

Source Within the Seal: Organic-Rich Shales Within the Onion Creek Diapir, Moab, Utah*

Samuel M. Hudson¹, Trevor Tuttle¹, and Matthew Wood¹

Search and Discovery Article #10874 (2016)**
Posted October 31, 2016

*Adapted from oral presentation given at AAPG Annual Convention & Exhibition, Calgary, Alberta, Canada, June 19-22, 2016

**Datapages © 2016 Serial rights given by author. For all other rights contact author directly.

¹Brigham Young University, Provo, Utah (sam.hudson@byu.edu)

Abstract

The Pennsylvanian Paradox Formation near Moab, Utah is composed of interbedded evaporites, shales, and limestones. Sediment loading caused by the uplift of the Uncompahgre orogeny caused the Paradox salt, a ‘dirty’ salt containing a substantial volume of non-evaporitic strata, to form a series of diapiric salt walls parallel to the NW-SE orogenic front. At present, the Onion Creek Diapir, one of the most proximal diapiric salt structures in the basin, is exposed at the surface. Exposures show that appreciable amounts of the Paradox shale were incorporated within the salt diapir, both along the margins and within the interior. Some of the stringers of non-evaporitic strata preserved within the diapir are of substantial size – the largest blocks of interbedded shale and limestone observed within the diapir are upwards of 20 meters thick and over 100 meters along bedding.

A large sample suite of the Paradox shale has been collected along the margins and within the interior of the exposed caprock at Onion Creek, and samples have been analyzed using source rock pyrolysis techniques. Pyrolysis results show that samples typically have high Total Organic Content (TOC) values (upwards of 20% TOC), and are Type II to Type II/III oil-prone source rocks. Tmax values and PI ratios from the sample suite show that samples have passed through the early to main oil window, indicating hydrocarbons have been generated. In multiple localities throughout the diapir, hydrocarbon staining can be seen in proximity to shale exposures, and analysis of the altered strata shows that there are hydrocarbons associated with this staining. This alteration can be seen throughout the diapir from the margins to the center, and within all Paradox Formation lithologies including salt, suggesting that some expulsion has occurred even in instances where these isolated packages of shale are fully encapsulated within salt. These observations have implications for systems where a large amount of organic-rich shale is interbedded within evaporites, and perhaps broader implications for the numerous salt basins worldwide in which salt is invoked as a hydrocarbon seal.

References Cited

Giles, K.A., and T.F. Lawton, 2002, Halokinetic sequence stratigraphy adjacent to the El Papalote diapir, northeastern Mexico: AAPG Bulletin, v. 86/5, p. 823-840.

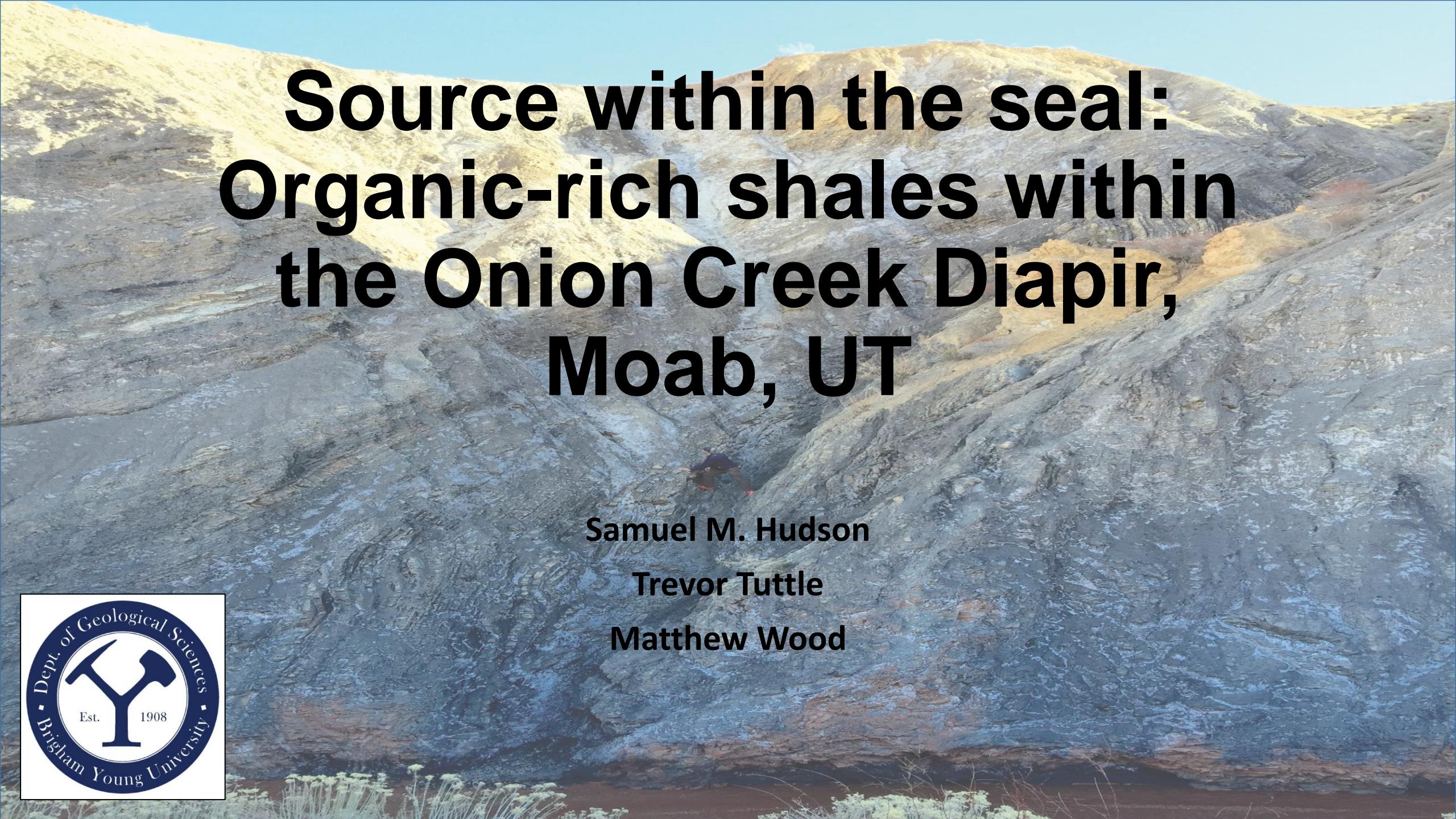
Hearon, T.E., M.G. Rowan, T.F. Lawton, P.T. Hannah, and K.A. Giles, 2015, Geology and tectonics of Neoproterozoic salt diapirs and salt sheets in the eastern Willouran Ranges, South Australia: Basin Research, v. 27, p. 183-207. doi:10.1111/bre.12067

Hintze, L.F., and B.J. Kowallis, 2009, Geologic History of Utah: Provo, Utah, Brigham Young University, 225 p.

Hudson, S.M., and A.D. Hanson, 2010, Thermal maturation and hydrocarbon migration within La Popa Basin, northeastern Mexico, with implications for other salt structures: AAPG bulletin v. 94/3, p. 273-291.

Peters, K.E., 1986, Guidelines for evaluating petroleum source rock using programmed pyrolysis: AAPG Bulletin, v. 70, p. 318-329.

Rasmussen, L., and D.L. Rasmussen, 2009, Burial history analysis of the Pennsylvanian petroleum system in the deep Paradox Basin Fold and Fault Belt, Colorado and Utah, *in* W.S. Houston, L.L. Wray, and P.G. Moreland, eds., The Paradox Basin revisited – New developments in petroleum systems and basin analysis: Denver, Rocky Mountain Association of Geologists, Special Publication, p. 24-94.

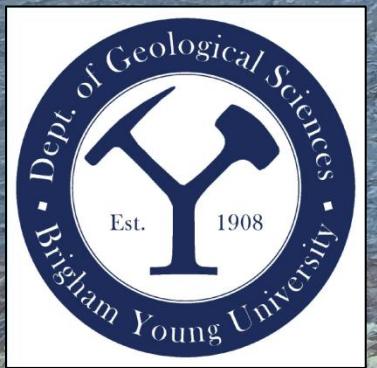


Source within the seal: Organic-rich shales within the Onion Creek Diapir, Moab, UT

Samuel M. Hudson

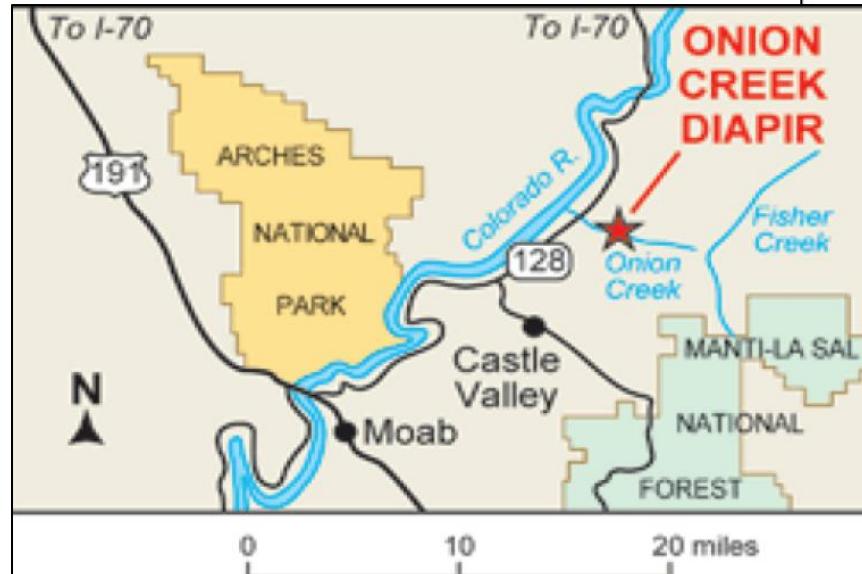
Trevor Tuttle

Matthew Wood

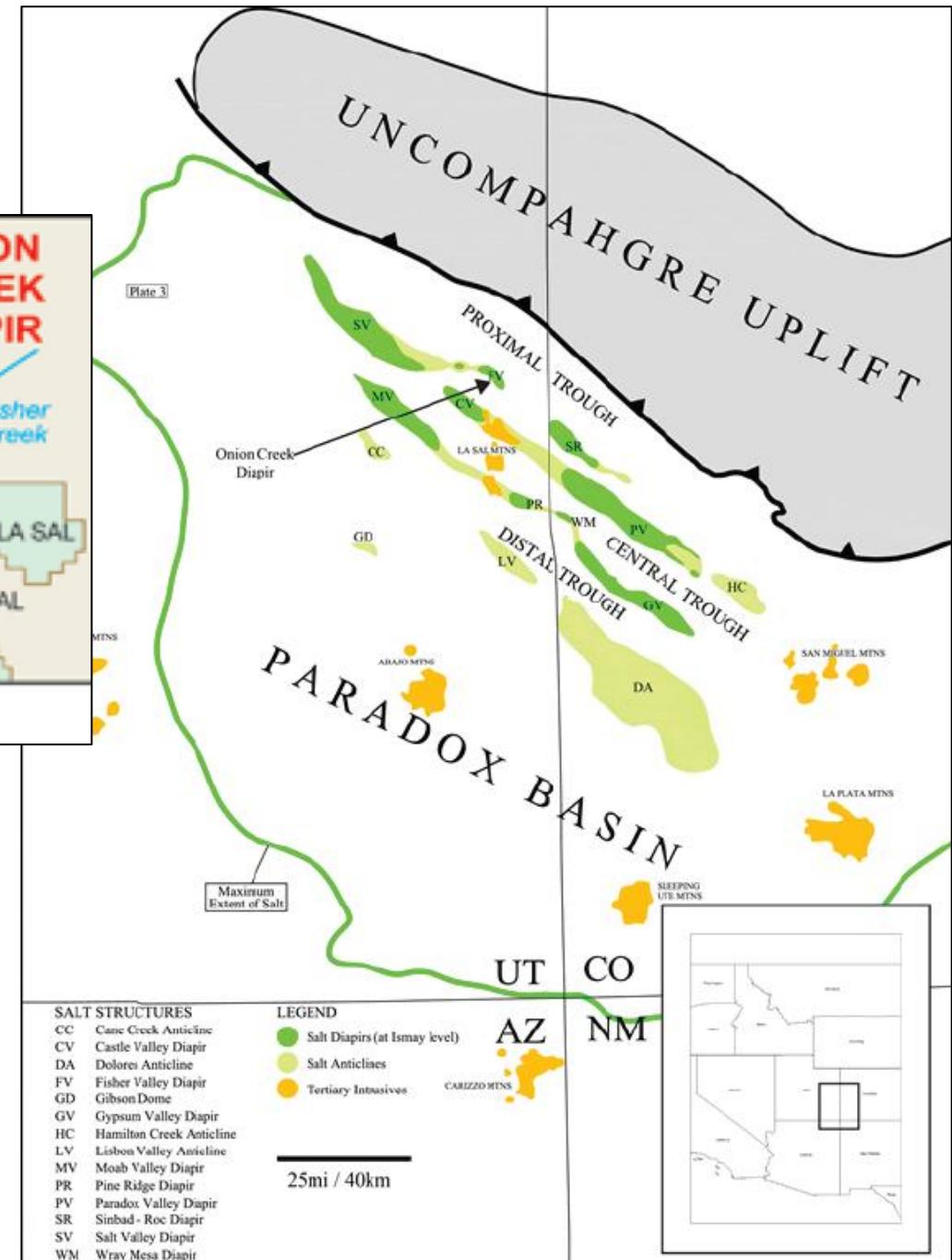


Onion Creek diapir – Moab,

PERMIAN	Cutler Group	White Rim Ss	0-430
		Organ Rock Sh	0-400
		Cedar Mesa Sandstone	200-1200
		Arkosic Facies	400-3000
		Elephant Canyon Fm	0-1500
PENNSYLVANIAN	Hermosa Group	Honaker Trail Formation	0-5000
		Paradox Fm	0-14,000
		Pinkerton Trail Fm	0-150
M		Molas Formation	0-100
		Leadville Dolomite	300-600



from Hintze & Kowallis, 2009
Rasmussen, 2009
Fitzpatrick, 2012



Introduction

- Onion Creek diapir is a good exposed example of a ‘dirty salt’
- While studying carbonate, shale stringers within the diapir, we noticed abundant potential secondary HC staining
- Meaning, time for some geochemistry!



Paradox Stringers

- Interbedded evaporite, shale, carbonates
- Documented cycles from nearby wells (80 in larger group)
- Incorporated into diapirs



Organic shales



Onion Creek Diapir - Observations



Cutler Formation

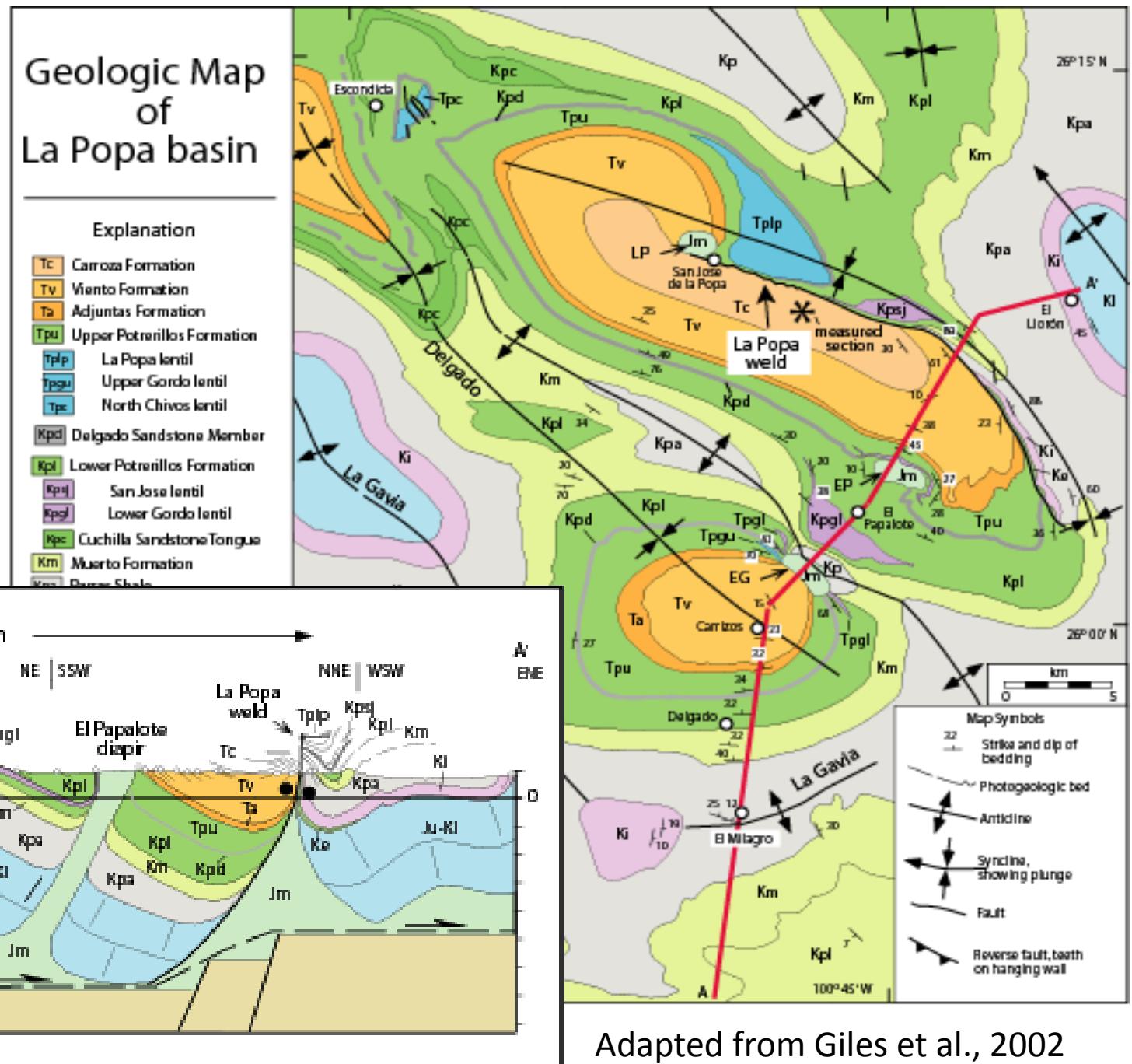
Onion Creek diapir

Alteration near the edge of salt

Onion Creek Diapir - Observations



Analogues – La Popa salt weld, Mexico

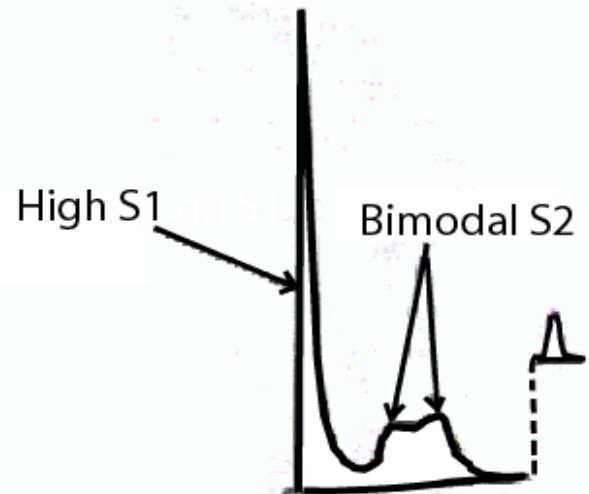
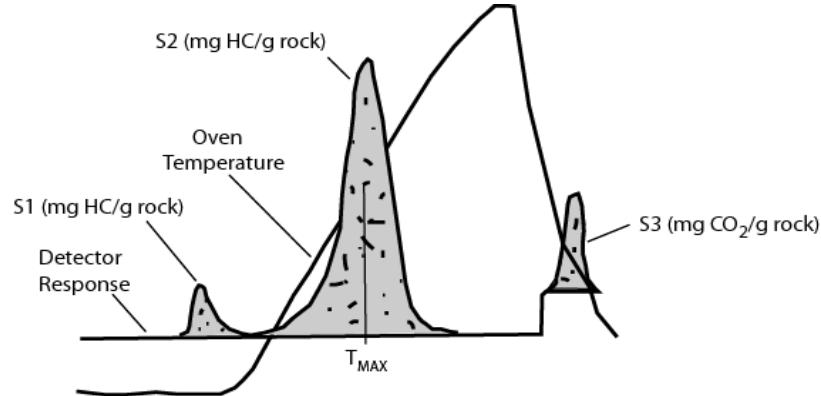


Analogues – La Popa salt weld, Mexico



- HC staining within evaporates, along contact, within fractures and pore space of adjacent strata.

Migrated Hydrocarbons - Pyrolysis



Modified from Peters, 1986

- Must have:
 - Sufficient carbon content (TOC)
 - $S1 > S2$

La Popa data

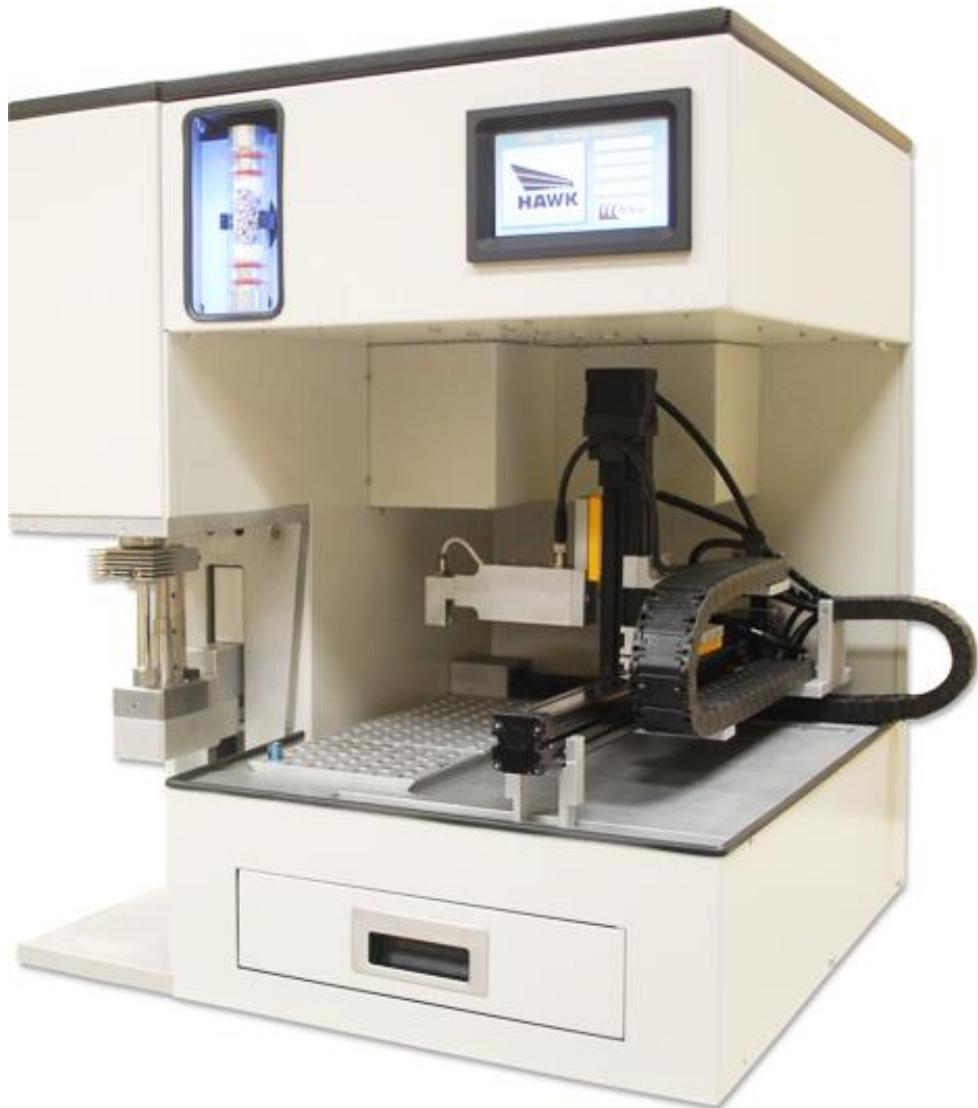
Table 1. Geochemical Results from Background Samples, Potential Migrated Hydrocarbon Samples, and Effective Source Rock Samples*

Sample location	Sample Id.	TOC	S1	S2	S3	T _{max} (°C)	HI	OI	S1/TOC	PI
Background Carroza Samples										
Carroza	01MO04	0.22	0.01	0.02	0.11		9	50	5	0.33
Carroza	05LP6	0.19	0.00	0.00	0.05		0	26	0	
Potential Migrated Samples										
Weld	01MO05	1.06	0.27	0.21	0.50	514	20	47	25	0.56
Weld	02LP01	0.59	0.34	0.06	0.00	395	10	0	58	0.85
Weld	02LP03	0.10	0.02	0.00	0.46	m	0	460	20	1.00
Weld	02LP04	0.09	0.02	0.01	0.45	m	11	479	21	0.67
Weld	02LP09	0.17	0.01	0.03	0.12	423	18	71	6	0.25
Weld	03LP13	0.08	0.02	0.01	0.06	335	12	73	24	0.67
Weld	03LP14	0.06	0.01	0.01	0.06	410	17	105	17	0.50
Weld	03LP16	0.18	0.07	0.05	0.36	340	28	200	39	0.58
Weld	03LP22	0.02	0.01	0.01	0.02	466	50	100	50	0.50
Weld	03LP32	0.18	0.03	0.05	0.10	399	28	56	17	0.37
Weld	03LP35	0.09	0.00	0.00	0.38	m	0	422	0	
Weld	05LP3	0.88	0.17	0.05	0.24	357	6	27	19	0.77
Weld	05LP5	0.76	0.06	0.05	0.57	355	7	75	8	0.55
Boca la Carroza	01MO08	0.12	0.01	0.01	0.72	m	8	600	8	0.50
Portrerillos	03LP15	0.08	0.02	0.02	0.06	421	26	78	26	0.50
Carroza	03LP23	0.12	0.04	0.06	0.12	434	50	100	33	0.40
Carroza	03LP24	0.41	0.15	0.02	0.10	298	5	24	36	0.88
Carroza	03LP31	0.16	0.02	0.06	0.16	456	37	99	12	0.25
Carroza	02LP02	0.24	0.01	0.00	0.12	m	0	49	4	1.00
Carroza	03LP12	0.08	0.03	0.06	0.25	362	72	301	36	0.33

Adapted from Hudson et al., 2010

- 18 samples along the weld
- Migrated samples had elevated S1 peaks, low bimodal S2 peaks
- Migrated samples had moderate TOC
- Biomarker analysis of samples confirmed hydrocarbons within migrated samples

Onion Creek Data



Onion Creek Data

Sample ID	TOC-Total Organic Carbon (Weight %)	S1-Free Oil (mgHC/g rock)	S2-Kerogen Yield (mgHC/g rock)	S3 (mgCO2/g rock)	Tmax-Maturity (°C)	CC-Carbonate Carbon (Weight %)	GOC-Generative OC (Weight %)	NGOC-Non-generative OC (Weight %)	PI-Production Index	HI-Hydrogen Index (mgHC/gTOC)	OI-Oxygen Index (mgCO2/gTOC)	S1/(S1+S2)
03 SC 15	1.23	0.12	0.4	0.17	374	17.85	0.05	1.17	0.24	32	14	23%
T 1.7	0.64	0.17	0.55	0.2	446	0.2	0.07	0.57	0.23	85	31	24%
T 1.9	1.71	0.1	0.37	0.3	428	2.45	0.05	1.66	0.21	21	17	21%
T 2.1	0.66	0.08	0.34	0.19	439	0.23	0.04	0.62	0.19	51	28	19%
T 1.8	1.12	0.1	0.43	0.13	426	0.36	0.06	1.06	0.19	38	11	19%
T 4.2	1.66	0.09	0.42	0.37	449	0.67	0.06	1.6	0.17	25	22	18%
T 4.1	1.15	0.07	0.35	0.29	442	7.35	0.05	1.1	0.17	30	25	17%
T 1.5	0.65	0.14	0.77	0.25	441	0.26	0.09	0.56	0.16	118	38	15%
T 1.6	0.65	0.11	0.6	0.24	441	0.44	0.07	0.57	0.15	93	37	15%
T 1.10	0.72	0.08	0.5	0.26	453	18.3	0.06	0.66	0.13	70	36	14%
T 1.3	1.59	0.17	1.58	0.3	438	3.47	0.16	1.43	0.1	99	18	10%
T 1.12	0.94	0.08	1.21	0.33	460	0.75	0.13	0.82	0.06	128	35	6%
T 4.13	20.26	7.78	125.83	0.45	439	0.63	11.38	8.88	0.06	621	2	6%
T4 S13 C	20.23	6.36	94.9	2.37	435	0.7	8.75	11.48	0.06	469	11	6%
T4 S13 B	19.44	6.92	103.85	1.48	435	0.31	9.48	9.95	0.06	534	7	6%
T4 S13 A	20.32	7.67	122.1	0.71	440	0.19	11.07	9.25	0.06	600	3	6%
T 4.12	10.92	2.81	50.7	0.77	433	0.15	4.58	6.34	0.05	464	7	5%
T 4.7	60.22	17.99	356.31	4.56	437	0.37	32	28.22	0.05	591	7	5%
T4.11	2.56	0.33	10.47	0.28	435	12.04	0.93	1.63	0.03	409	11	3%
T 1.2	16.99	2.75	107.39	0.79	438	0.22	9.41	7.59	0.03	632	4	2%
T 4.3	7.25	0.73	45.25	0.25	431	5.64	3.92	3.33	0.02	624	3	2%
T 4.14	18.01	2.8	127.4	0.73	439	0.45	11.09	6.92	0.02	707	4	2%
T 1.1	8	0.31	28.09	1.25	439	0.33	2.46	5.53	0.01	351	15	1%
T 4.5	6.14	0.25	20.51	0.61	437	1.8	1.79	4.36	0.01	333	9	1%
T 4.6	9.8	0.38	55.49	0.37	437	2.83	4.77	5.03	0	566	3	1%

Onion Creek Data

Sample ID	TOC-Total Organic Carbon (Weight %)	S1-Free Oil (mgHC/g rock)	S2-Kerogen Yield (mgHC/g rock)	S3 (mgCO2/g rock)	Tmax-Maturity (°C)	CC-Carbonate Carbon (Weight %)	GOC-Generative OC (Weight %)	NGOC-Non-generative OC (Weight %)	PI-Production Index	HI-Hydrogen Index (mgHC/gTOC)	OI-Oxygen Index (mgCO2/gTOC)	S1/(S1+S2)
03 SC 15	1.23	0.12	0.4	0.17	374	17.85	0.05	1.17	0.24	32	14	23%
T 1.7	0.64	0.17	0.55	0.2	446	0.2	0.07	0.57	0.23	85	31	24%
T 1.9	1.71	0.1	0.37	0.3	428	2.45	0.05	1.66	0.21	21	17	21%
T 2.1	0.66	0.08	0.34	0.19	439	0.23	0.04	0.62	0.19	51	28	19%
T 1.8	1.12	0.1	0.43	0.13	426	0.36	0.06	1.06	0.19	38	11	19%
T 4.2	1.66	0.09	0.42	0.37	449	0.67	0.06	1.6	0.17	25	22	18%
T 4.1	1.15	0.07	0.35	0.29	442	7.35	0.05	1.1	0.17	30	25	17%
T 1.5	0.65	0.14	0.77	0.25	441	0.26	0.09	0.56	0.16	118	38	15%
T 1.6	0.65	0.11	0.6	0.24	441	0.44	0.07	0.57	0.15	93	37	15%
T 1.10	0.72	0.08	0.5	0.26	453	18.3	0.06	0.66	0.13	70	36	14%
T 1.3	1.59	0.17	1.58	0.3	438	3.47	0.16	1.43	0.1	99	18	10%
T 1.12	0.94	0.08	1.21	0.33	460	0.75	0.13	0.82	0.06	128	35	6%
T 4.13	20.26	7.78	125.83	0.45	439	0.63	11.38	8.88	0.06	621	2	6%
T4 S13 C	20.23	6.36	94.9	2.37	435	0.7	8.75	11.48	0.06	469	11	6%
T4 S13 B	19.44	6.92	103.85	1.48	435	0.31	9.48	9.95	0.06	534	7	6%
T4 S13 A	20.32	7.67	122.1	0.71	440	0.19	11.07	9.25	0.06	600	3	6%
T 4.12	10.92	2.81	50.7	0.77	433	0.15	4.58	6.34	0.05	464	7	5%
T 4.7	60.22	17.99	356.31	4.56	437	0.37	32	28.22	0.05	591	7	5%
T4.11	2.56	0.33	10.47	0.28	435	12.04	0.93	1.63	0.03	409	11	3%
T 1.2	16.99	2.75	107.39	0.79	438	0.22	9.41	7.59	0.03	632	4	2%
T 4.3	7.25	0.73	45.25	0.25	431	5.64	3.92	3.33	0.02	624	3	2%
T 4.14	18.01	2.8	127.4	0.73	439	0.45	11.09	6.92	0.02	707	4	2%
T 1.1	8	0.31	28.09	1.25	439	0.33	2.46	5.53	0.01	351	15	1%
T 4.5	6.14	0.25	20.51	0.61	437	1.8	1.79	4.36	0.01	333	9	1%
T 4.6	9.8	0.38	55.49	0.37	437	2.83	4.77	5.03	0	566	3	1%

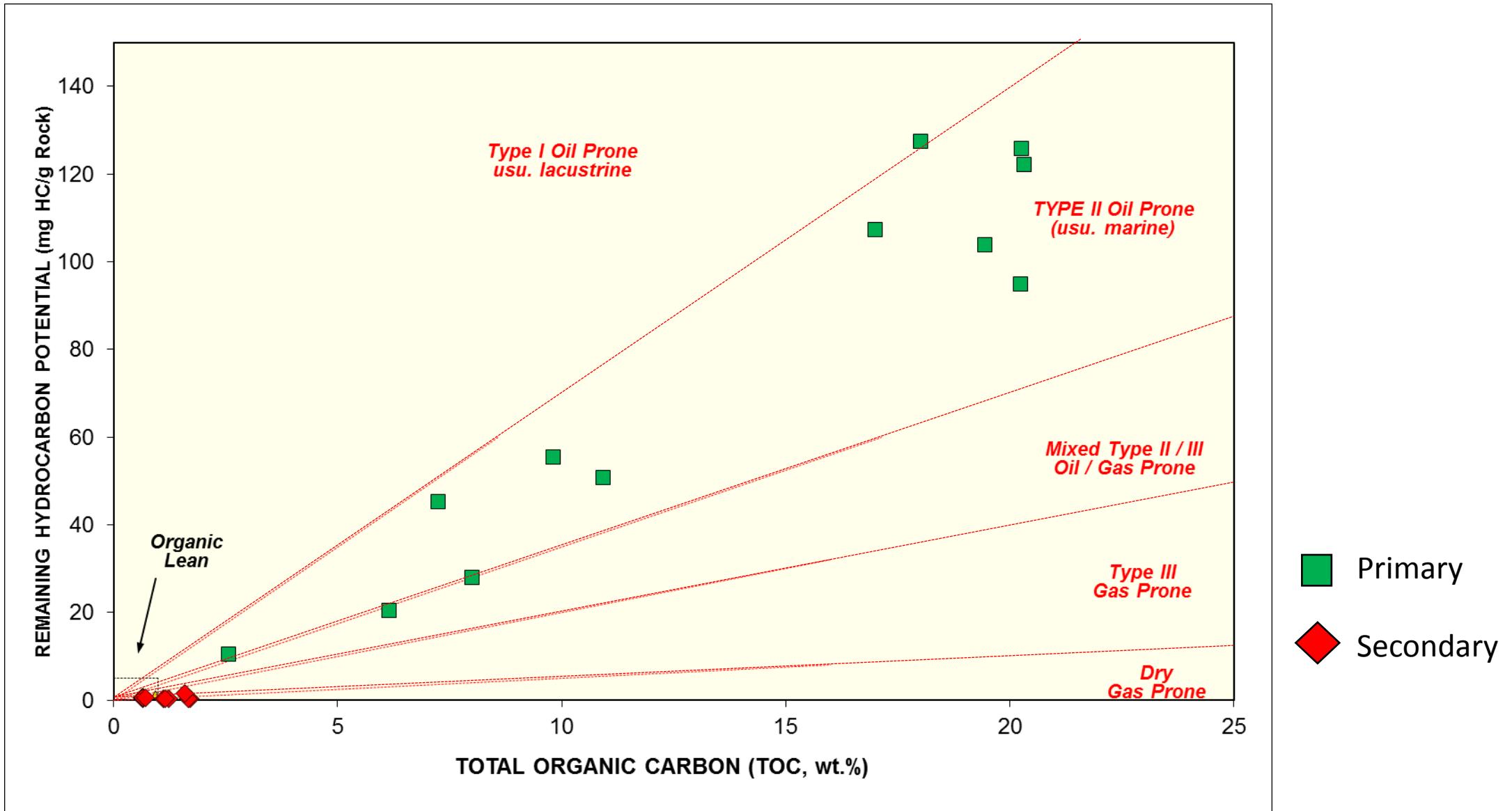
Primary

Onion Creek Data

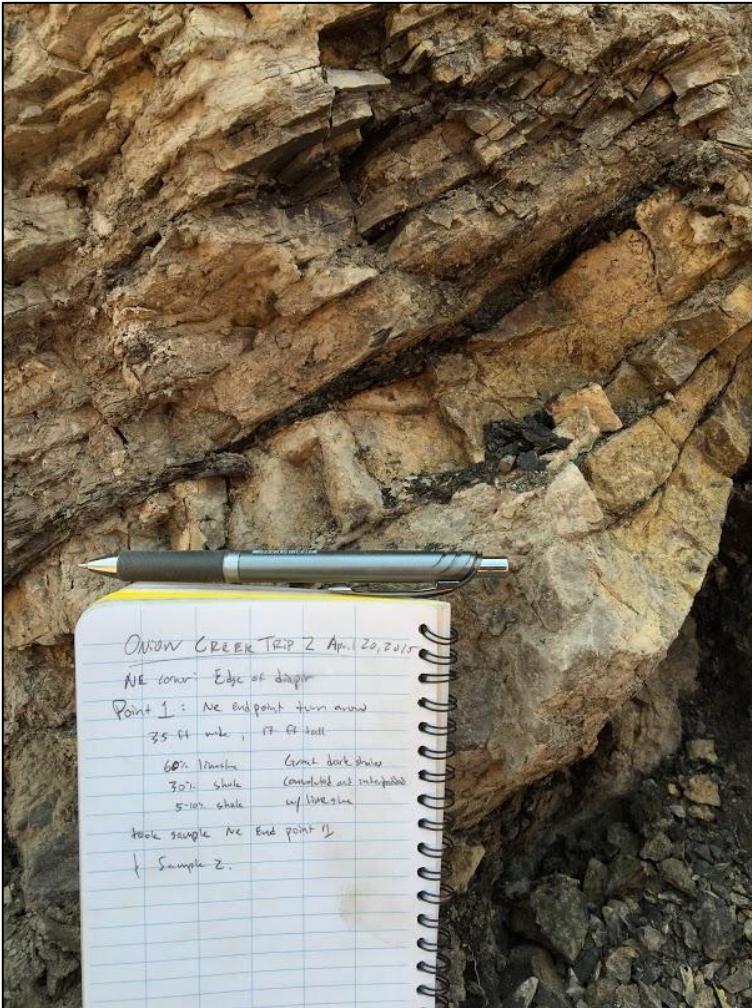
Sample ID	TOC-Total Organic Carbon (Weight %)	S1-Free Oil (mgHC/g rock)	S2-Kerogen Yield (mgHC/g rock)	S3 (mgCO2/g rock)	Tmax-Maturity (°C)	CC-Carbonate Carbon (Weight %)	GOC-Generative OC (Weight %)	NGOC-Non-generative OC (Weight %)	PI-Production Index	HI-Hydrogen Index (mgHC/gTOC)	OI-Oxygen Index (mgCO2/gTOC)	S1/(S1+S2)
03 SC 15	1.23	0.12	0.4	0.17	374	17.85	0.05	1.17	0.24	32	14	23%
T 1.7	0.64	0.17	0.55	0.2	446	0.2	0.07	0.57	0.23	85	31	24%
T 1.9	1.71	0.1	0.37	0.3	428	2.45	0.05	1.66	0.21	21	17	21%
T 2.1	0.66	0.08	0.34	0.19	439	0.23	0.04	0.62	0.19	51	28	19%
T 1.8	1.12	0.1	0.43	0.13	426	0.36	0.06	1.06	0.19	38	11	19%
T 4.2	1.66	0.09	0.42	0.37	449	0.67	0.06	1.6	0.17	25	22	18%
T 4.1	1.15	0.07	0.35	0.29	442	7.35	0.05	1.1	0.17	30	25	17%
T 1.5	0.65	0.14	0.77	0.25	441	0.26	0.09	0.56	0.16	118	38	15%
T 1.6	0.65	0.11	0.6	0.24	441	0.44	0.07	0.57	0.15	93	37	15%
T 1.10	0.72	0.08	0.5	0.26	453	18.3	0.06	0.66	0.13	70	36	14%
T 1.3	1.59	0.17	1.58	0.3	438	3.47	0.16	1.43	0.1	99	18	10%
T 1.12	0.94	0.08	1.21	0.33	460	0.75	0.13	0.82	0.06	128	35	6%
T 4.13	20.26	7.78	125.83	0.45	439	0.63	11.38	8.88	0.06	621	2	6%
T4 S13 C	20.23	6.36	94.9	2.37	435	0.7	8.75	11.48	0.06	469	11	6%
T4 S13 B	19.44	6.92	103.85	1.48	435	0.31	9.48	9.95	0.06	534	7	6%
T4 S13 A	20.32	7.67	122.1	0.71	440	0.19	11.07	9.25	0.06	600	3	6%
T 4.12	10.92	2.81	50.7	0.77	433	0.15	4.58	6.34	0.05	464	7	5%
T 4.7	60.22	17.99	356.31	4.56	437	0.37	32	28.22	0.05	591	7	5%
T4.11	2.56	0.33	10.47	0.28	435	12.04	0.93	1.63	0.03	409	11	3%
T 1.2	16.99	2.75	107.39	0.79	438	0.22	9.41	7.59	0.03	632	4	2%
T 4.3	7.25	0.73	45.25	0.25	431	5.64	3.92	3.33	0.02	624	3	2%
T 4.14	18.01	2.8	127.4	0.73	439	0.45	11.09	6.92	0.02	707	4	2%
T 1.1	8	0.31	28.09	1.25	439	0.33	2.46	5.53	0.01	351	15	1%
T 4.5	6.14	0.25	20.51	0.61	437	1.8	1.79	4.36	0.01	333	9	1%
T 4.6	9.8	0.38	55.49	0.37	437	2.83	4.77	5.03	0	566	3	1%

Secondary

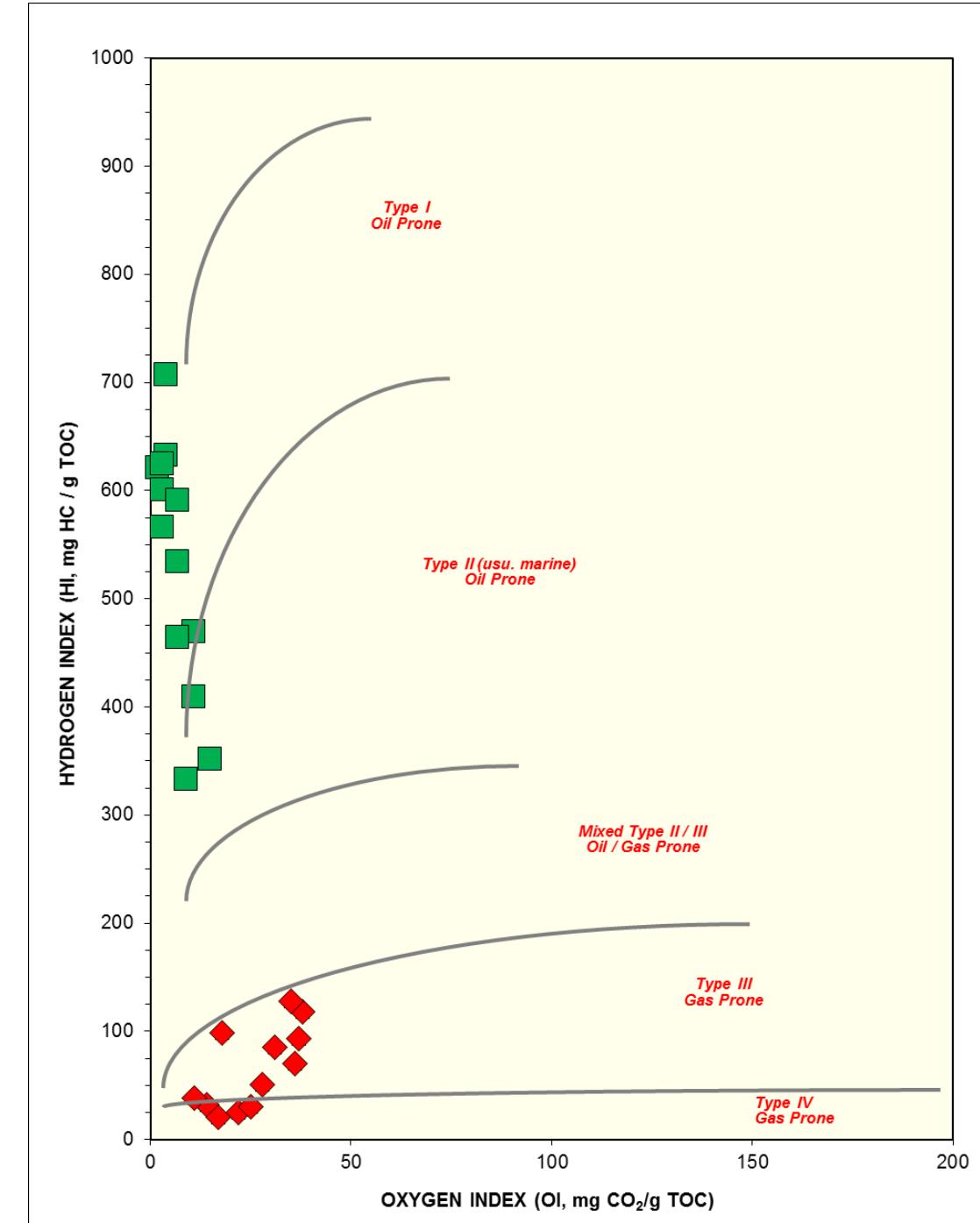
Onion Creek Data



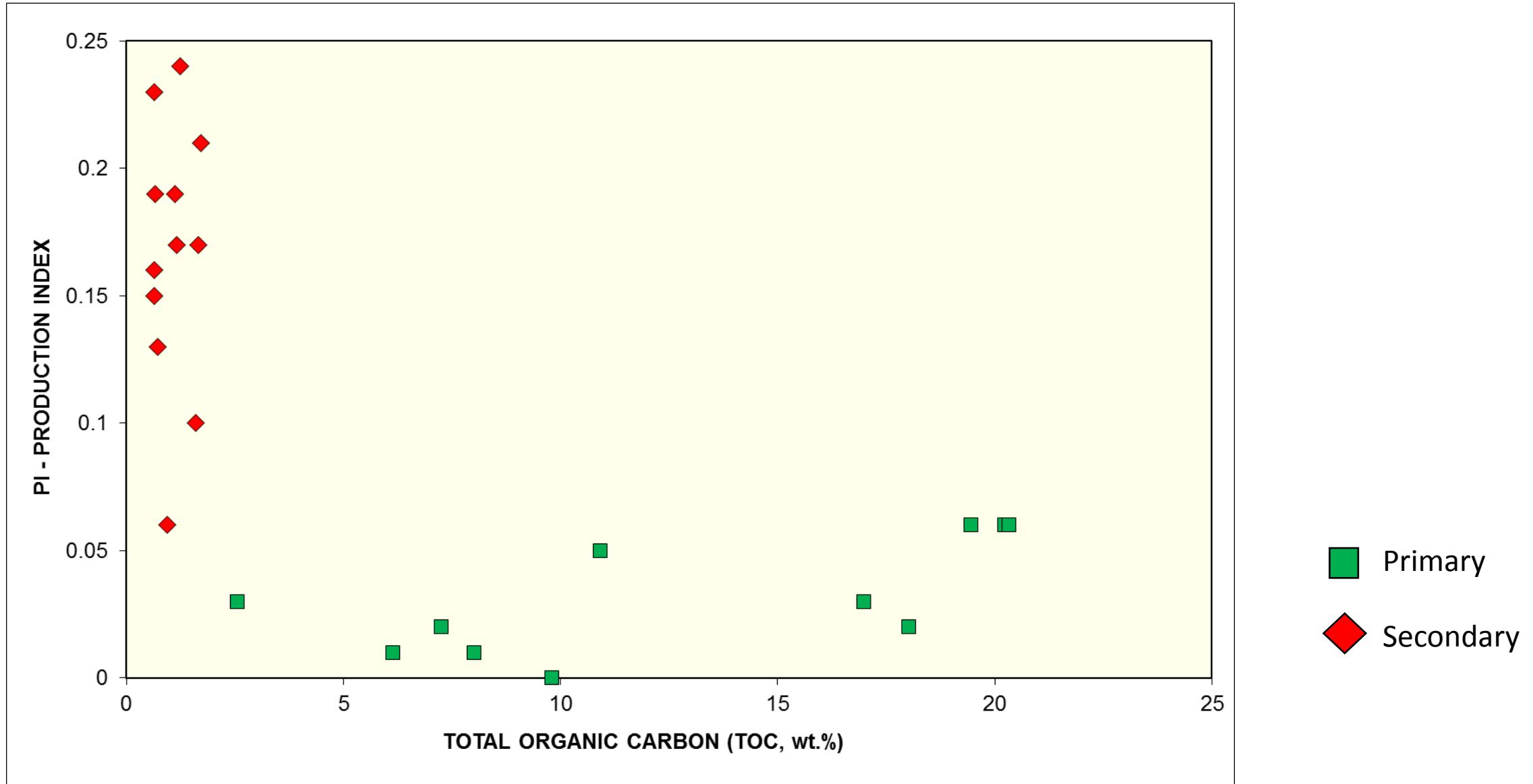
Onion Creek Data



■ Primary
◆ Secondary



Onion Creek Data



Onion Creek Data

Sample ID	TOC-Total Organic Carbon (Weight %)	S1-Free Oil (mgHC/g rock)	S2-Kerogen Yield (mgHC/g rock)	S3 (mgCO2/g rock)	Tmax-Maturity (°C)	CC-Carbonate Carbon (Weight %)	GOC-Generative OC (Weight %)	NGOC-Non-generative OC (Weight %)	PI-Production Index	HI-Hydrogen Index (mgHC/gTOC)	OI-Oxygen Index (mgCO2/gTOC)	S1/(S1+S2)
03 SC 15	1.23	0.12	0.4	0.17	374	17.85	0.05	1.17	0.24	32	14	23%
T 1.7	0.64	0.17	0.55	0.2	446	0.2	0.07	0.57	0.23	85	31	24%
T 1.9	1.71	0.1	0.37	0.3	428	2.45	0.05	1.66	0.21	21	17	21%
T 2.1	0.66	0.08	0.34	0.19	439	0.23	0.04	0.62	0.19	51	28	19%
T 1.8	1.12	0.1	0.43	0.13	426	0.36	0.06	1.06	0.19	38	11	19%
T 4.2	1.66	0.09	0.42	0.37	449	0.67	0.06	1.6	0.17	25	22	18%
T 4.1	1.15	0.07	0.35	0.29	442	7.35	0.05	1.1	0.17	30	25	17%
T 1.5	0.65	0.14	0.77	0.25	441	0.26	0.09	0.56	0.16	118	38	15%
T 1.6	0.65	0.11	0.6	0.24	441	0.44	0.07	0.57	0.15	93	37	15%
T 1.10	0.72	0.08	0.5	0.26	453	18.3	0.06	0.66	0.13	70	36	14%
T 1.3	1.59	0.17	1.58	0.3	438	3.47	0.16	1.43	0.1	99	18	10%
T 1.12	0.94	0.08	1.21	0.33	460	0.75	0.13	0.82	0.06	128	35	6%
T 4.13	20.26	7.78	125.83	0.45	439	0.63	11.38	8.88	0.06	621	2	6%
T4 S13 C	20.23	6.36	94.9	2.37	435	0.7	8.75	11.48	0.06	469	11	6%
T4 S13 B	19.44	6.92	103.85	1.48	435	0.31	9.48	9.95	0.06	534	7	6%
T4 S13 A	20.32	7.67	122.1	0.71	440	0.19	11.07	9.25	0.06	600	3	6%
T 4.12	10.92	2.81	50.7	0.77	433	0.15	4.58	6.34	0.05	464	7	5%
T 4.7	60.22	17.99	356.31	4.56	437	0.37	32	28.22	0.05	591	7	5%
T4.11	2.56	0.33	10.47	0.28	435	12.04	0.93	1.63	0.03	409	11	3%
T 1.2	16.99	2.75	107.39	0.79	438	0.22	9.41	7.59	0.03	632	4	2%
T 4.3	7.25	0.73	45.25	0.25	431	5.64	3.92	3.33	0.02	624	3	2%
T 4.14	18.01	2.8	127.4	0.73	439	0.45	11.09	6.92	0.02	707	4	2%
T 1.1	8	0.31	28.09	1.25	439	0.33	2.46	5.53	0.01	351	15	1%
T 4.5	6.14	0.25	20.51	0.61	437	1.8	1.79	4.36	0.01	333	9	1%
T 4.6	9.8	0.38	55.49	0.37	437	2.83	4.77	5.03	0	566	3	1%

Pyrolysis data distribution

Clear division between ‘primary’ organic shales and migrated HC’s

Paradox Shale samples

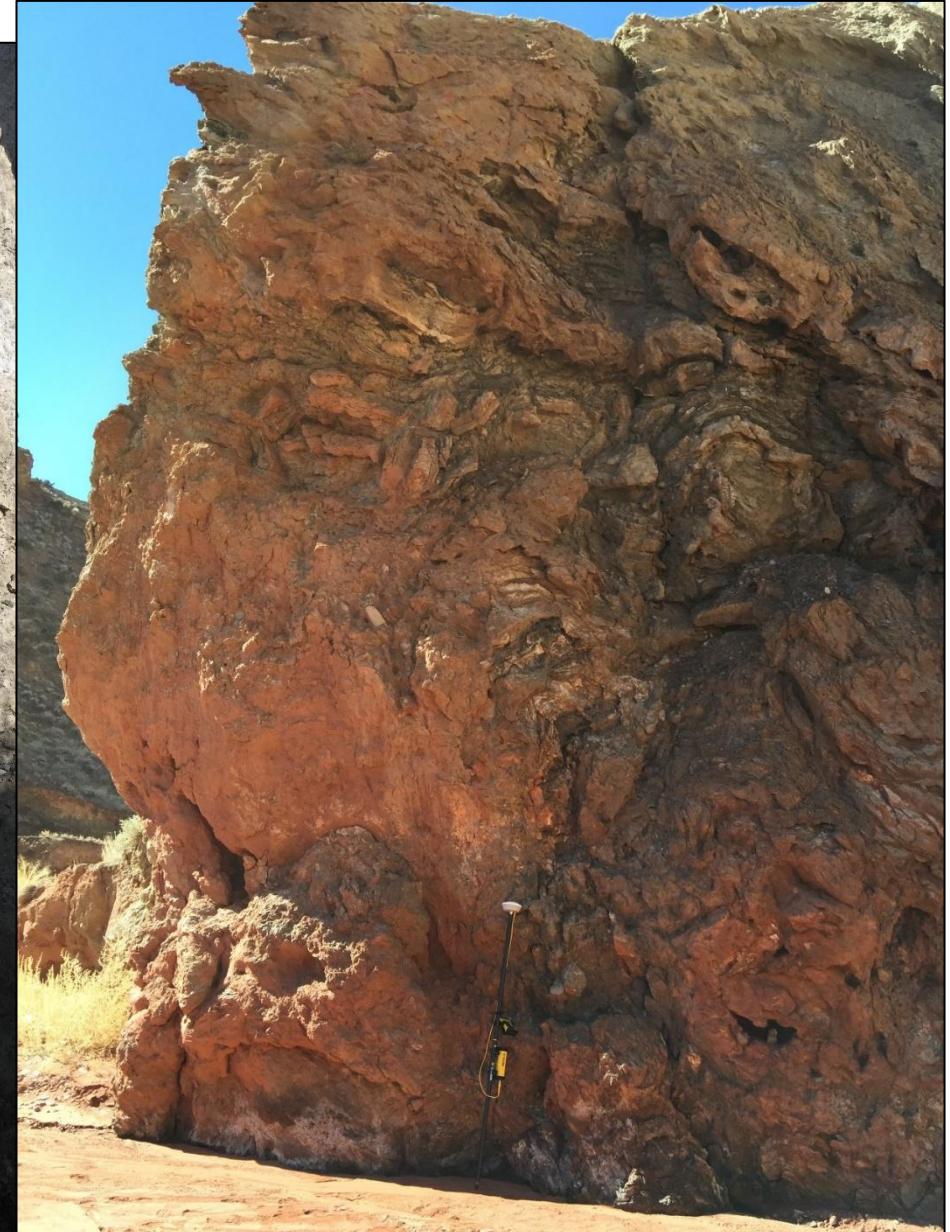
- Moderate to high TOC
- Low PI – low S1 to total OC ratio
- Clear, strong S2 peak

Migrated HC samples

- Low to moderate TOC
- High relative PI, despite low thermal maturity
- Strong S1 peak, less dominant, often bimodal S2 peak

HC Migration within the diapir

- Local migration into more porous strata
- Longer migration through evaporates, which are often highly deformed, banded



Learnings

- Onion Creek stringers contain abundant carbonates, organic-rich shales
- Black shales from within the Onion Creek diapir can be extremely rich in organics
- High OC shales within the diapir are frequently associated with secondary migration
- This staining can be found in carbonates, shales, evaporites
- Suggestions that this migration can cover significant distances within the Onion Creek diapir

Implications?

- Interbedded organic-rich shales can be abundant in salt bodies (similar depositional conditions).
- Salt, at least in this case, is not prohibiting HC migration.
- Could this be enough to give us false shows, even small accumulations???