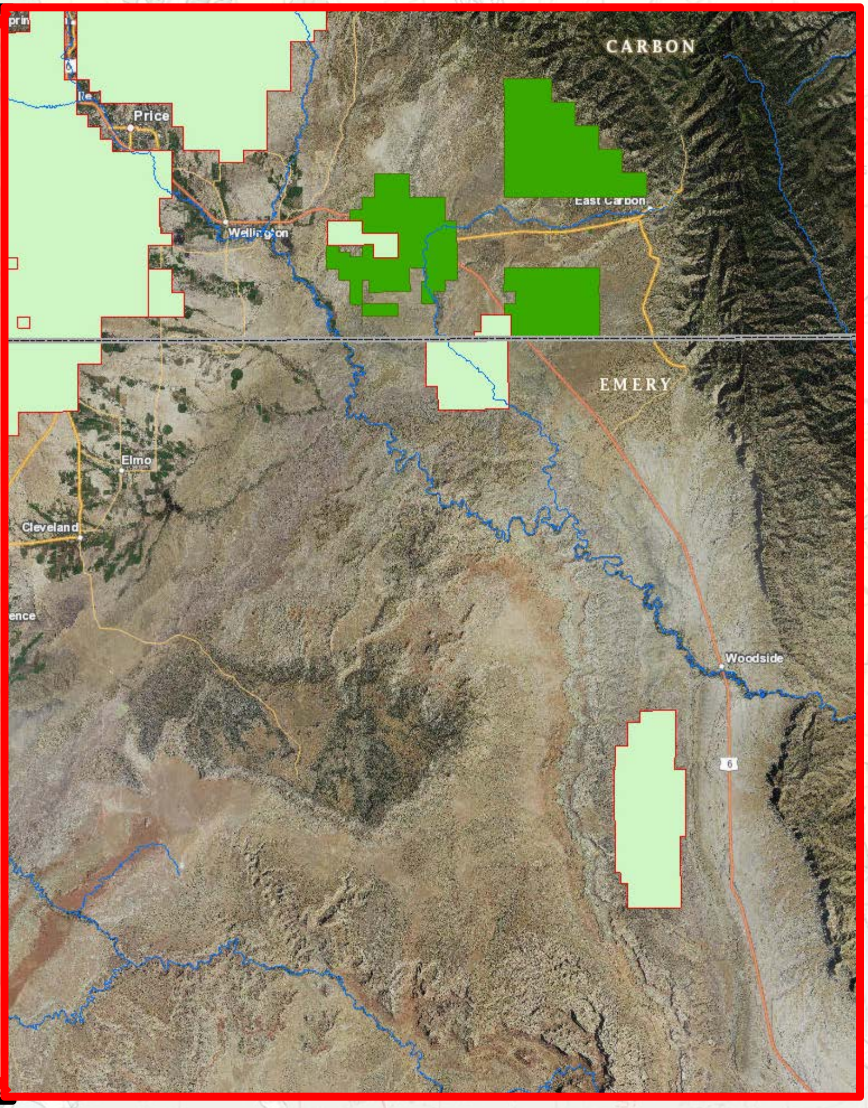
1. Where does the CO_2 in these fields come from?

2. Use gas geochemistry and field geology from Farnham Dome and Grassy Trails fields to identify and group related natural CO_2 accumulations into a Total Carbon Dioxide System (TCDS).

    - Focus on defining a common source, migration path, trapping method and timing of events.

San Rafael Swell Region





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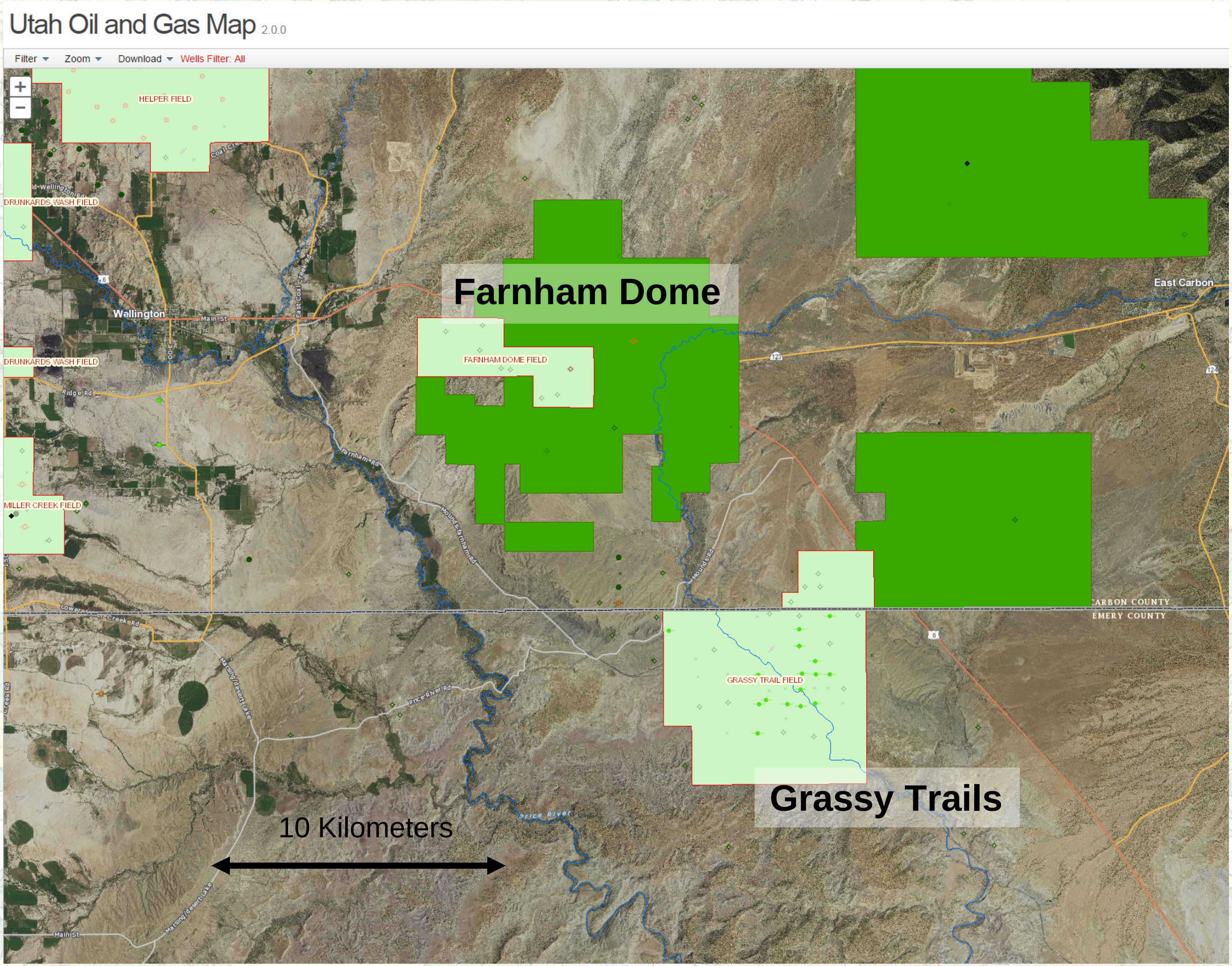
Interactive Utah Oil & Gas Well Locator Map



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Interactive Utah Oil & Gas Well Locator Map, accessed 10/16/2014

CO_2 Origin Unknown

Sources of CO_2 at Farnham Dome are unknown and may have come from a variety of sources.

–Morgan (2007)

Current hypotheses in the literature specific to CO_2 sources for Farnham Dome or Grassy Trails fields…

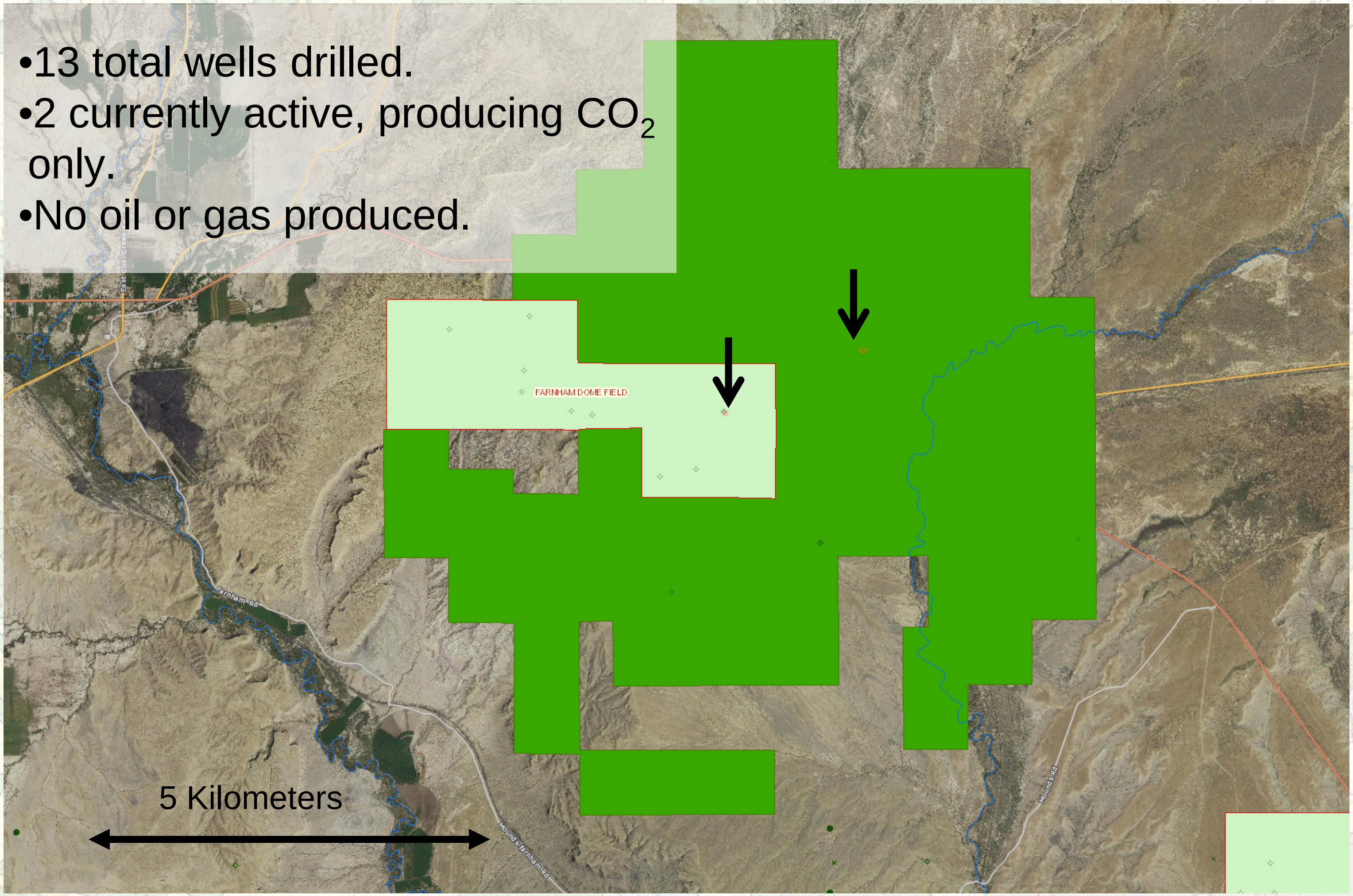
1. Thermal decomposition of Paleozoic sediments in the Uinta Basin from burial depth.
2. Thermal decomposition of carbonates via heat from igneous intrusives or extrusives.

Additional potential sources

3. Basement degassing
4. Thermo-chemical sulfate reduction of hydrocarbons

Farnham Dome

- 13 total wells drilled.
- 2 currently active, producing CO_2 only.
- No oil or gas produced.



Production at Farnham Dome

Glen Canyon Group
-**Navajo Sandstone**

-Wingate Sandstone

Moenkopi Formation
-Sinbad Limestone

Park City Formation
White Rim Sandstone

Pennsylvanian
-undifferentiated

Samples →

CO$_2$ reservoir

CRET. (part)	Cedar Mtn Fm	Upper member	150-750
		Buckhorn Ce Mbr	0-50
JURASSIC	Morrison Formation		800
	Summerville Formation		120-180
	Curtis Formation		140-180
	Entrada Formation		150-950
	Carmel Formation		300-700
	Page Sandstone		70
	Navajo Sandstone		150-300
	Kayenta Formation		120-200
	Wingate Sandstone		300-400
TRIASSIC	Chinle Fm	Upper member	200-300
		Moss Back Mbr	20-60
	Moenkopi Fm	Upper member	550-700
		Sinbad Ls Mbr	50
		Black Dragon Mbr	250-350
PERMIAN	Black Box Dolomite		170
	White Rim Sandstone		500-700
	Pakoon Dolomite		650-800
PENN	Callville Limestone		250-300
MISS	Doughnut Formation		600-700
	Humbug Formation		400-500
	Redwall Dolomite		750-970
DEV	Pinyon Peak Ls		20
	Ouray Formation		110-160
CAMB	Cambrian dolomite		350
	Ophir Shale		200
	Tintic Quartzite		210
pC (PROT)	Crystalline basement		NULL

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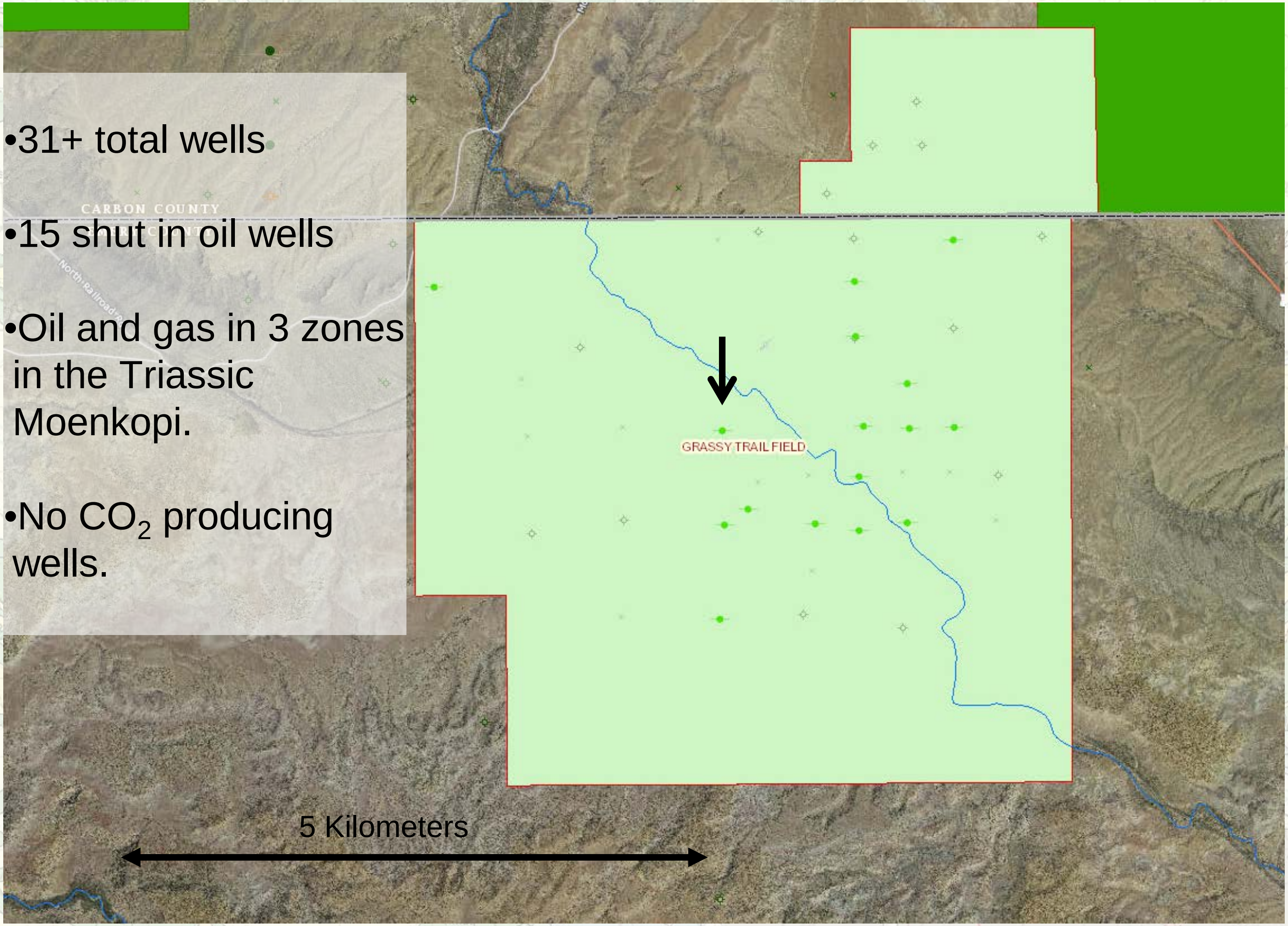
Morgan, 2007; UtahGeology.com, accessed 10/16/2014

Grassy Trails

- 31+ total wells
- 15 shut in oil wells
- Oil and gas in 3 zones in the Triassic Moenkopi.
- No CO_2 producing wells.



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Production at Grassy Trails

Glen Canyon Group
-**Navajo Sandstone**

Moenkopi Formation
-Torrey Member
-Black Dragon Member

Samples →

CRET. (part)	Cedar Mtn Fm	Upper member	150-750
		Buckhorn Cg Mbr	0-50
JURASSIC	Morrison Formation		800
	Summerville Formation		120-180
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CO_2 reservoir

Oil and gas reservoir

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Morgan, 2007; UtahGeology.com, accessed 10/16/2014

Samples

Isotopic analysis, which would help identify possible sources, is unavailable for these fields.
-Morgan and Chidsey Jr. (1991)

Additional work is needed to understand the source and timing of entrapment of CO_2 and the quality of the seals that have trapped the gas for tens of millions of years.
-Morgan (2007)

Farnham Dome

- 4 samples from the 2 active wells in the field.
- Sampled in 2014 and 2015

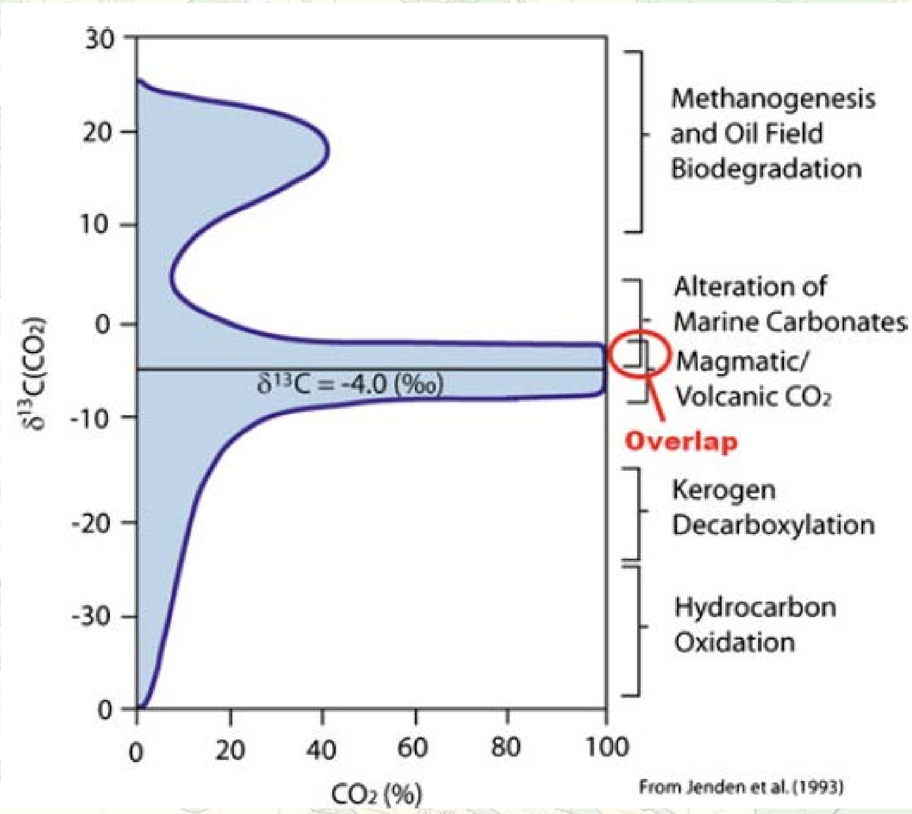
- Four gas composition analyses provided by the operator.

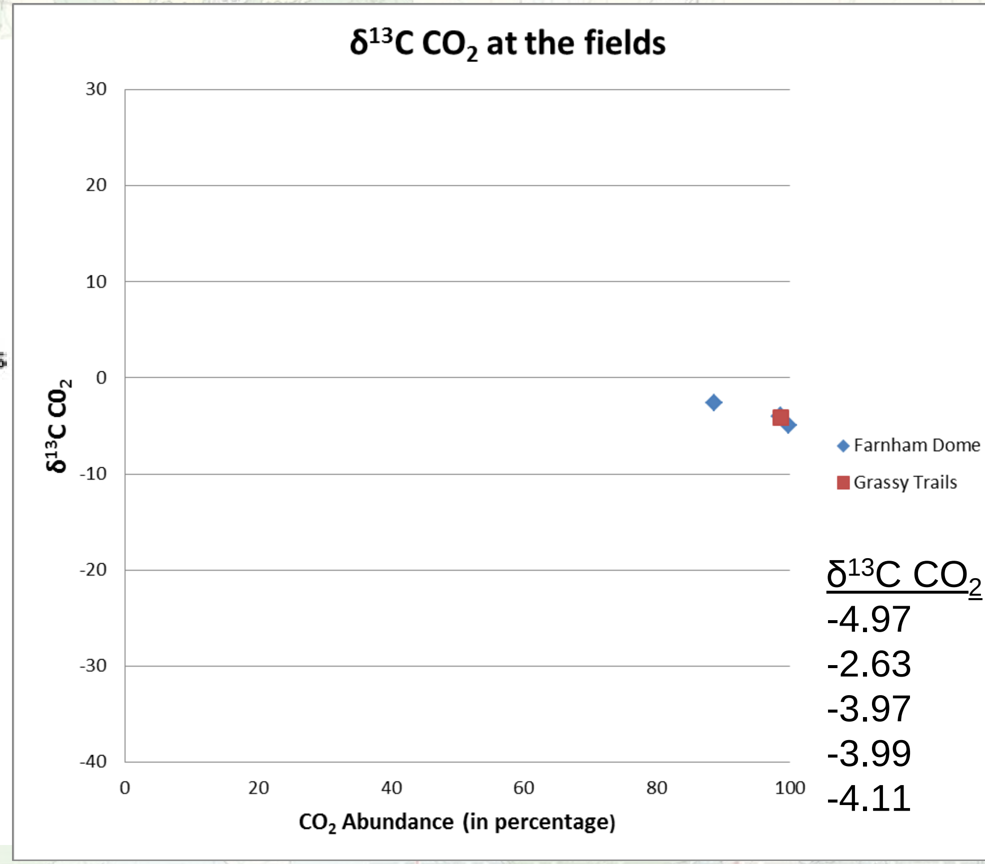
Grassy Trails

- 1 sample
- Operator collected CO_2 from Navajo for this study.
- This is the first analysis of CO_2 from this field.

Gas composition : Stable isotope (H, C, N, O, S) : Noble gas isotope

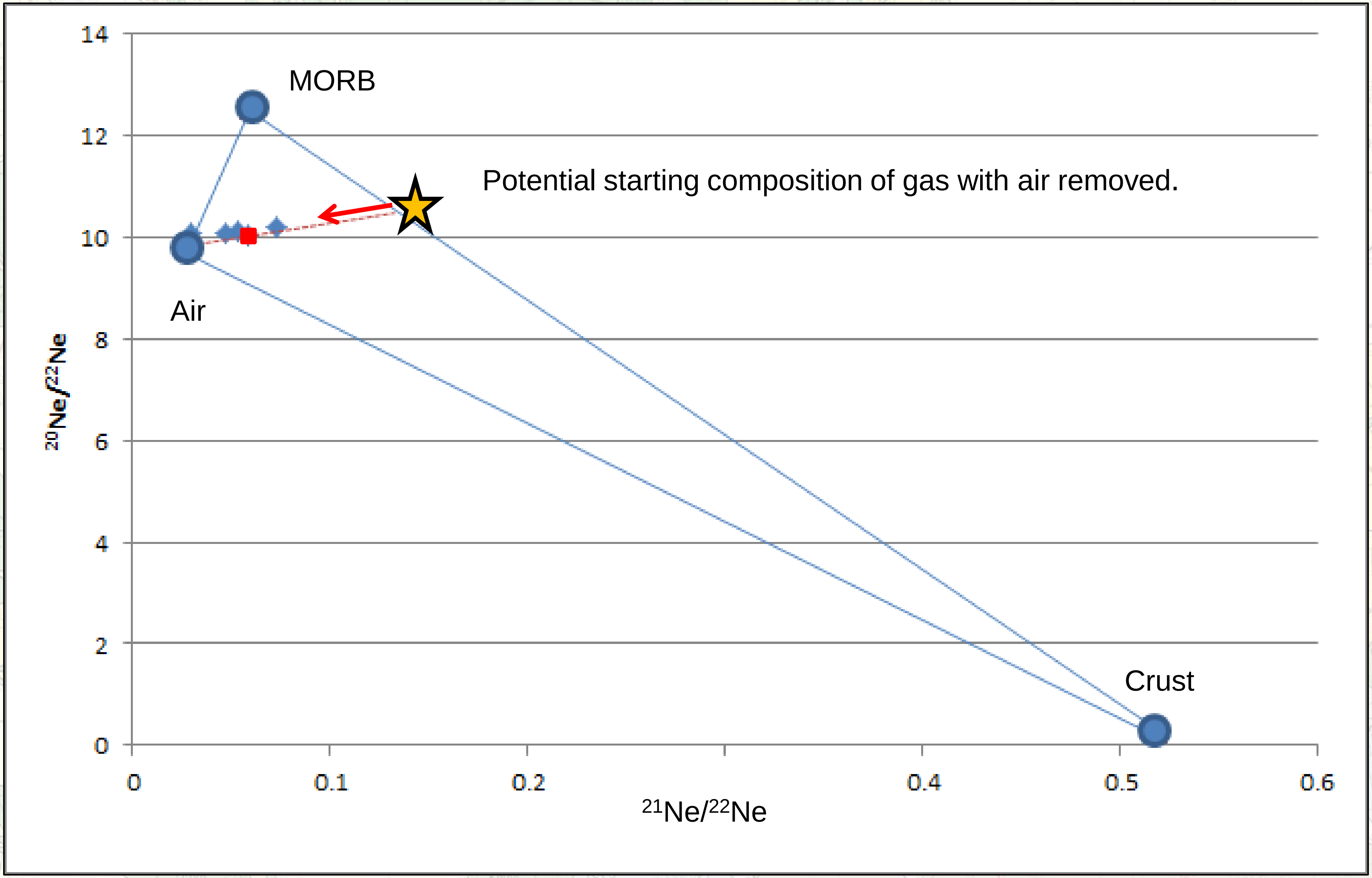
Carbon Isotopes – CO_2 Source



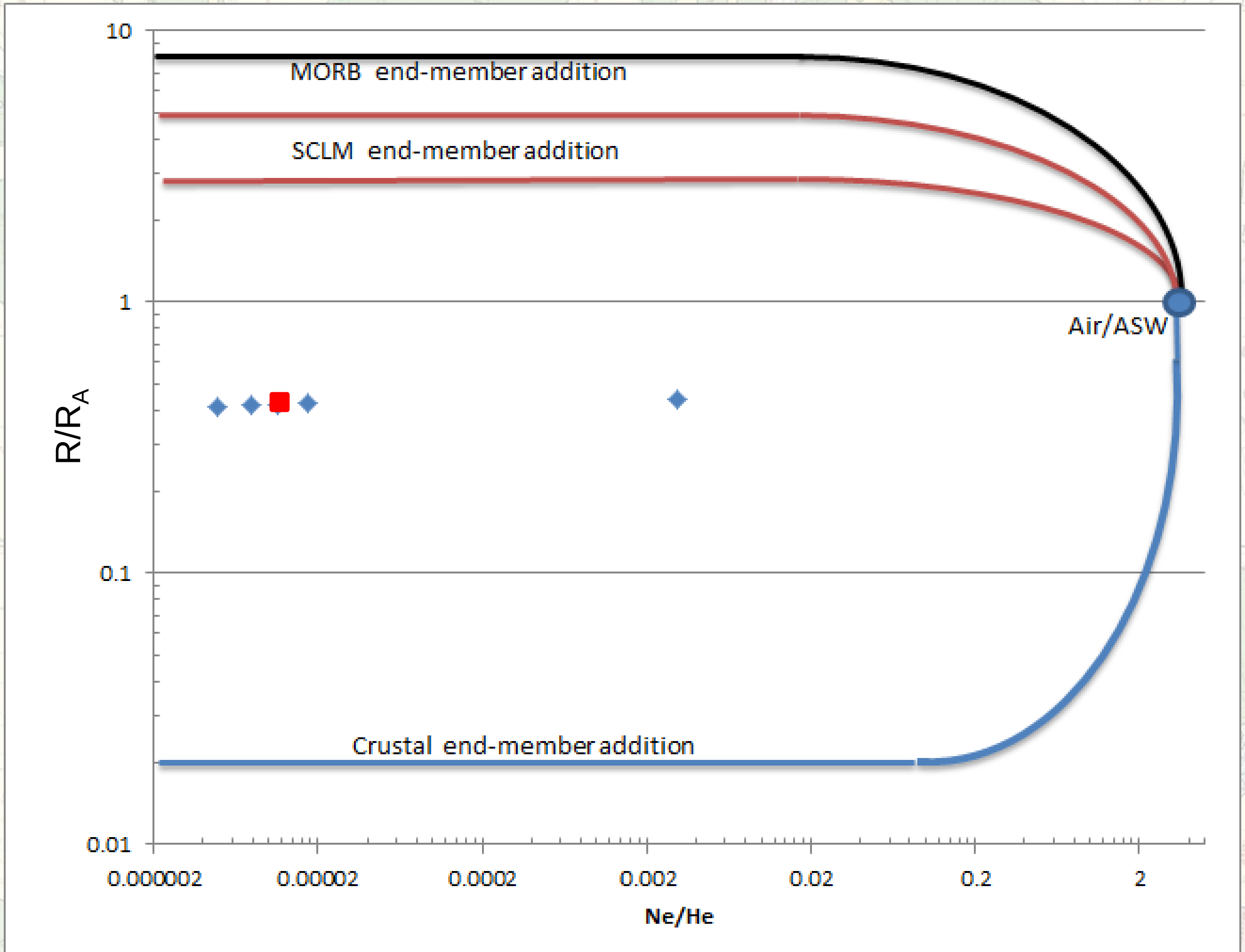


Holland and Gilfillan, 2013

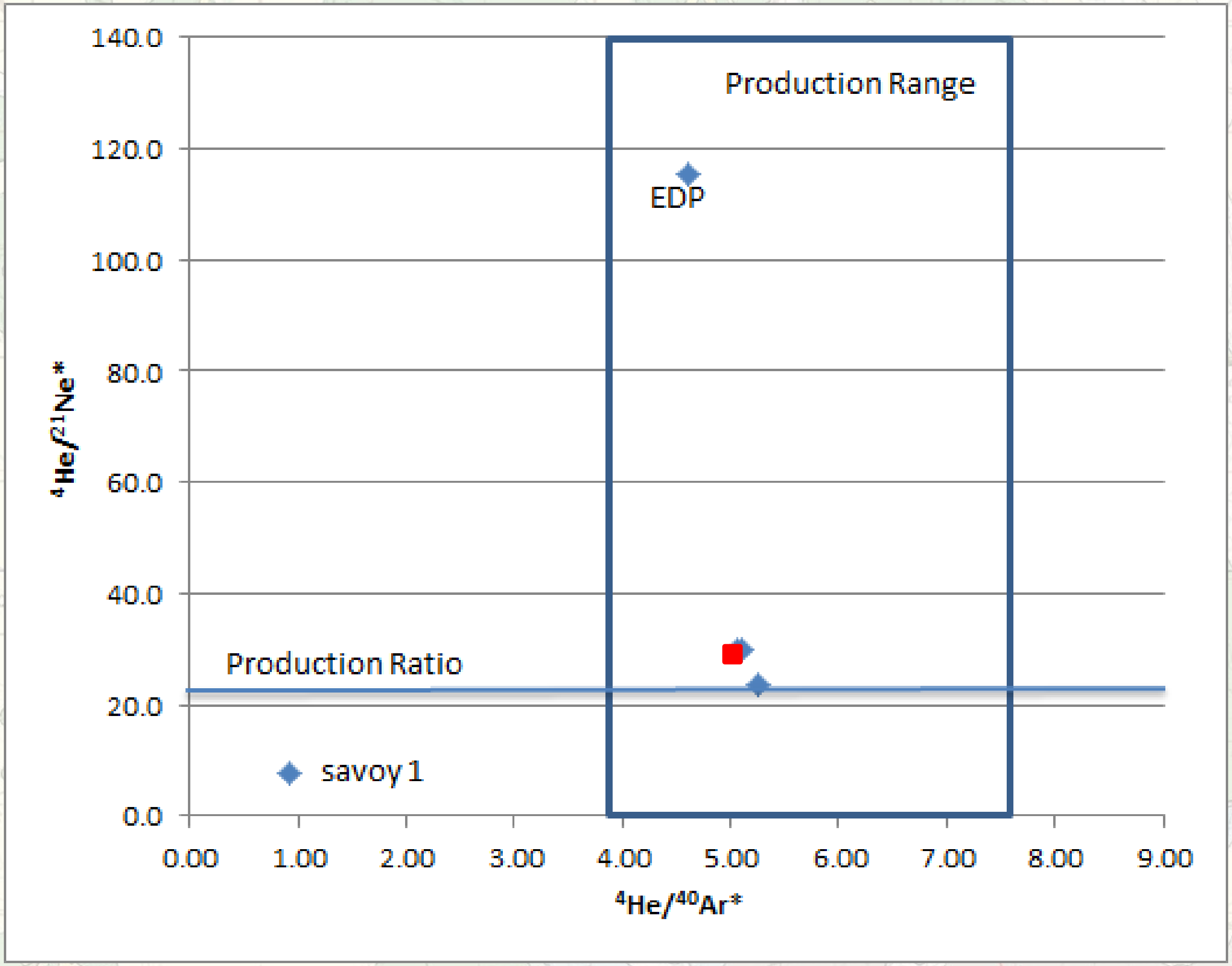
Neon Isotopes – Crustal vs. Mantle vs. Air



Helium Isotopes and End Members



Fractionation



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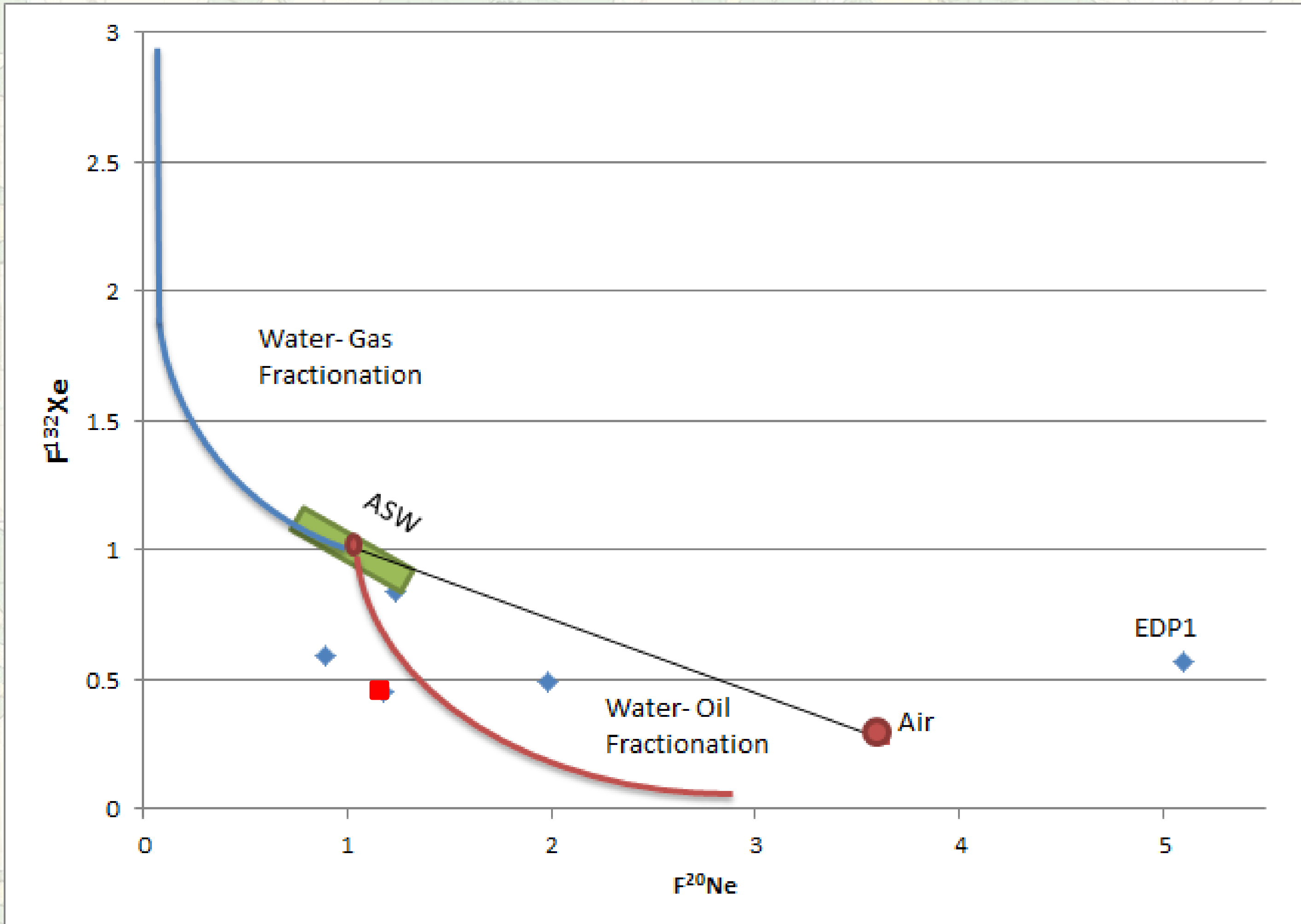
Fractionation



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Theories Revisited

1. Basement degassing

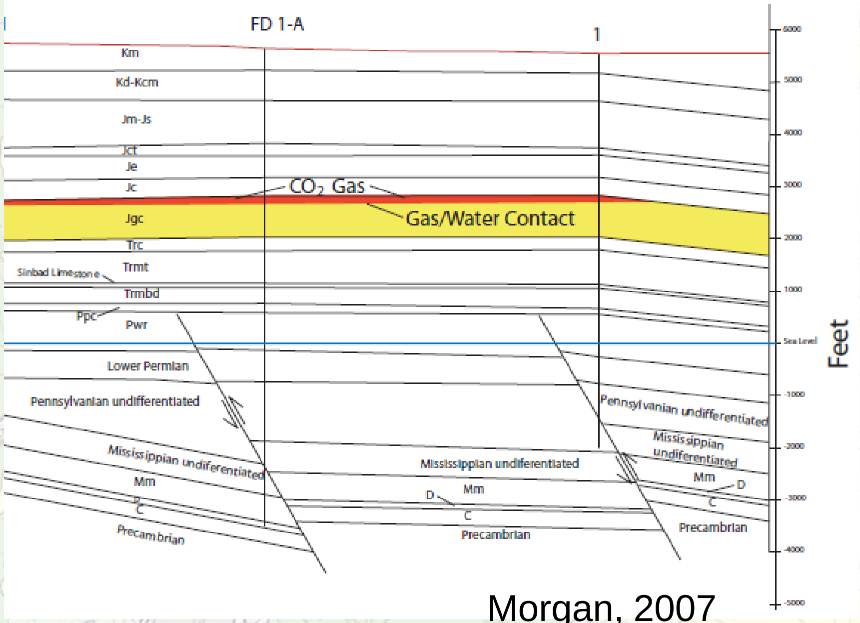
2. Thermo-chemical sulfate reduction of hydrocarbons

3. Thermal decomposition of Paleozoic sediments in the Uinta Basin from burial depth

4. Thermal decomposition of carbonates via heat from igneous intrusive or extrusive

1. Basement degassing

- Basement rooted faults are present at Farnham Dome, but not Grassy Trails.
- Expect lower R/R_A ratios for Helium near 0.2.
- Basement degassing results in higher nitrogen and helium abundance.



Morgan, 2007

Well	Nitrogen %	Helium cc/cc (10^{-6})
EDP-1 2014	0.05	2
EDP-1 2015	0.96	402
Savoy-1 2014	6.4	4726
Savoy-1 2015	1.05	335
FED 11-11	1.06	274

Well	R/R_A
EDP-1 2014	0.440
EDP-1 2015	0.420
Savoy-1 2014	0.409
Savoy-1 2015	0.427
FED 11-11	0.415

Well	CO_2 %
EDP-1 2014	99.8
EDP-1 2015	98.6
Savoy-1 2014	88.7
Savoy-1 2015	98.5
FED 11-11	98.6

2. Thermo-chemical Sulfate Reduction

- Source of sulfate required.
- High H_2S or sulfide abundance, residual hydrocarbons and hydrogen gas are often present.
- Not commonly known to produce CO_2 abundances over 60%.

Well	H_2S %	H_2 %	CH_4 %
EDP-1 2014	BDL	BDL	0.04
EDP-1 2015	0.2818	BDL	0.42
Savoy-1 2014	0.042	BDL	4.6
Savoy-1 2015	0.3988	BDL	0.41
FED 11-11	0.4286	BDL	0.31

Sulfate deposits are common in the Jurassic Carmel Formation on the western San Rafael Swell.

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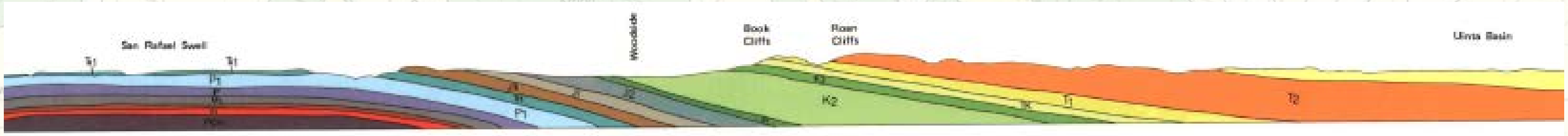

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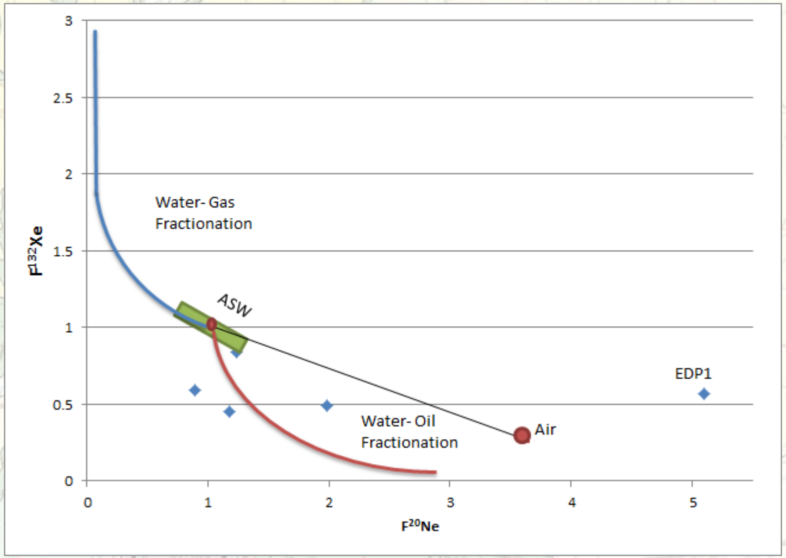
3. Thermal Decomposition of Uinta Basin Carbonates

- Structurally possible.
- Water-gas fractionation would be expected over such long migration distances.
- R/R_A ratio for Helium is higher than would be expected for crustal Paleozoic sediments.
- Burial depth heat required is plausible but not probable.



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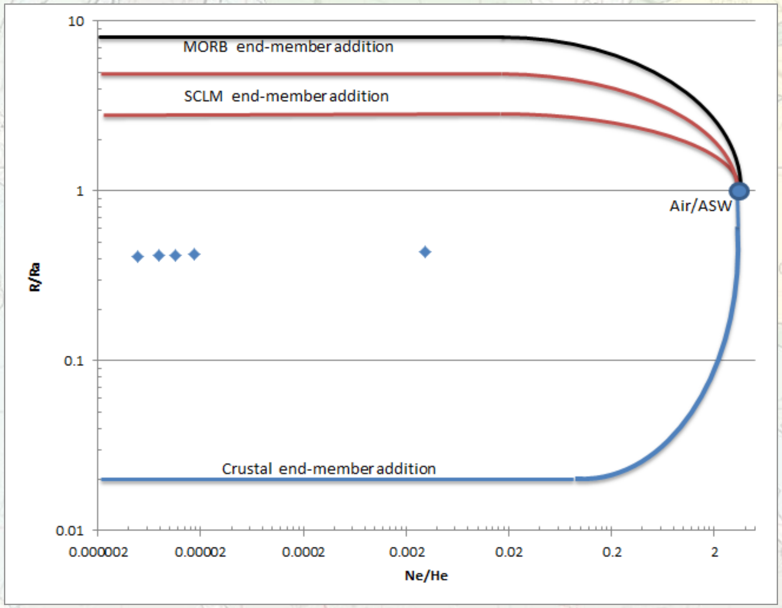

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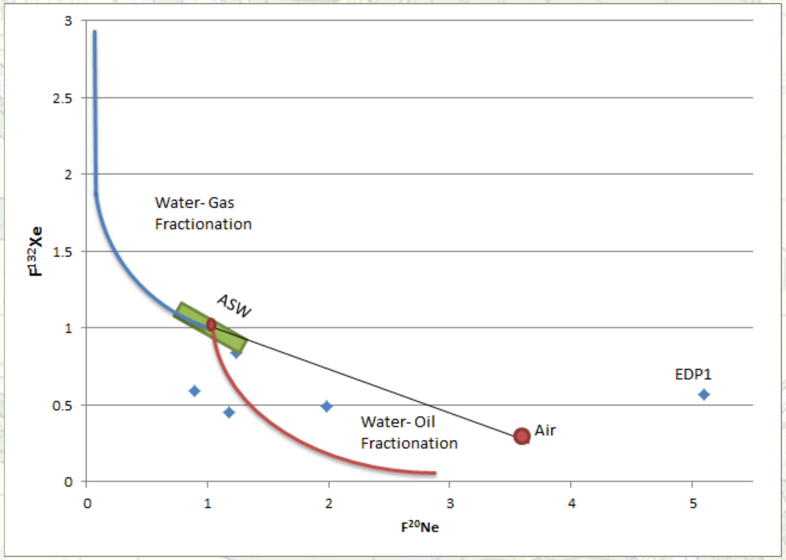
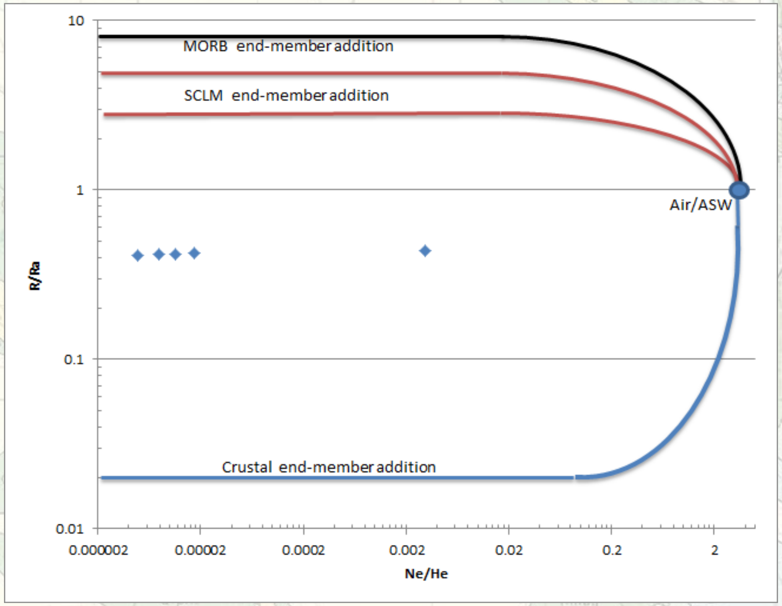


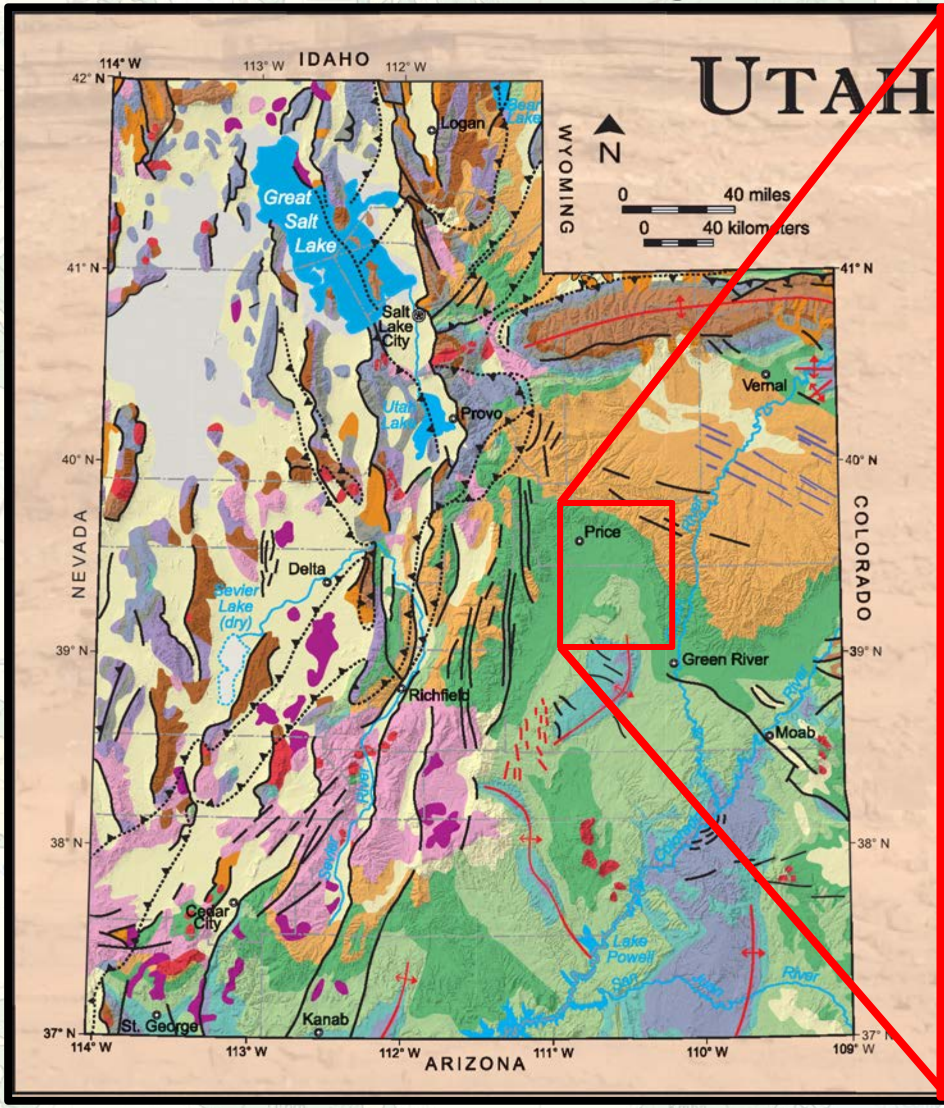


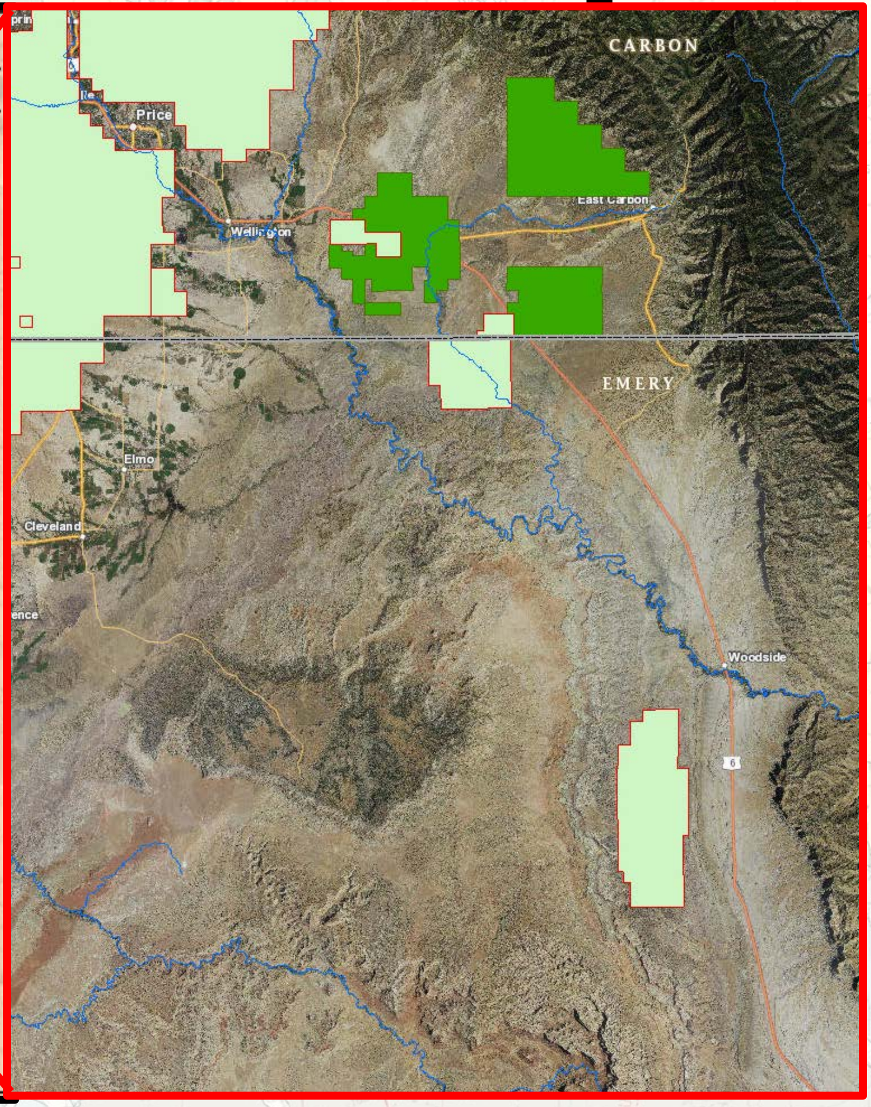
Are there local igneous rocks?

4. Thermal decomposition of carbonates via heat from igneous intrusive or extrusive.

- R/R_A values show a mix of MORB and crustal helium isotopes.
- Local igneous rocks could de-gas crustal sediments and produce low water-gas fractionation noble gas results found.

Potential Igneous Sources of CO_2





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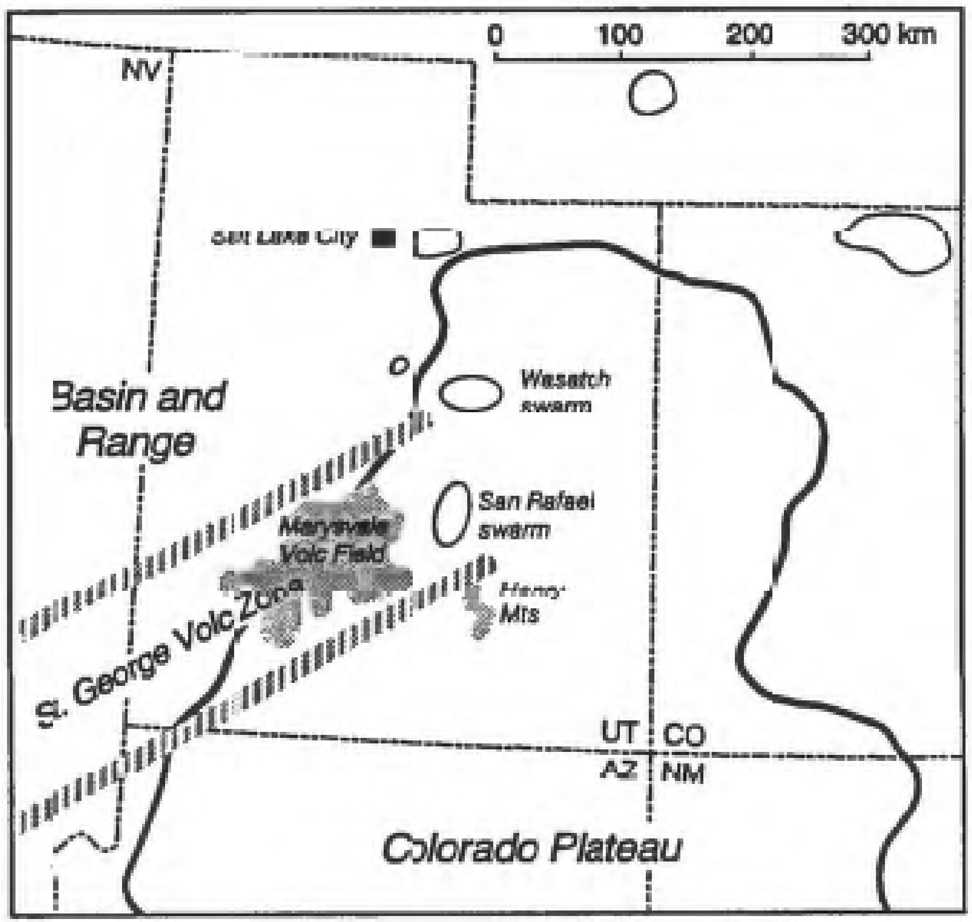
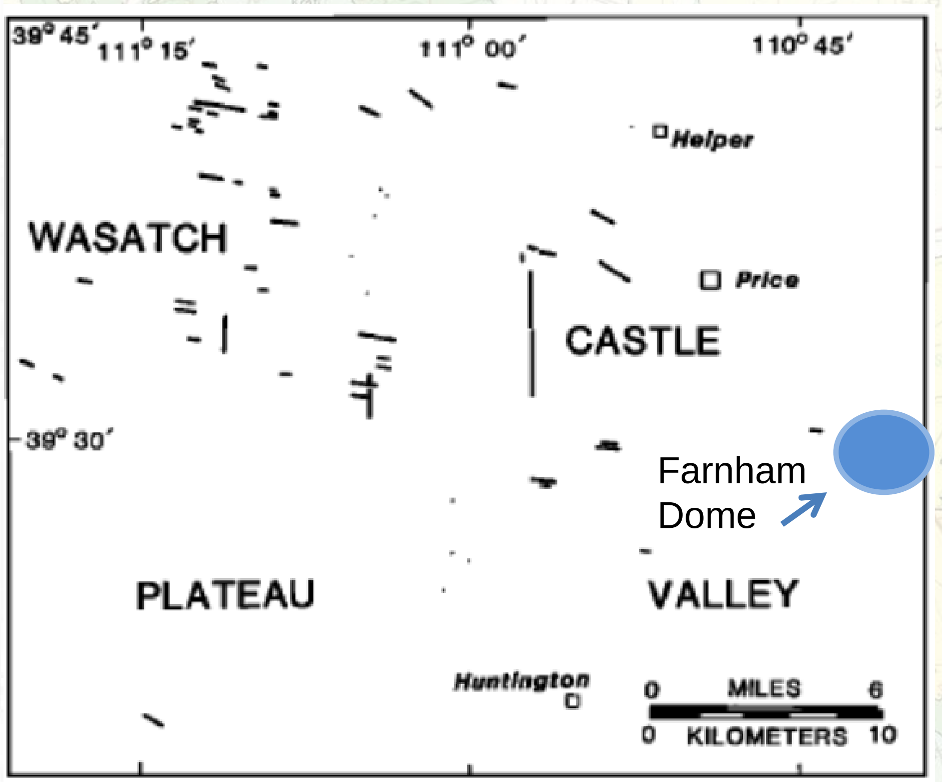
Interactive Utah Oil & Gas Well Locator Map

Wasatch Plateau Dike Swarm



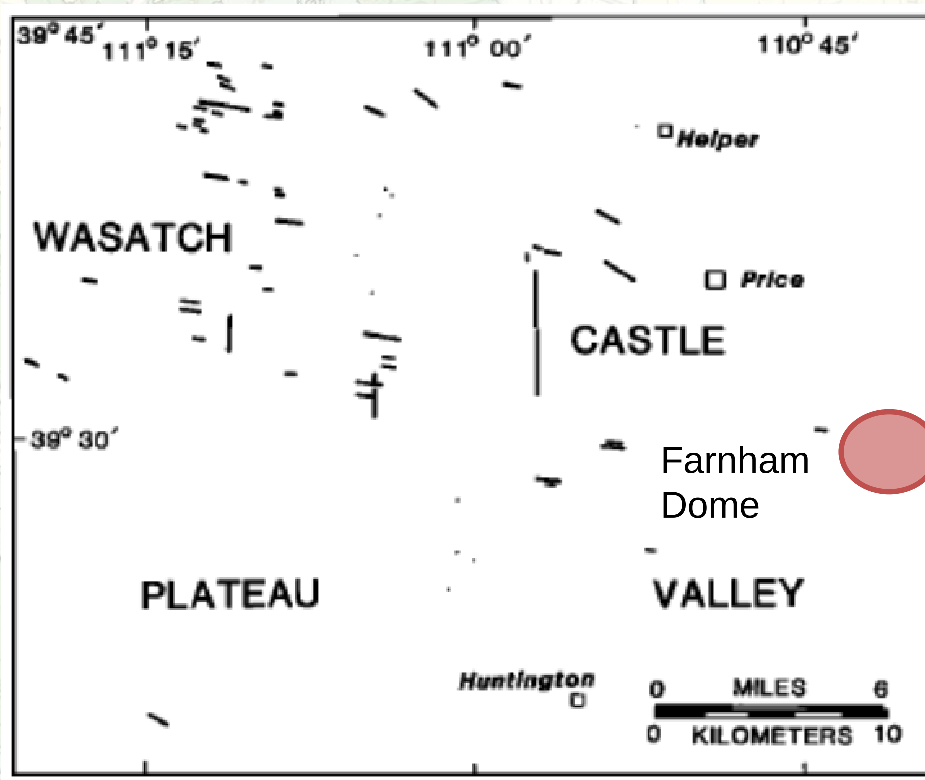


Delany and Gartner, 1995

Tingey et al., 1991

Wasatch Plateau Dike Swarm

- Primitive alkali mafic dikes
- Emplaced 24, 18, and 7-8 Ma.
- 110 = n, with an average of <2m width.
- Sills of 10s of meters have been noted in coal seams. Few sills are evident at the surface.



Tingey et al., 1991

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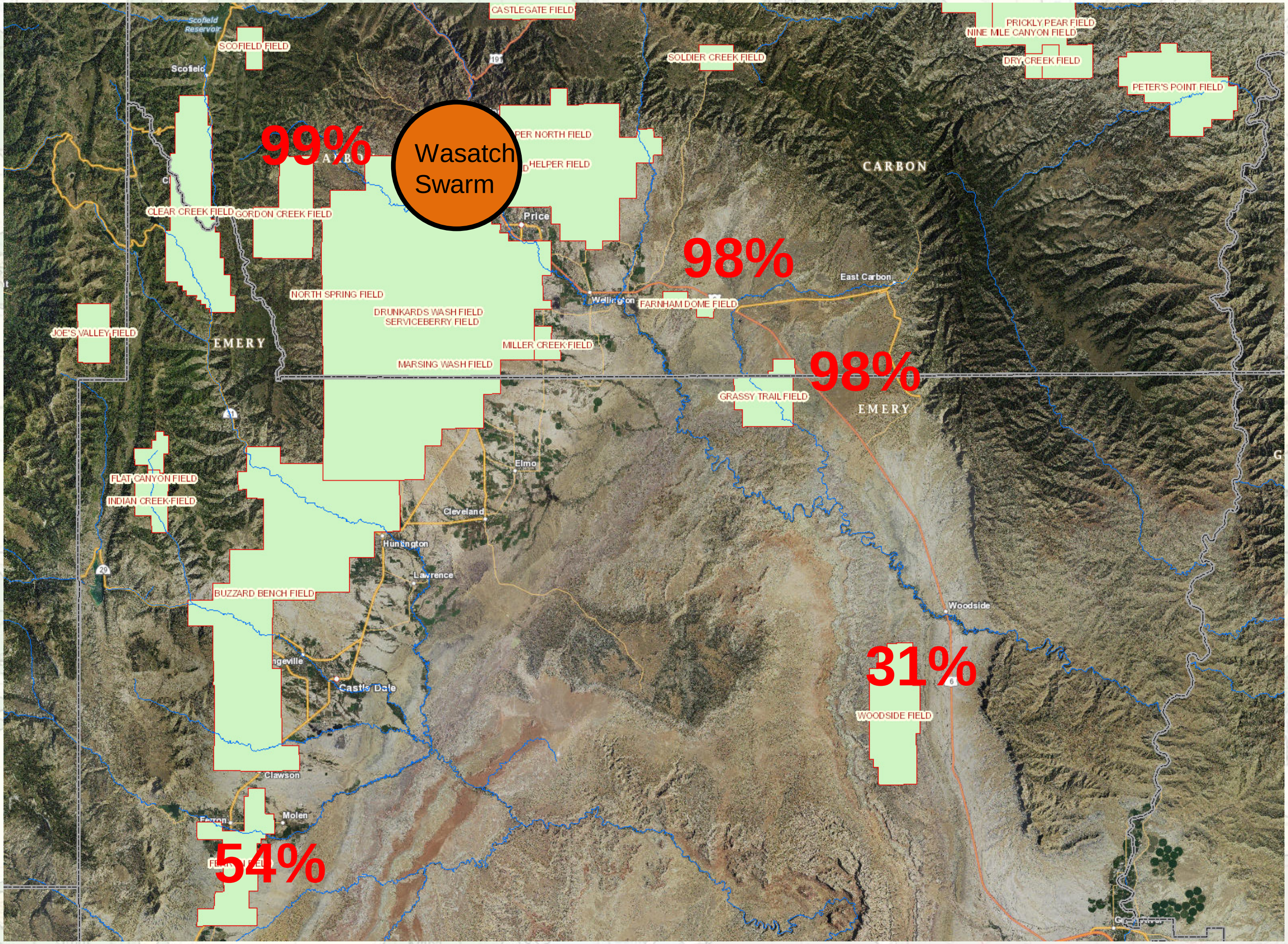
CO_2 Abundance



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Conclusions

- The CO_2 gas at Farnham Dome and Grassy Trails is from the same source.
  - Gas composition
  - Stable Isotopes
  - Noble Gas Isotopes

Conclusions

- Geochemical data favors
  - short migrations from source for noble gases
  - mantle gas components

- A local igneous emplacement post Sevier orogeny could both degas nobles from Paleozoic rocks and provide mantle type gas as well.

- The Wasatch Plateau Dike Swam satisfies these requirements.

Total CO_2 System?

- The gas in these two fields are presumed to be within the same total carbon dioxide system (TCDS) which may also include the Gordon Creek Field.
- Source: Requires fluid inclusion work on gases in the Wasatch Plateau Dike Swarm rocks.
- Migration: Requires more CO_2 samples from fields.
- Trapping: Known, but will improve with better source and migration path information.
- Timing: Constrained to mafic rock age and structure formation.

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