Unraveling the Source and Dynamics of Produced Water from Hydraulically Fractured Middle Bakken and Three Forks Wells in the Williston Basin, ND Using Novel Water Geochemical Methods*

Shawn Wright[1], Steve Franks[2], John Pantano[3], Margie Kloska[1], and Jennifer Wolters[1]

Search and Discovery Article #42435 (2019)**
Posted September 9, 2019

*Adapted from oral presentation given at 2019 AAPG Annual Convention and Exhibition, San Antonio, Texas, May 19-22, 2019
 DOI:10.1306/42435Wright2019

[1]Hess Corporation, Houston, TX (swright@hess.com)
[2]RockFluid Systems, McKinney, TX
[3]Consultant, Bozeman, MT

Abstract

In the Williston Basin, thin reservoirs coupled with large stimulation jobs result in large vertical hydraulic fractures and out-of-zone contribution of fluids to the wells. To understand the extent of vertical fracture growth and the source of fluids reaching the wellbore, the time-lapse elemental and isotopic composition of produced waters was compared with the in-situ pore water chemistry reconstructed from core analysis (Residual Salts Analysis [RSA]) for a set of wells in Williams County, ND. These data were integrated with production data to determine the time-dependent fluid contributions from the different formations that are possibly contributing fluids through hydraulic fractures. RSA was performed on 26 core plugs from the Lodgepole, Upper Bakken Shale, Middle Bakken (MB), Lower Bakken Shale, and Three Forks (TF). RSA data indicate that the sampled formations have distinct fingerprints, predominantly in terms of strontium abundance and isotopic compositions. Once baseline compositions for all formations were established, time-lapsed produced water samples were taken from two lateral wells (1MB and 1TF; high-impact stimulation) proximal to the baseline RSA data. Time-lapsed water chemistry from both lateral wells indicates that from initial flowback through 7 months of production >80% of the produced water is sourced from muddy intervals of the TF with minimal water contribution from other formations. Large compositional changes in the produced water within this time-period are caused by operational disturbances and changes in flow rate. In contrast, the chemistry of produced water from older wells (2010) with lower impact stimulation indicate more contribution of pore water from the MB, with the smallest impact stimulation showing >90% contribution from the MB. The preliminary data suggest that high-impact stimulation results in large vertical hydraulic fractures that stay open for at least 7 months, resulting in produced water being dominated by a TF source. Based on the data from older wells, the relative contribution of water from the TF diminishes over time, indicating diminished communication with the TF. Results from this study also have implications about irreducible and critical water saturations, which both have critical impact in reservoir models. A comprehensive understanding of the origins of fluids from different subsurface storage units improves well stimulation and production programs, and ultimately, well economics.

Reference Cited

Smalley, P.C., A.C. Higgins, R.J. Howarth, H. Nicholson, C.E. Jones, N.H.M. Swinburne, and J. Bessa, 1994, Seawater Sr Isotope Variations Through Time: A Procedure for Constructing a Reference Curve to Date and Correlate Marine Sedimentary Rocks: Geology, v. 22/5, p. 431-434. doi.org/10.1130/0091-7613(1994)022<0431:SSIVTT>2.3.CO;2

Unraveling the Source and Dynamics of Produced Water from Hydraulically Fractured Middle Bakken and Three Forks Wells in the Williston Basin, ND Using Novel Water Geochemical Methods

Shawn Wright*[1], Steve Franks[2], John Pantano[3], Margie Kloska[1], Jennifer Wolters[1]

1. Hess Corporation, 2. RockFluid Systems, 3. Consultant

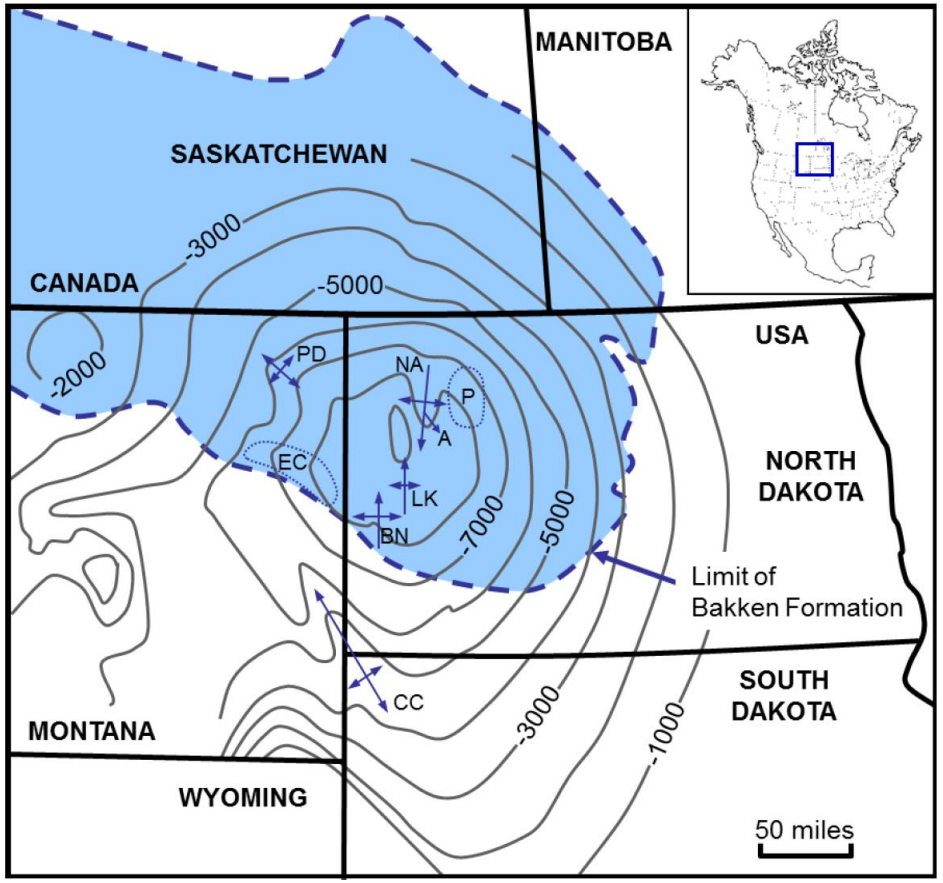
May 22nd, 2019

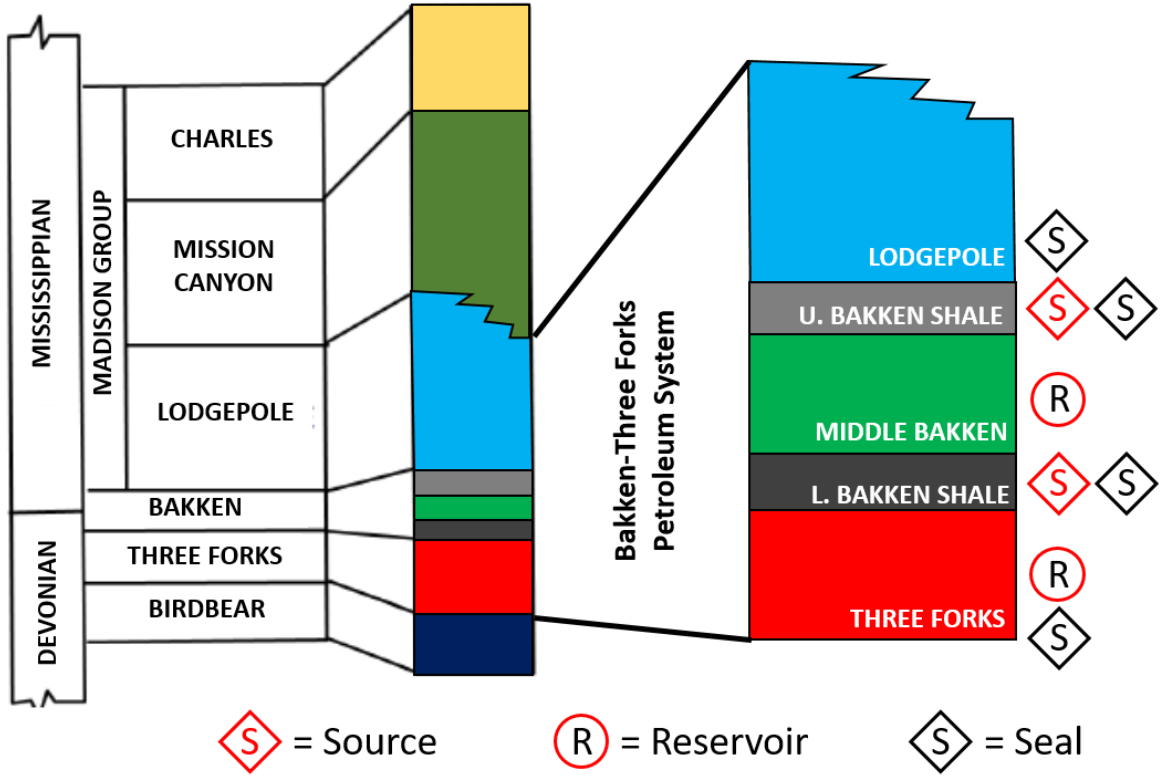
ISOBRINE solutions

NCS NESET CONSULTING SERVICE

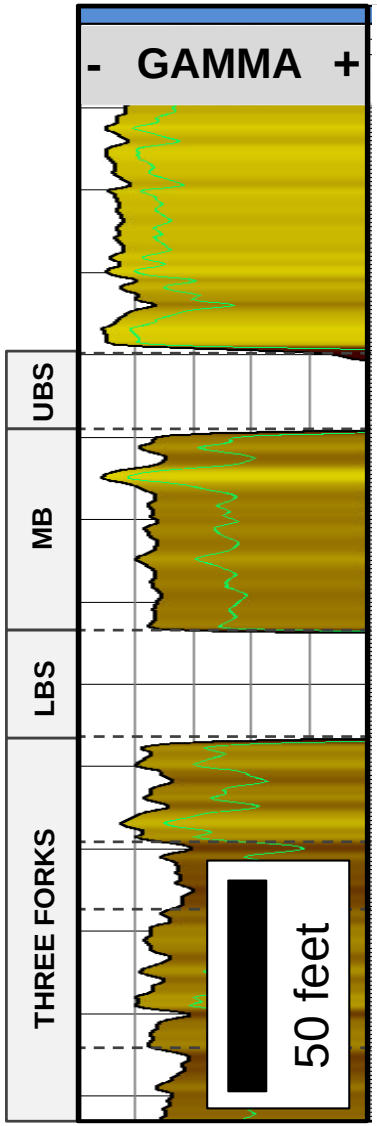
ISOTOPIC

The Williston Basin / Bakken Petroleum System

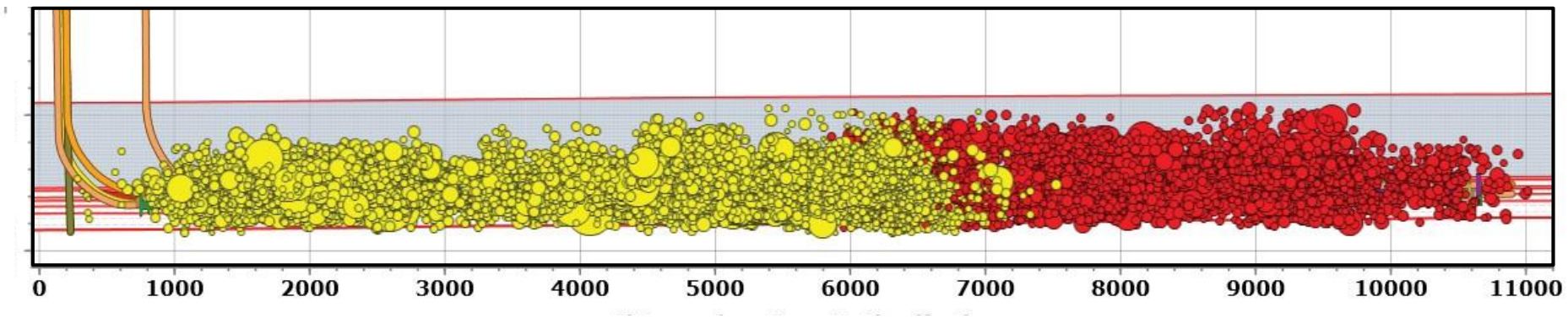




The Problem

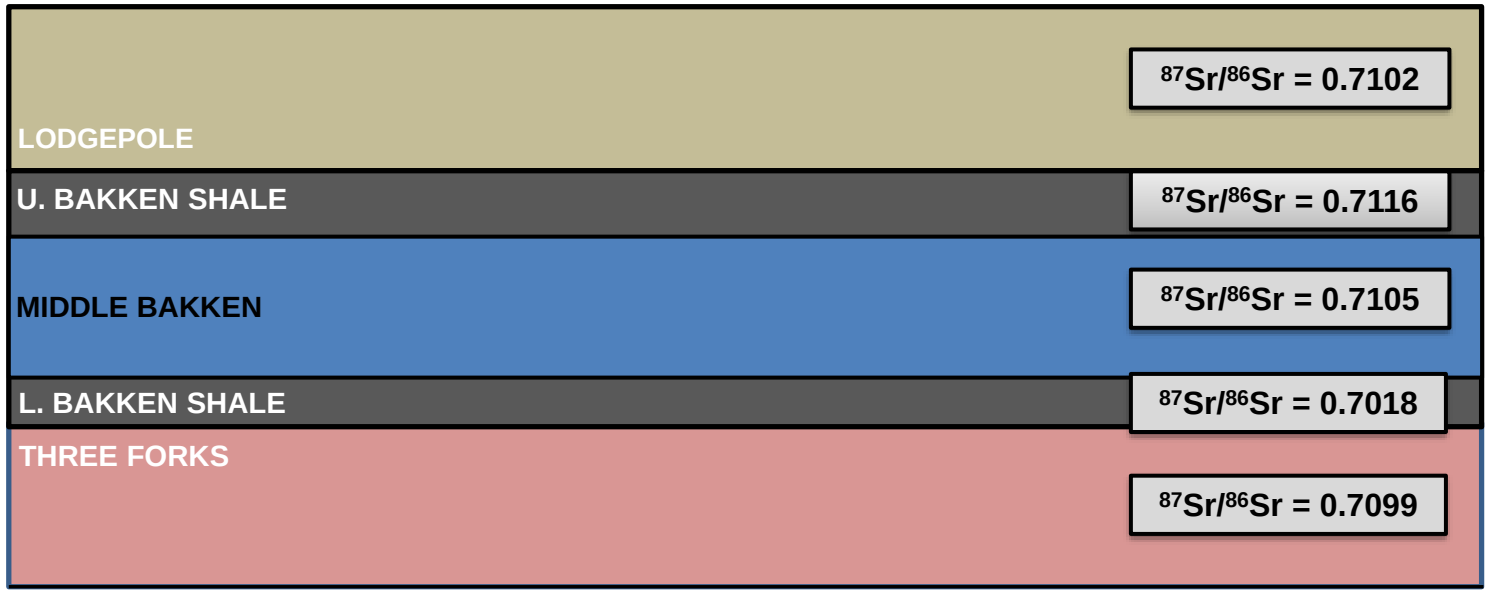


1. Low permeability reservoirs (100's – 1000's of nD) require hydraulic fracturing for economic oil production.
2. Thin reservoirs (~50 feet in study area) coupled with hydraulic fracturing results in out-of-zone vertical fracture growth
3. Assessing reservoir connectivity helps in optimizing acreage development decisions
4. This study uses water chemistry to tackle this issue



Project Concept

Conceptually, there are geochemical differences in the pore waters between the Lodgepole, UBS, MB, LBS, and Three Forks formations.

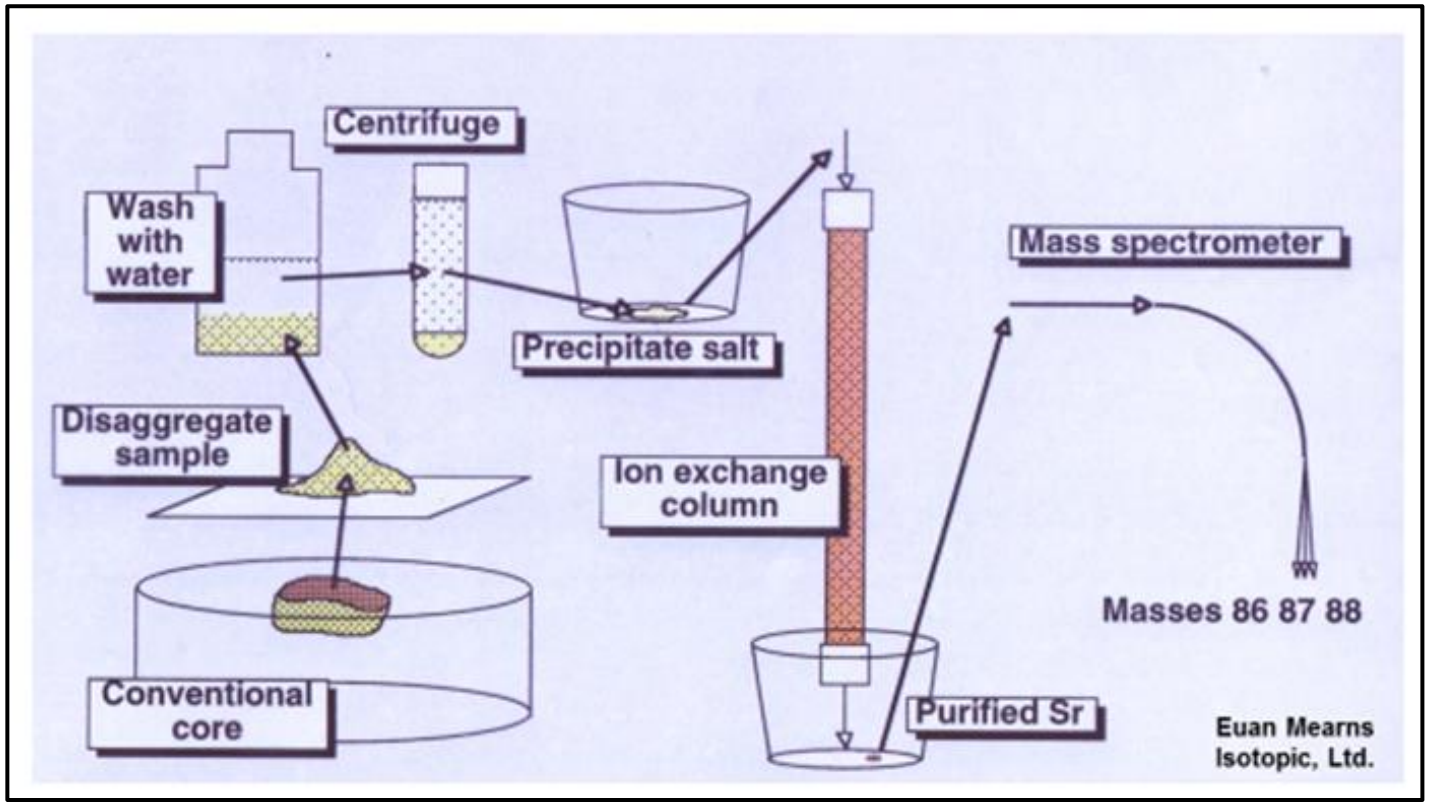


*Not to scale

If true… we can measure the composition of produced waters, with time, to determine the amount of water production that is coming from potential “in-communication” formations….

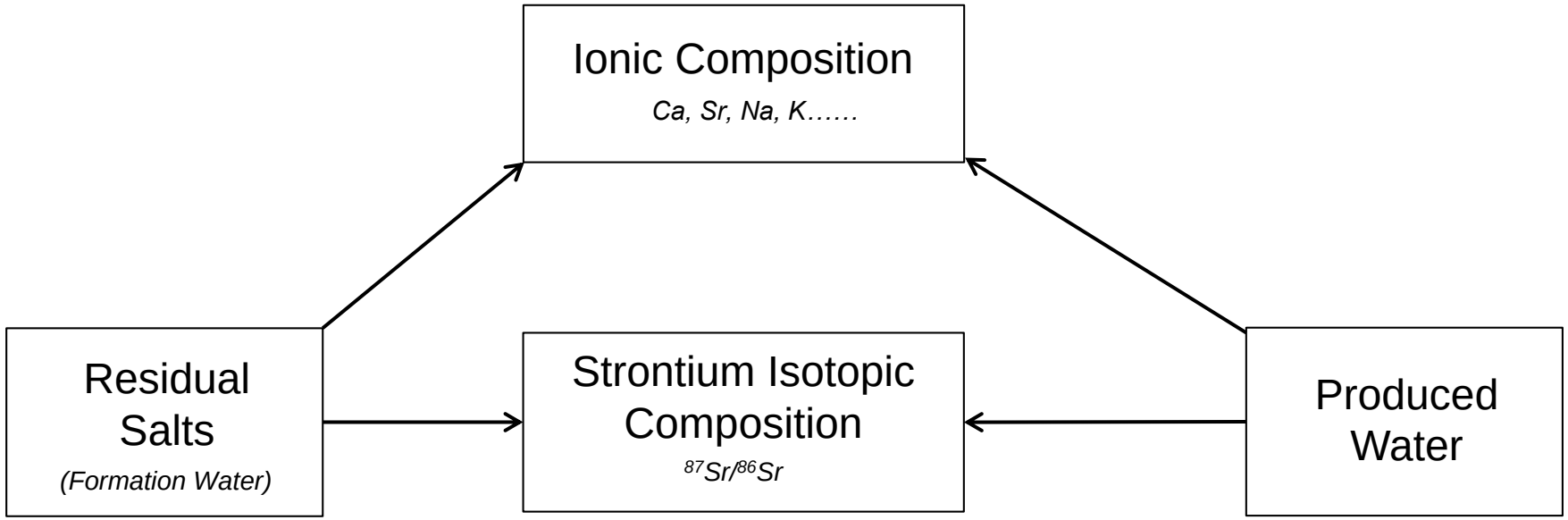
Methods: Residual Salts Analysis (RSA)

Residual Salts Analysis (RSA) provides a means of determining the ionic and strontium isotopic composition of the pore waters within each formation of interest.



Provides: Ca, K, Mg, Na, Ba, Sr, Cl, Br, B, I, HCO_3, SO_4, $^{87}Sr/^{86}Sr$

Project Workflow



Controls on Formation Water Composition

Waters, like oils and gases, carry their own fingerprint of origin, including water/rock diagenetic reactions and mixing of fluids in the subsurface.

The composition of subsurface formation waters is controlled by:

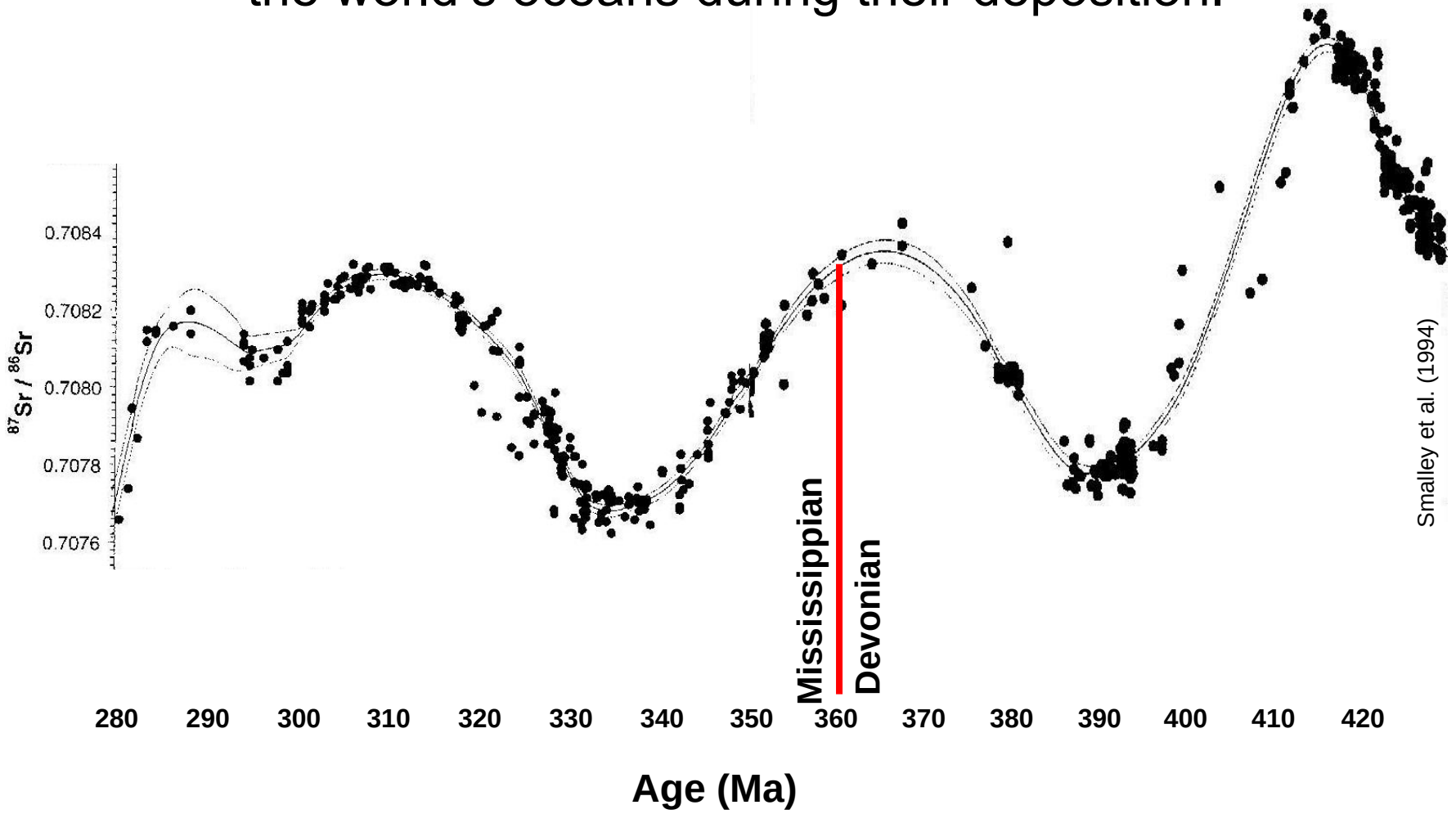
1. The composition of the original pore water (e.g., fresh-water, marine)
   - Bakken = marine

2. Interaction with organisms and minerals during diagenesis (e.g., bacterial sulphate reduction, ionic exchange)
   - (e.g., dolomitization, smectite-illite transition, thermal maturation)

3. Mixing with other fluids (e.g., aquifers, fault fluids, salt dissolution)

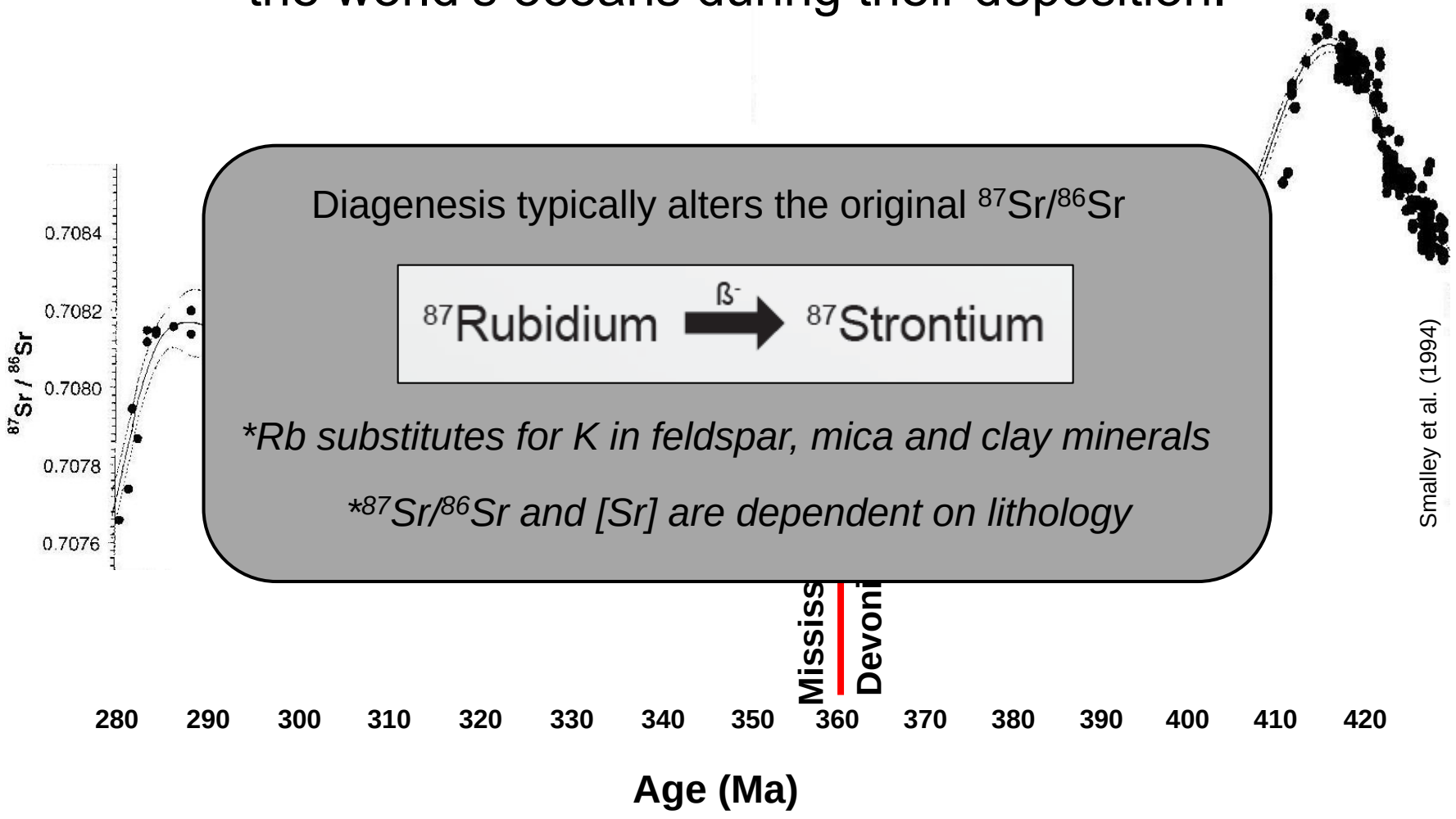
Water Chemistry: Strontium Isotopes

Initial water in the pores of marine sediments will inherit the $^{87}Sr/^{86}Sr$ of the world's oceans during their deposition.

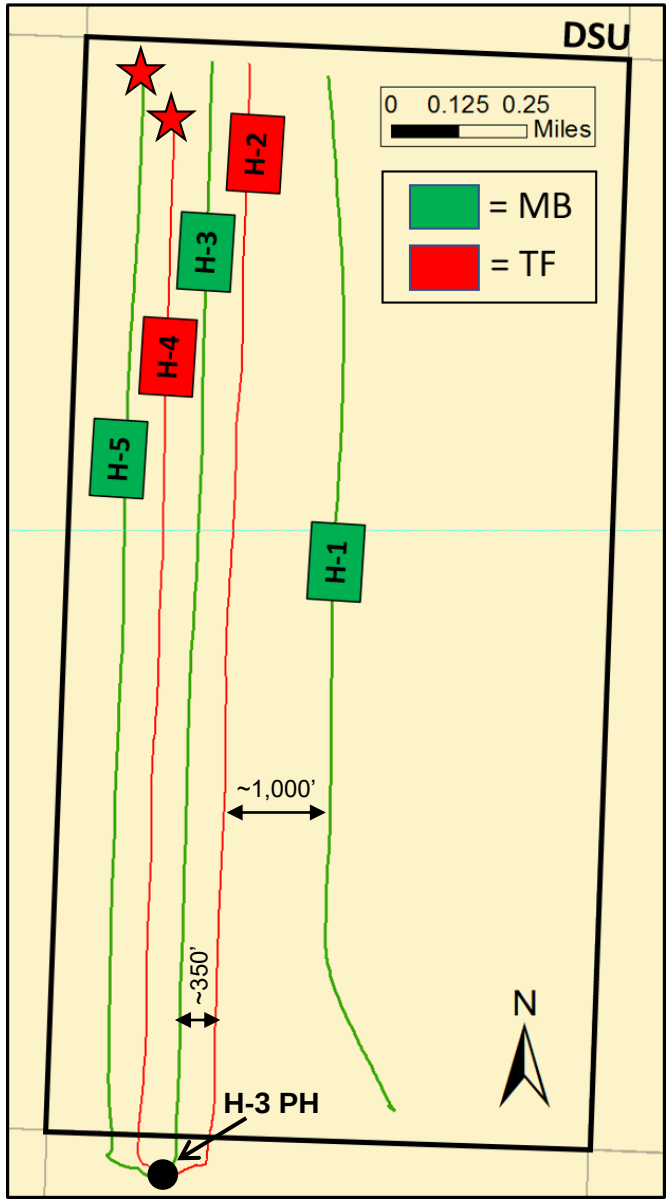


Water Chemistry: Strontium Isotopes

Initial water in the pores of marine sediments will inherit the $^{87}Sr/^{86}Sr$ of the world's oceans during their deposition.



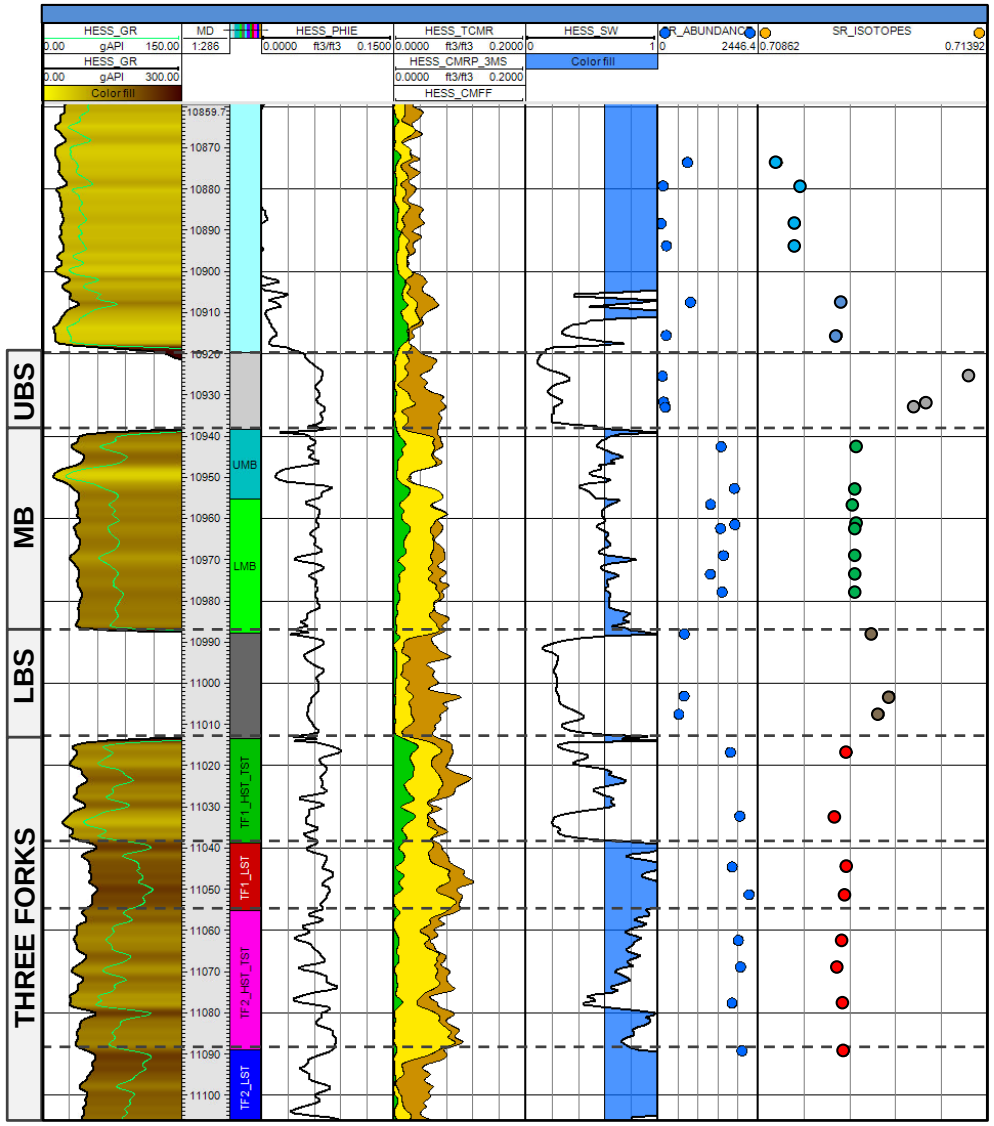
Project DSU Overview



Drill Spacing Unit (DSU):

- RSA on H-3 PH core (n=28)
  - 4 Lodgepole
  - 2 Scallion
  - 3 UBS
  - 8 MB
  - 3 LBS
  - 8 Three Forks
- Time-Lapsed Produced Water Sampling on H-4 (TF) and H-5 (MB)
  - Ionic Composition
  - Stable Isotopes (H and O)
  - Strontium Isotopes
- Real-time production and water density monitoring

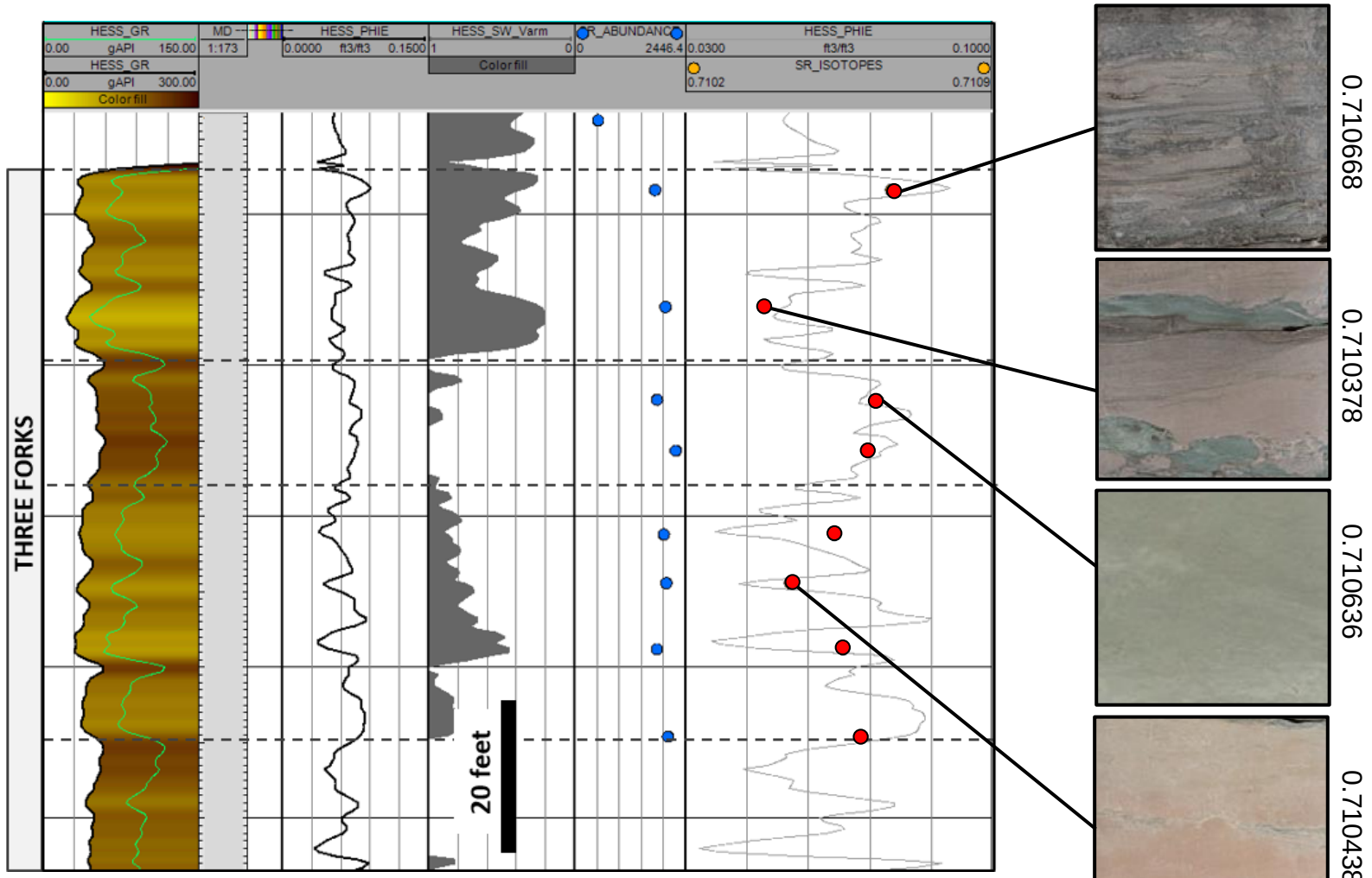
Residual Salts Analysis (RSA) - Observations



Each formation water has a unique water fingerprint

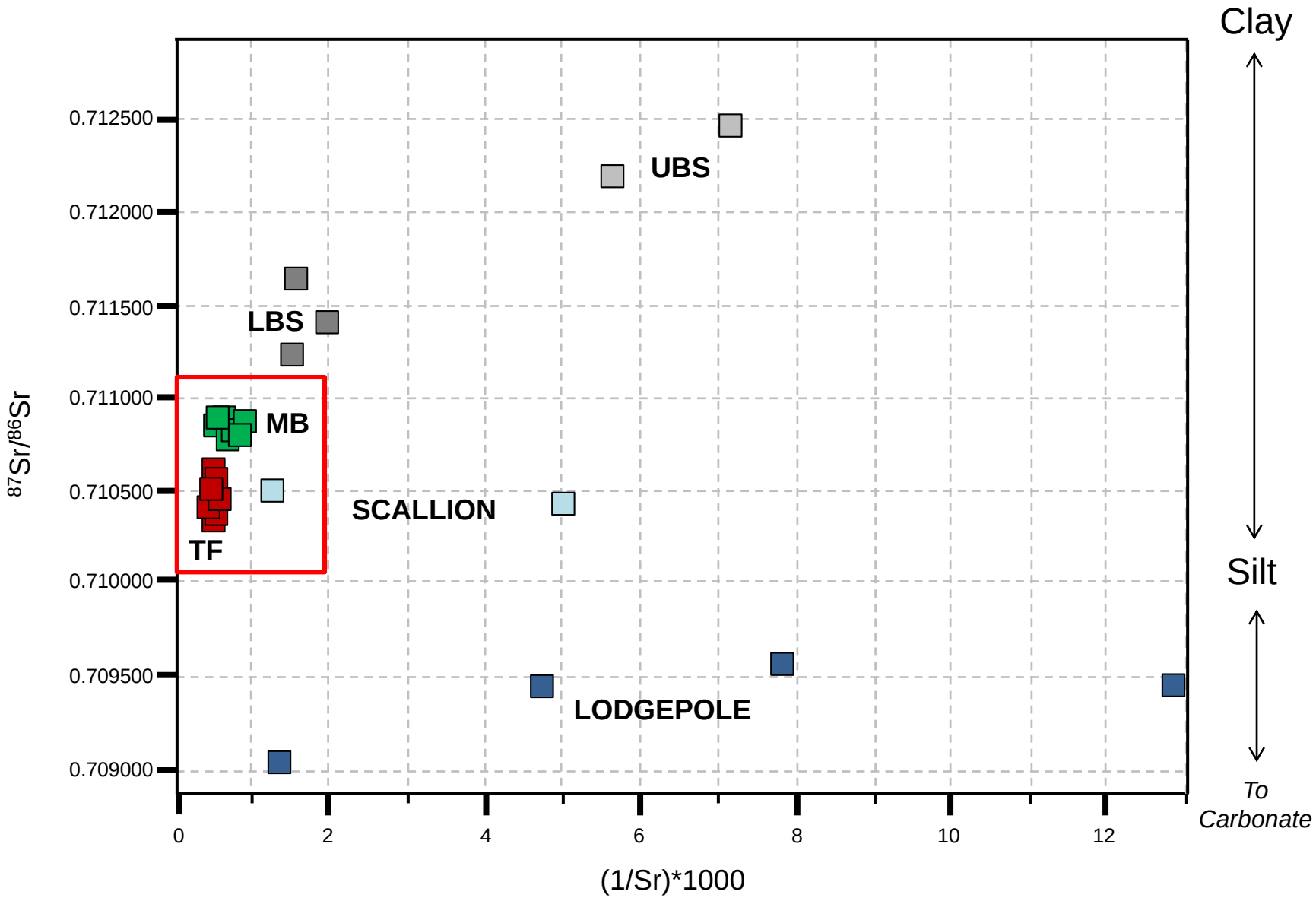
- Variation in $^{87}Sr/^{86}Sr$ and [Sr]

Residual Salts Analysis (RSA) – TF Trends

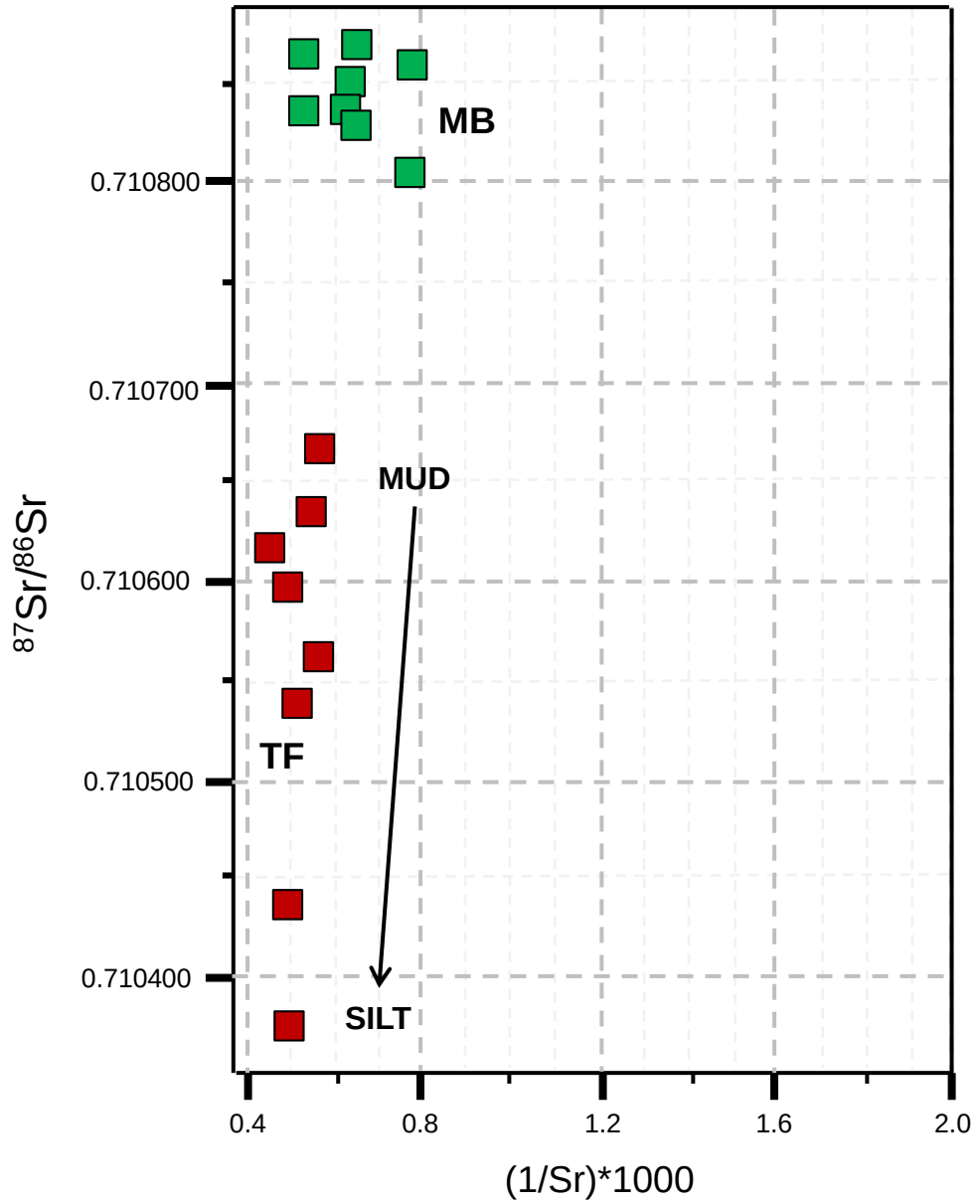


Muddy facies are typically the most water saturated

Residual Salts Analysis (RSA) - Uniqueness

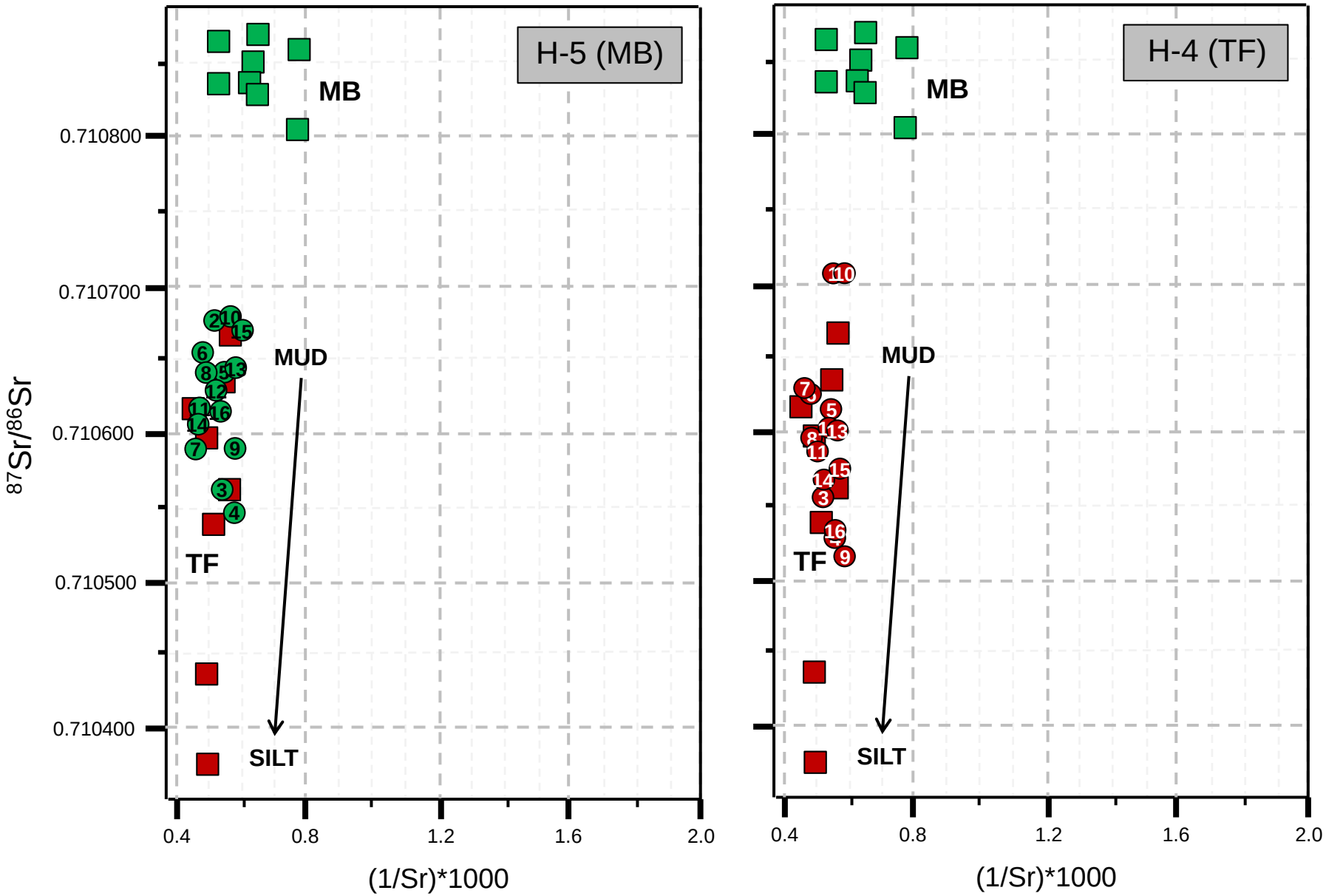


RSA vs. Produced Water Chemistry



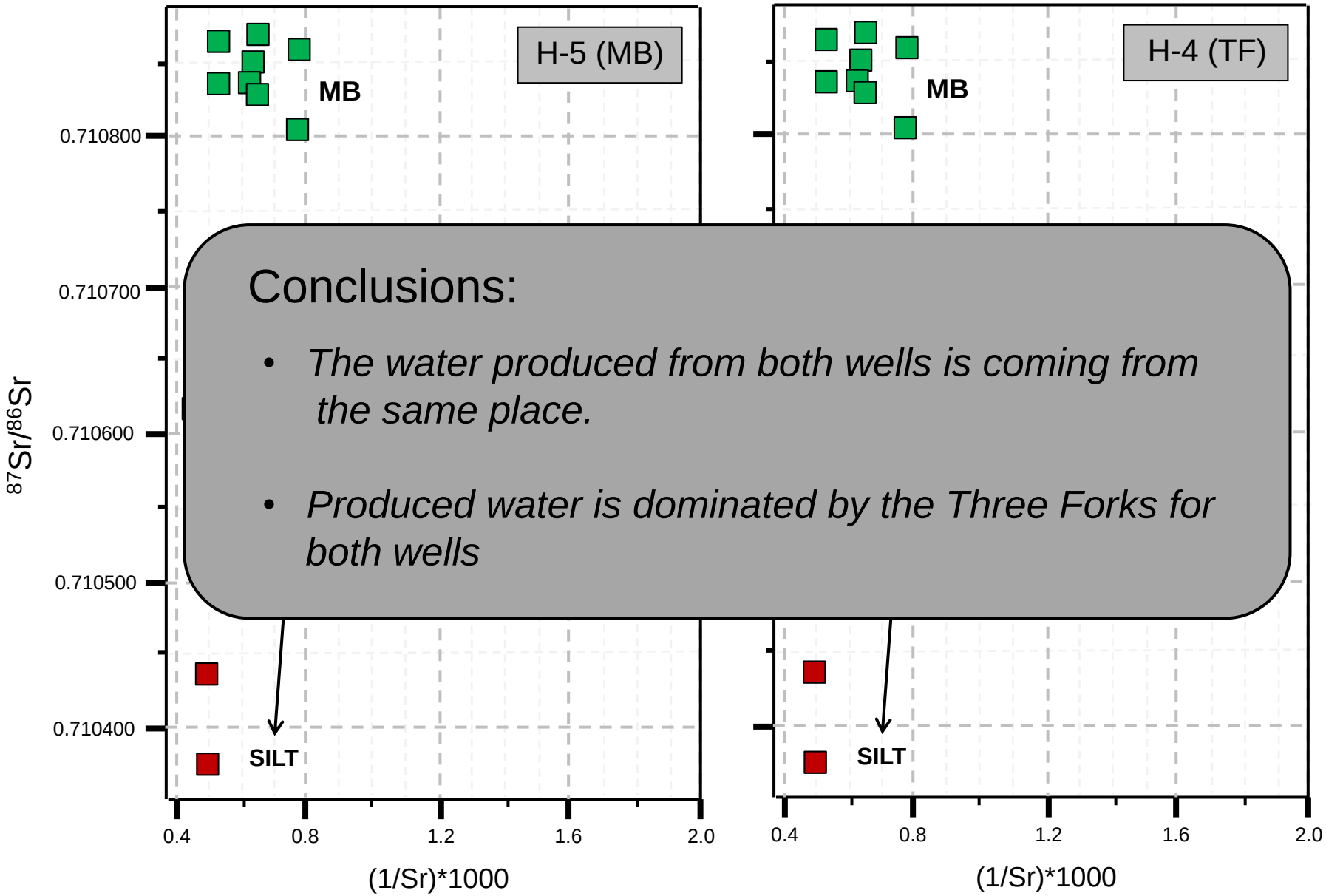
RSA vs. Produced Water Chemistry

1	3/14
2	3/20
3	3/27
4	4/10
5	4/25
6	5/9
7	5/21
8	6/4
9	6/19
10	7/2
11	7/17
12	7/31
13	8/14
14	8/28
15	9/12
16	9/15



RSA vs. Produced Water Chemistry

1	3/14
2	3/20
3	3/27
4	4/10
5	4/25
6	5/9
7	5/21
8	6/4
9	6/19
10	7/2
11	7/17
12	7/31
13	8/14
14	8/28
15	9/12
16	9/15

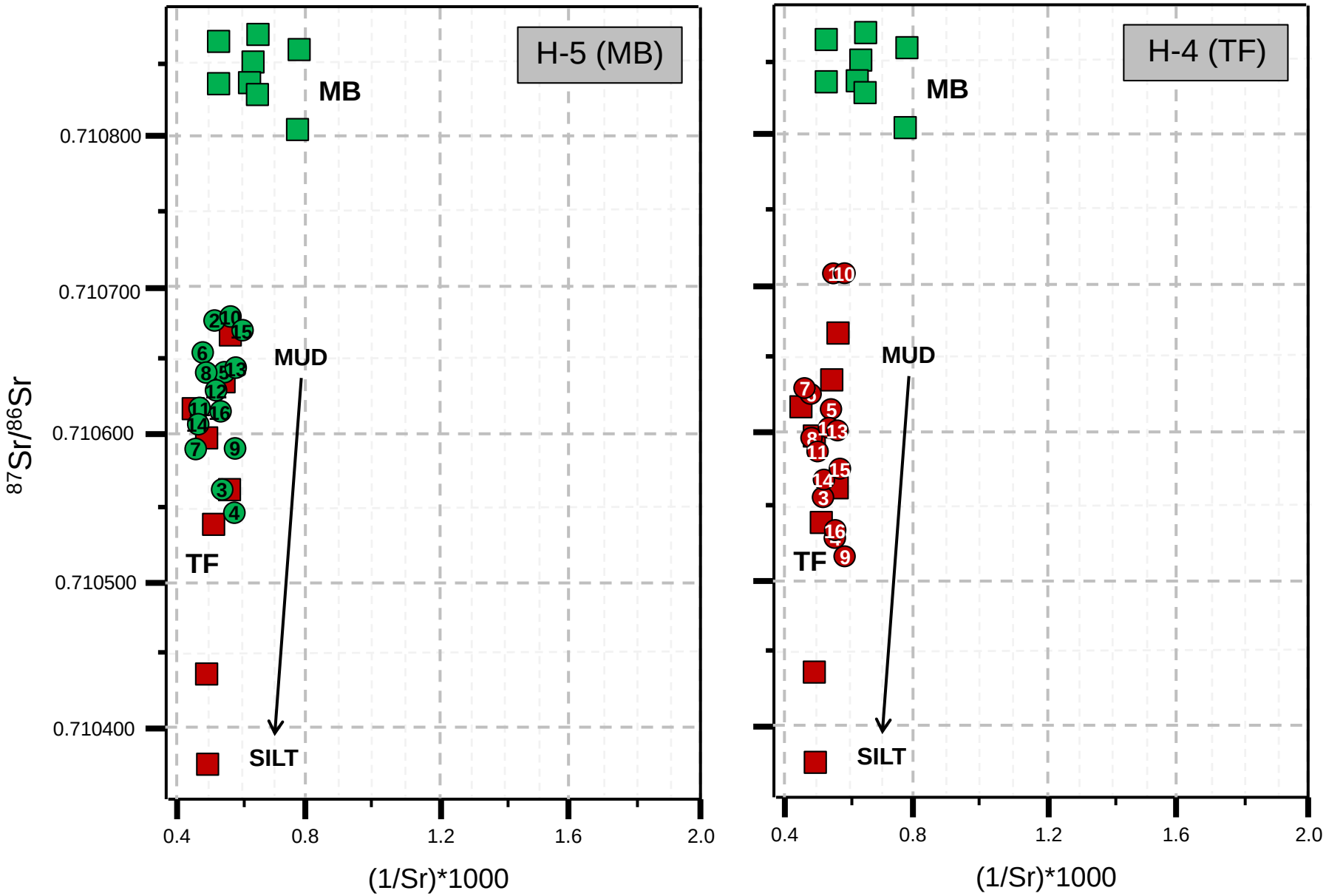


Conclusions:

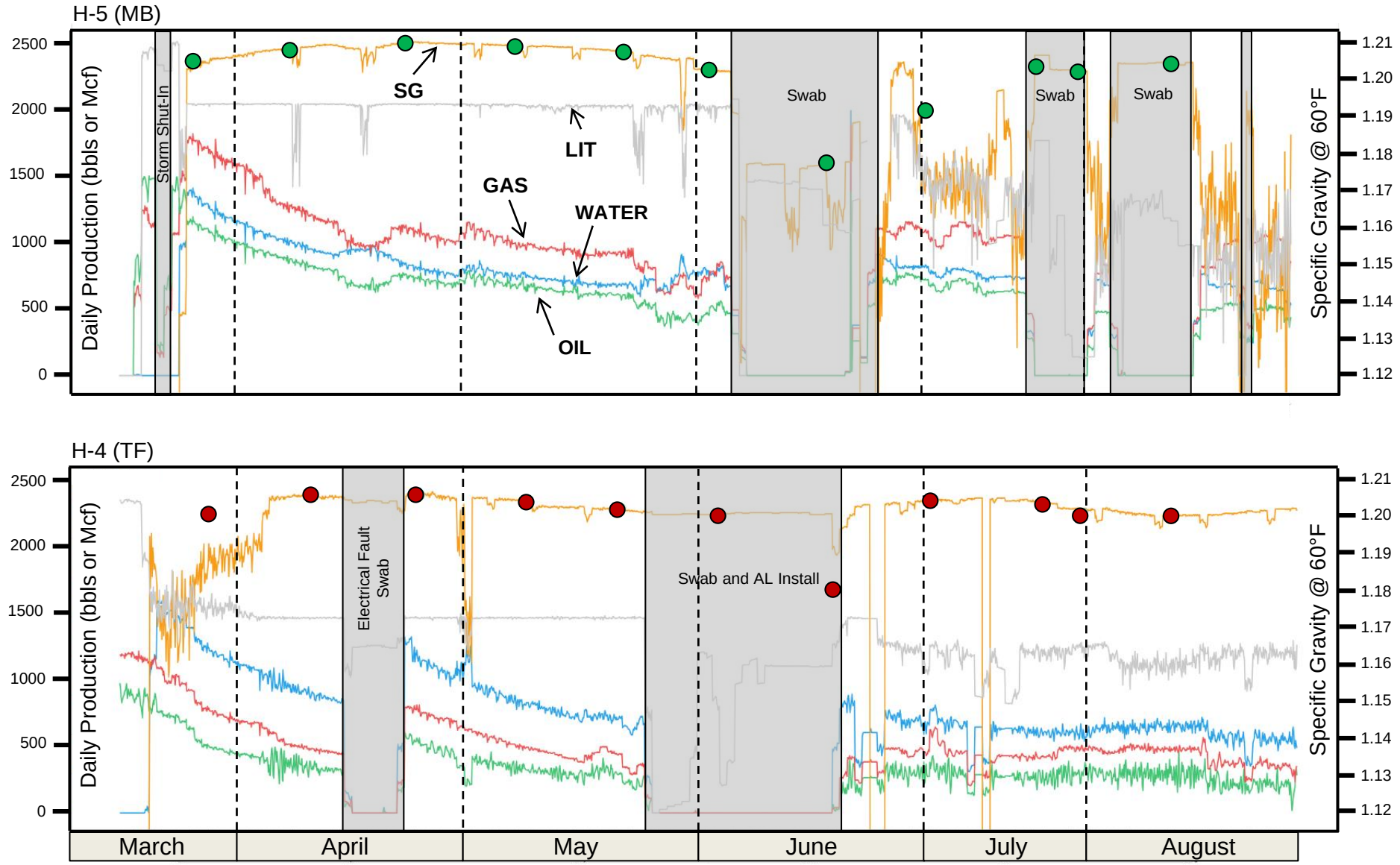
- *The water produced from both wells is coming from the same place.*
- *Produced water is dominated by the Three Forks for both wells*

RSA vs. Produced Water Chemistry

1	3/14
2	3/20
3	3/27
4	4/10
5	4/25
6	5/9
7	5/21
8	6/4
9	6/19
10	7/2
11	7/17
12	7/31
13	8/14
14	8/28
15	9/12
16	9/15



Production Data



Conclusions

- RSA is a reliable method to reconstruct pore water chemistry
  - $^{87}Sr/^{86}Sr$ is the most reliable and give us the most information
- Produced water from MB and TF wells is coming from the TF
  - 40-60% MB/TF mixture?
  - 80-90% muddy facies within the TF?
- There is no to very minimal contribution of water from the Scallion, Lodgepole, UBS, or LBS to MB and TF wells *within the time-period sampled*
  - Due to low permeabilities, irreducible water saturation?
- There is no systematic trend in changes in the source of the water
  - Time frame: 6 months (H-4; H-5); 6 years (H-1)
  - Implications for continued open fracture communication

Conclusions

- Produced Water ≠ Produced Oil
  - We cannot assume that produced oil is coming from the same place as produced water
  - Water does tell us about communication between reservoirs
  - Allocation of oil / water may change with time due to changing reservoir conditions
  - No water production from the shales ≠ No oil production from the shales

- Event driven sampling > Fixed interval sampling
  - Can provide more information about operational-induced, and production rate related changes in the source of produced waters

End

Thank You!