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Passive Microseismics: A Valuable Technique For Monitoring CO_2 Injections

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From a compliance, environmental, and human impact standpoint, critical goals of any CO_2 injection monitoring program are to: 1) identify the position of the CO_2 plume, and 2) to verify the integrity of the cap rock. The questions are whether passive microseismic monitoring is capable of achieving these goals, and whether there is any value to its implementation into an integrated CO_2 injection monitoring program.

During the Midwest Regional Carbon Sequestration Partnership's (MRCSP) geologic field test in Otsego County, Michigan, passive microseismic monitoring was implemented as part of their comprehensive monitoring program. The field test itself consisted of the injection of roughly 10,000 tonnes of CO_2 over 31 days in early 2008. Injection rates ranged from several hundred to approximately 600 tonnes per day of CO_2, while pressures remained below fracture pressure.

Two temporary downhole eight-level triaxial geophone arrays were deployed in individual observation wells located within 750m of the injection well. The arrays were configured with an inter-sensor spacing of 49.2 ft (15m), providing an overall aperture of 344.5 ft (105m). Theoretically, the array configuration provided detectability for events of moment magnitude ~-3 or greater originating within the target volume.

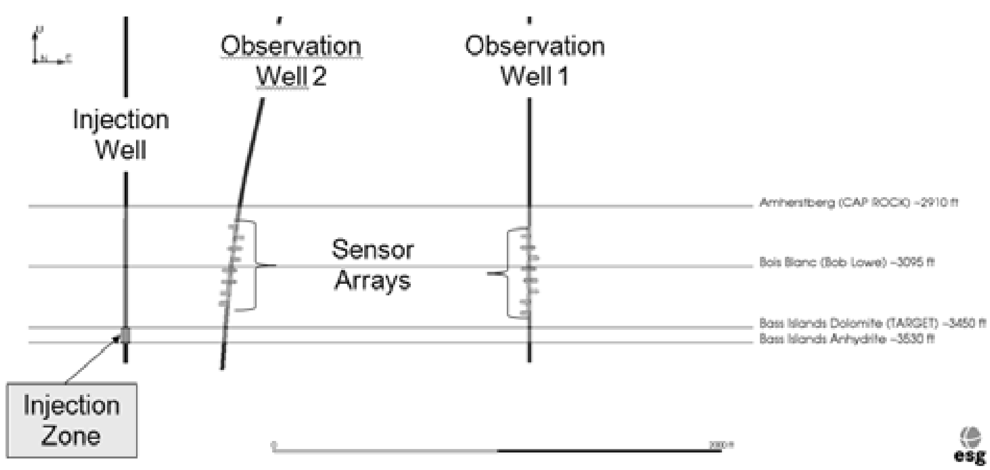

Figure 1: Michigan field test CO_2 injection site (depth view); the Amherstberg / Bob Low boundary defines the base of the cap rock (seal) in this system

Data were continuously recorded and analyzed during the deployment period. One hundred (100) microseismic events (including 7 orientation shots) were identified, ranging in moment magnitude from -2.5 to 0. Of these, only one event of distinct character was observed during the injection into the target formation. This event occurred during a period of high relative injection rate and was located immediately below the base of the cap rock within the permitted injection interval. This suggests a possible linkage with pressure change or fluid mobilization caused by CO_2 injection processes. All other events, although microseismic in nature, are considered to be the result of EOR activity in the field at depth (~2200 ft below the target injection zone) and not related to the permitted injection of CO_2. The EOR injection activity was terminated as the field test was initiated.

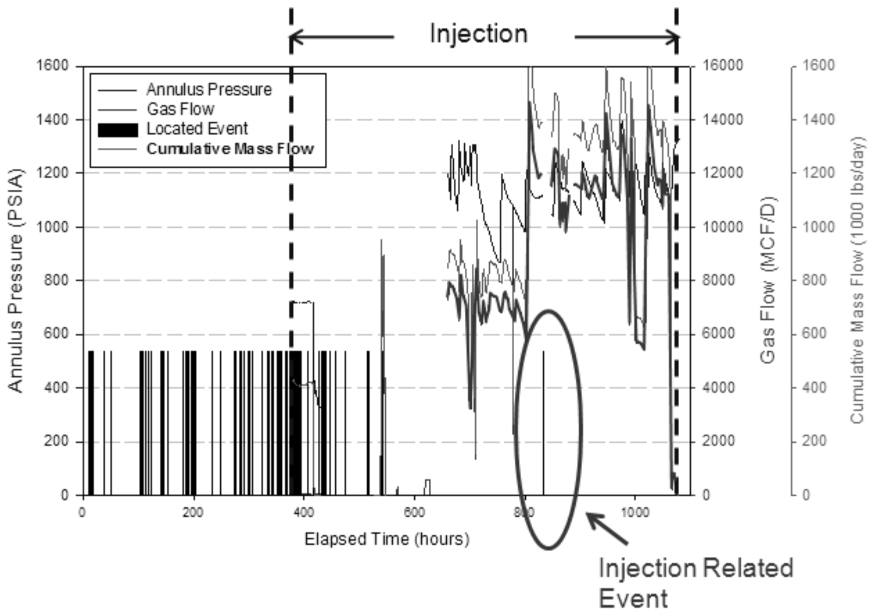

Figure 2: Microseismic event distribution and CO_2 injection data

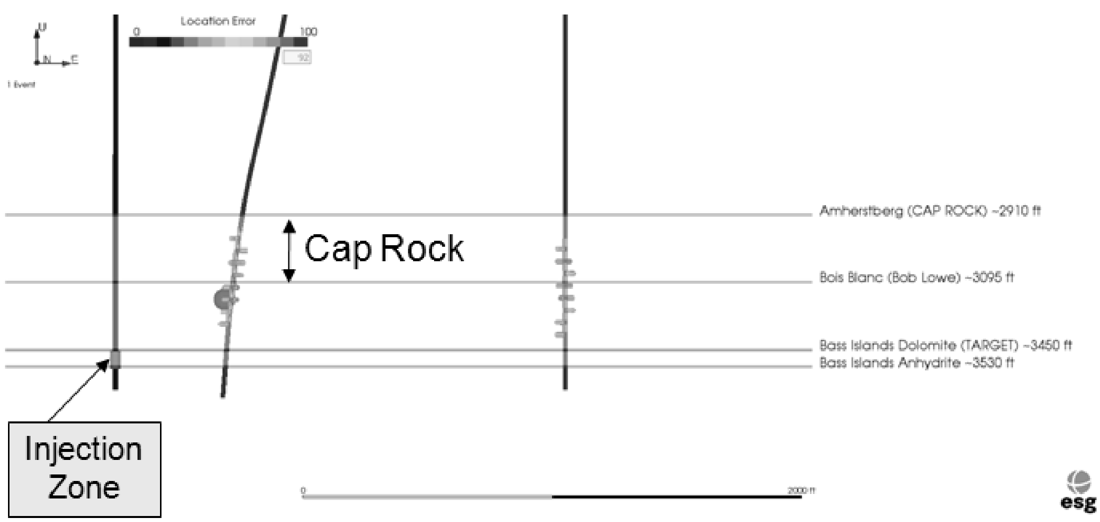

Figure 3: Injection related event located at the cap rock (depth view); this event has moment magnitude -2.3 and is located to an accuracy of ±15 ft (~5m)

Seismic Moment Tensor Inversion (SMTI) analysis performed on the single injection event revealed a complex failure mechanism (25% istropic, 54% CLVD, and 21% double couple) that is consistent with a crack opening. A potential failure plane oriented at N24°E is supported by the orientation of the maximum horizontal stress in the region.

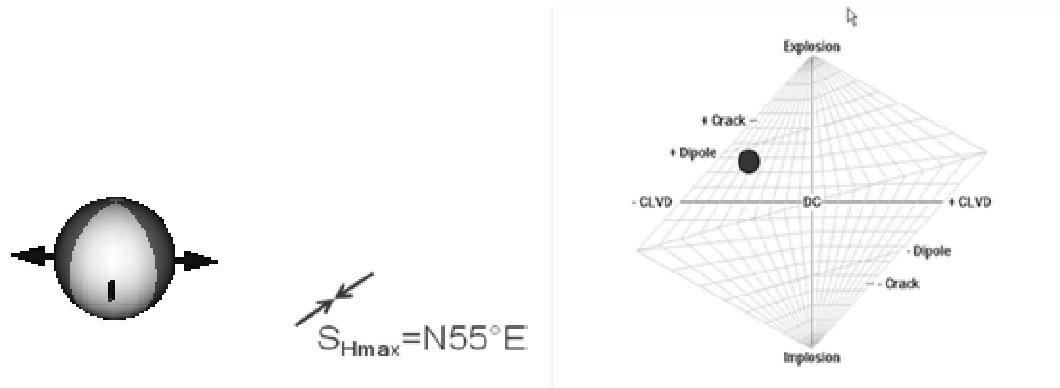

Figure 4: Seismic Moment Tensor Inversion indicates mechanism of failure consistent with fracture initiation

In the case of the MRCSP field test, passive microseismic monitoring did not appear to provide insight into the CO_2 plume development. However, infringement on the cap rock does identify one possible position of the plume. Microseismic monitoring has proved to be a valuable technique for monitoring cap rock behavior for compliance, environmental, and human impact purposes. Further investigations are in progress.