

## Farnham Dome and Grassy Trails Fields, Utah

### CO<sub>2</sub> accumulation sources and migration paths

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U.S. Department of the Interior U.S. Geological Survey

## USGS - Natural CO<sub>2</sub> and Helium

Reservoirs and analogues for anthropogenic CO<sub>2</sub> 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



#### Geologic CO<sub>2</sub> Sequestration

News Overview Research Data Multimedia Related Links

#### Overview

#### Carbon Seguestration – Geologic Research and Assessments

Geological sequestration (storage) of carbon dioxide (CO2), a greenhouse gas, is an available technology that injects and stores anthropogenic CO<sub>2</sub> produced by various industries and electric generation facilities in porous and permeable subsurface rock units thereby preventing the release of the CO2 into the atmosphere where it may contribute to global warming. Few large-scale CO2 geologic sequestration projects exist today and more research is needed to better understand the geologic controls on subsurface rock storage capacities, the geologic and environmental bazards, and economic feasibility associated with geologic storage of CO2



omposed by Douglas W. Duncan and illustrated by Eric .



- Project Homepage
- **Project Publications**
- Assessment Methodologies
- National Storage Assessment Results
- Collaborators
- Helpful Definitions
- Project Staff



#### Find Data



EnergyVision A single map viewer portal incorporating a range of maps, data and services

National Coal Resources Data System USGS coal resources databases of nationa SCODE

[+] ALL TOOLS



http://energy.usgs.gov/EnvironmentalAspects/EnvironmentalAspectsofEnergyProductionandUse/GeologicCO2Sequestration.aspx

# 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<sub>2</sub> from which geologically grounded, organized, scaleable, and comparable investigations can be conducted.



# Goal

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

- Use gas geochemistry and field geology from Farnham Dome and Grassy Trails fields to identify and group related natural CO<sub>2</sub> 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



Utah Geological Survey

#### Interactive Utah Oil & Gas Well Locator Map

#### Utah Oil and Gas Map 20.0





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

# CO<sub>2</sub> Origin Unknown

Sources of CO<sub>2</sub> at Farnham Dome are unknown and may have come from a variety of sources.

-Morgan (2007)

Current hypotheses in the literature specific to CO<sub>2</sub> 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<sub>2</sub> only.





### Production at Farnham Dome

Samp

#### Glen Canyon Group -Navajo Sandstone

-Wingate Sandstone

Moenkopi Formation -Sinbad Limestone

Park City Formation White Rim Sandstone

Pennsylvanian -undifferentiated

CO<sub>2</sub> reservoir

	CRET.	Cedar Mtn Upper member 1		150-750	
	(part)	Fm Buckhorn Ce Mbr		0-50	
		Morrison Formation		800	
ne		Summerville Formation		120-180	111 111 111
		Cur	tis Formation	140-180	
Csw Kmbg		Entr	Entrada Formation 1 Carmel Formation 3 Page Sandstone		
	JURASSIC	Carr			
		Pa			
$\rightarrow$		Nav	ajo Sandstone	150-300	
		Kaye	enta Formation	120-200	
Att Wellington		Wing	ate Sandstone	300-400	
The work		Chinle Em	Upper member	200-300	
		chinte r hi	Moss Back Mbr	20-60	
	TRIASSIC	Maankani	Upper member	550-700	
T We what		Em	Sinbad Ls Mbr	50	7.7.
			Black Dragon Mbr	250-350	1
1 Strand		Black Box Dolomite		170	144
A Star Millor	PERMIAN	White Rim Sandstone		500-700	
		Pakoon Dolomite		650-800	14/
	PENN	Cally	Callville Limestone		7.7
X / X		Doughnut Formation		600-700	
	MISS	Humbug Formation		400-500	7.7
		Redwall Dolomite		750-970	141
and here the	DEV	Pinyon Peak Ls		20	144
		Ouray Formation		110-160	7.7.
AL A		Cam	350	134	
100 9 18	CAMB		200		
		Tin	tic Quartzite	210	
	pC (PROT)	Crysta	alline basement	NULL	" C "



### **Grassy Trails**

- •31+ total wells
- •15 shut in oil wells
- •Oil and gas in 3 zones in the Triassic Moenkopi.
- •No CO<sub>2</sub> producing wells.



**5** Kilometers



### Production at Grassy Trails

Samples -

#### Glen Canyon Group -Navajo Sandstone

Moenkopi Formation -Torrey Member -Black Dragon Member

CO<sub>2</sub> reservoir

Oil and gas reservoir

	CRET.	Cedar Mtn Upper member 1		150-750	
	(part)	Fm Buckhorn Ce Mbr		0-50	
		Morrison Formation		800	
TK Mare		Summerville Formation		120-180	1,1,1
		Curtis Formation 1		140-180	
		Entrada Formation 1		150-950	
	JURASSIC	Carr	mel Formation	300-700	
		Pag	ge Sandstone	70	
		Nav	ajo Sandstone	150-300	
		Kaye	nta Formation	120-200	
		Wing	Wingate Sandstone		
Land C		Chiple Em	Upper member	200-300	
5 ser l'		Chine Fin	Moss Back Mbr	20-60	
EPER NIN	TRIASSIC	Upper member		550-700	
		Em Sinbad Ls Mbr		50	7-7
Carlos -			Black Dragon Mbr	250-350	
Color Color		Black Box Dolomite		170	144
	PERMIAN	White Rim Sandstone		500-700	
		Pakoon Dolomite		650-800	14/
	PENN	Callville Limestone		250-300	7-7
> / 2		Doughnut Formation		600-700	
	MISS	Humbug Formation		400-500	7-7
		Redwall Dolomite		750-970	144
Greep First	DEV	Pinyon Peak Ls		20	144
		Ouray Formation		110-160	7-7-2
Kan		Cambrian dolomite		350	144
S K	CAMB	Ophir Shale		200	
		Tintic Quartzite		210	
	pC (PROT)	Crystalline basement		NULL	" C. #.



### 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<sub>2</sub> 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<sub>2</sub> Source



### Neon Isotopes - Crustal vs. Mantle vs. Air



**USGS** 

Source For AleitalGioto Confile Farthers Geographic TRES (Althin DS USDA (KdC AFK) Getmanded Annor

### Helium Isotopes and End Members





### Fractionation





Source: Est, Aleitatologo, Samelle, Estimate Geographics CHESTATIONS DS, USDA, UKIC, AEN Germapping, Astronom, 168, 169, 300000

### Fractionation





Source: Est. Atellatolodo, Savello, Estitutur Geographic The Arros 55, USDA, USDA, USDA, USDA, Cherrapping, Aeroenia, IGA, IGA, Savel

### **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



source: est, aterial Globa, Careta, Earthstar Geographic Tata Arros 55, USDA, USDA, USDA, Germapping, Aeroend, IGN, IGP, Swist Ger

#### 1. Basement degassing

- Basement rooted faults are presen Farnham Dome, but not Grassy Tra
- •Expect lower R/R<sub>A</sub> ratios for Helium near 0.2.
- Basement degassing results in high nitrogen and helium abundance.

	Km		
	Kd-Kcm		
	Jm-Js		
	Ja		
1095	Je		
	JL	- CO <sub>2</sub> Gas	
	Jgc	Gas/Water Contact	
it at	Trc		
	Sinbad Limeston e		
ails	Trmbd		
	Ppc Pwr		
n () Qsw	Lower Permian		
	Pennsylvanian undifferentiated		Pennsylvanian undifferentia
hor	Mississippian undiferentiated	Mississippian undiferentiated	Mississippian undiferentiated Mm
	Mm	D Mm	
The man		C C	
KIN AS	Precambrian	Precambrian	Precambrian

FD 1-A

Morgan, 2007	Morgan,	2007	-
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Feet

erentiate

Well	Nitrogen %	Helium cc/cc (10 <sup>-6</sup> )	Kmi	Well	R/R <sub>A</sub>
EDP-1 2014	0.05	2		EDP-1 2014	0.440
EDP-1 2015	0.96	402	an	EDP-1 2015	0.420
Savoy-1 2014	6.4	4726	SE	Savoy-1 2014	0.409
Savoy-1 2015	1.05	335		Savoy-1 2015	0.427
FED 11-11	1.06	274		FED 11-11	0.415
OTpm	25/16	/ Kmbg	Con By	tool Marsh	



	Well	CO <sub>2</sub> %	Subst
CINK .	EDP-1 2014	99.8	
201	EDP-1 2015	98.6	
	Savoy-1 2014	88.7	
JEE //	Savoy-1 2015	98.5	
	FED 11-11	98.6	SAU

 $H_2 \%$ 

**BDL** 

BDL

BDL

BDL

BDL

CH<sub>4</sub> %

0.04

0.42

4.6

0.41

0.31

2. Thermo-chemical Sulfate Reduction

•Source of sulfate required.

•High H<sub>2</sub>S or sulfide abundance, residual hydrocarbons and hydrogen gas are often present.

•Not commonly known to produce CO<sub>2</sub> abundances over 60%.

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

<b>USGS</b>
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FED 11-11

Well

EDP-1

EDP-1

Savoy-1

Savoy-1

2015

2014

2015

2014

H<sub>2</sub>S %

0.2818

0.042

0.3988

0.4286

BDL

#### Utah Geological Survey

Dook

12140

- 3. Thermal Decomposition of Uinta Basin Carbonates
- Structurally possible.
- Water-gas fractionation would be expected over such long migration distances.
- •R/R<sub>A</sub> 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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- 3. Thermal Decomposition of Uinta Basin Carbonates
- •Structurally possible.

**≊USGS** 

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

0.002

Ne/He

0.02

0.2

Crustal end-member addition

0.0002

3

2.5

**ex** 22 1.5

0.5

0+

10

¶%

0.1

0.01

0.00002

Water-Gas Fractionation

٠

1

MORB end-member addition

SCLM end-member addition

ASW

Water-Oil

Fractionation

F<sup>20</sup>Ne

Air

EDP1

5

Air/ASW

2



#### Are there local igneous rocks?

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

- •R/R<sub>A</sub> 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<sub>2</sub>



Utah Geological Survey

**≥USGS** 

#### Interactive Utah Oil & Gas Well Locator Map

### Wasatch Plateau Dike Swarm



**USGS** 

Delany and Gartner, 1995

Tingey et al., 1991

### Wasatch Plateau Dike Swarm



- •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

## CO<sub>2</sub> Abundance





# Conclusions

- •The CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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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