Microseismic Monitoring During CO_2 Injection in a Pinnacle Reef Reservoir

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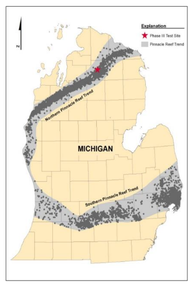
INTRODUCTION

The Midwest Regional Carbon Sequestration Partnership (MRCSP) is implementing a commercial-scale carbon capture utilization and storage (CCUS) project in multiple Silurian-age carbonate pinnacle reefs in northern Michigan that are in various phases of enhanced oil recovery. This poster presents results of a 21-day microseismic monitoring study during CO_2 injection into a closed boundary pinnacle reef reservoir at near-discovery pressure.

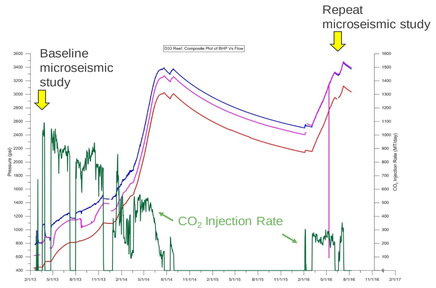


Location of the Study Reef within the Northern Pinnacle Reef Trend

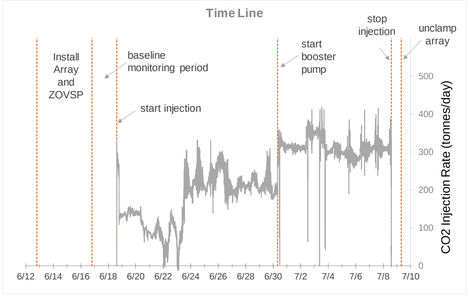
Objectives of Microseismic Monitoring Study

- Monitor microseismic activity while injecting CO_2 into a closed reservoir that is 1) in a pressure depleted state (baseline survey, 2013) and 2) at near discovery pressure (repeat survey, 2016)
- Determine if there is an increased likelihood of microseismic activity at end of reef fill-up when pressures are near discovery pressure

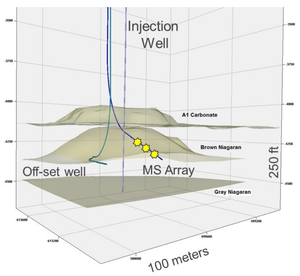
Timing of Baseline and Repeat Micro-Seismic Surveys and Pressure History in 3 Wells During CO_2 Injection



Time line of 21-day 2016 Repeat Micro-Seismic Study



MICROSEISMIC MONITORING LAYOUT



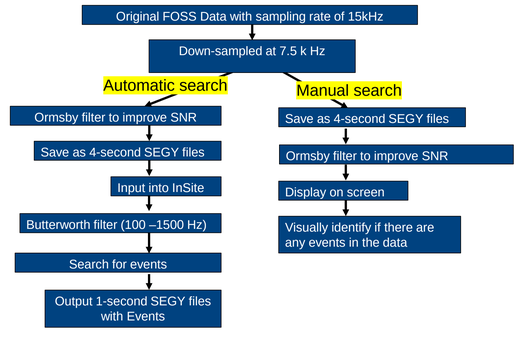
- Paulsson16-level 3C Fiber Optic Seismic Sensor (FOSS™) array with 25 ft spacing was deployed in the 5-33 well.
- Array depth: 5,572 – 5,947 ft
- Array aperture: 375 ft

Paulsson Fiber Optic Seismic Sensor (FOSS®)

Single 3C Optical Sensor (18 in. x 2 in. diam.)

Sensor Housing Showing Clamped Position

Microseismic Event Detection Workflow



Results of Manual Picking

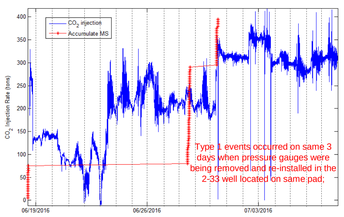
Manual picking was deemed more reliable than automatic method. Overall, thousands of "events" were detected, which were categorized into three distinct types based on waveform characteristics.

Type 1 (n=79) caused by work in nearby well
Type 2 (n= hundreds) are "Near Well and Very Small" events
Type 3 (n= thousands) are "Long Duration" events of unknown origin.

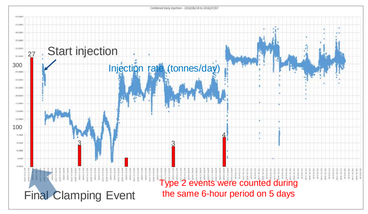
The estimated magnitude of all three types of events is less than M=-2

CHARACTERISTICS OF DETECTED EVENTS

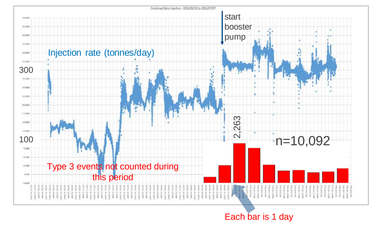
Type 1 Events Occurrence



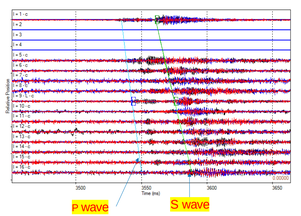
Type 2 Events Occurrence



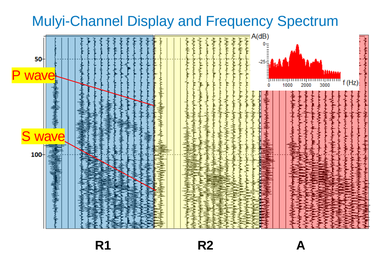
Type 3 Events Occurrence



Type 1 Events

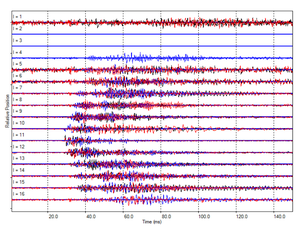


- Both P and S waves
- S waves are stronger than P waves
- Detected by all channels
- P and S waves have moveouts with first arrival at pod #1
- Fair S/N ratio
- All 79 Type 1 events came from similar direction

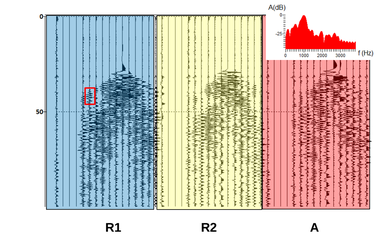


- Source is in the r1 direction.
- The frequency of the event is broad with a peak around 1500 Hz (similar to string shot).

Type 2 Events

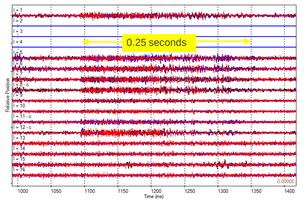


- Spread in arrival times along the length of the array (point source)
- Amplitude is greatest at pod(s) where signal is first detected but attenuates quickly along the array (source is small)
- Travel time difference between the P and S waves is very small, indicating the source is close to the receivers.

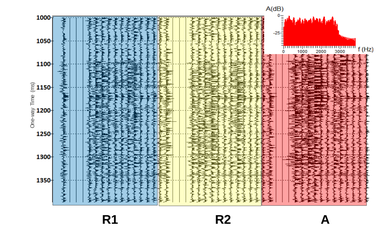


- The strongest signal is in the radial direction.
- Amplitude attenuates quickly along the array (a local event).
- Broad frequency spectrum with peak of 1,000 Hz

Type 3 Events



- Small events with low S/N ratio
- Usually last 0.2 to 3.0 seconds
- Cannot separate P and S waves (cannot locate)
- No obvious moveout (far away?)



- Type 3 Events have broad frequency spectrum up to 3000 Hz
- 3 components very similar

CONCLUSIONS

- We detected 3 types of "microseismic events"
- Type 1 events correlate to well work in nearby well on same pad
- Type 2 events may be caused by clamping mechanism
- More work is needed to understand Type 3 events, possibly related to fluid movement
- There appear to be no true micro seismic events from CO_2 injection induced fracturing or fault activation

ACKNOWLEDGMENTS

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