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Borehole Microseismic Monitoring at Napoleonville Salt Dome, Louisiana: Nine Years of Microseismicity Associated with Brining and Storage Facilities on a Gulf Coast Salt Dome, USA

Julie Shemeta
MEQ Geo Inc.

Abstract

Microseismic monitoring has been operational since October 2013 at the Napoleonville salt dome in Louisiana where a borehole seismic array was mandated by the State of Louisiana Department of Natural Resources directive in response to the sinkhole which first appeared in August 2012 adjacent to OXY GEISMAR NO. 3 cavern (State of Louisiana Department of Natural Resources Office of Conservation, Fifth Amendment to Declaration of Emergency and Directive, December 7, 2012). A 3000 ft (914 m) deep monitoring well (G-01) was drilled specifically for seismic instrumentation. The G-01 borehole is instrumented with a variety of seismic sensors: two Geospace analog seismic cable arrays (with 10 elements and 9 elements) which are instrumented with Geospace OMNI 2400 three-component 15 Hz geophones, and four IESE Model 21g-4.5 4.5 Hz geophones, for a total of 23 geophones. The wellbore is deviated from a wellhead location on the western salt dome and was drilled to the north-northwest and the bottom hole location is deviated 590 ft (180 m) north and 285 ft (87 m) west to 3115 ft (949 m) MD (3017 ft (920 m) TVD) at an azimuth of ~331 degrees. The inclination is over 20 degrees near TD.

The seismic instruments were cemented directly into salt and were deployed by clamping the instruments outside of a 4.5-inch tubing string and running the tools into the G-01 wellbore. The analog signals from the sensors are digitized on the surface at 2000 Hz and are continuously recorded and scanned for seismic events. The initial digitizers were REF TEK130S-01 units which were replaced by Stane0 D6BB-DIN-D9-DIN digitizers with a lower instrument noise floor in mid-July 2015 during an upgrade to the seismic recording equipment. The three-component horizontal sensors were oriented October 2013 using multiple string-shots in a nearby well and surface vibrator sources. The geophone calibration was repeated one year later with additional string shots in the same nearby well.

The G-01 borehole seismic array began recording data on October 17, 2013, and is still operational as of February 2023. The array continuously monitors ground motion and is processed to search for and locate seismic signals. The background noise level on the borehole array is generally very low (10-20 nm/sec) and allows for the detection and location of magnitude <0 seismic events. Baker Hughes' seismic monitoring group MAGNITUDE provides reports summarizing the microseismic activity. A catalog of seismic detections and seismic event locations and magnitudes has been compiled over nine years and is still actively processed. The MAGNITUDE group also tracks the borehole array's state of health and provides yearly maintenance for the instrumentation.

From October 13, 2013, to Dec 31, 2022, the seismic array detected 267,810 seismic events. Of these event detections, about 19% were of sufficient data quality (clear P- and S-wave arrivals with good signal to noise) to compute 49,534 event locations. The event locations report an event time, location in X, Y and Z and estimate the event size or "magnitude". The median magnitude over the past nine years is magnitude -1.1.

The event locations occur broadly over the west and central Napoleonville salt dome. The wide-spread microseismicity commonly clusters near storage and brine caverns located in the Napoleonville salt dome

and suggests it is likely that much of the observed microseismicity is related to normal storage and brining operations. Shallow microseismic events less than 1000 ft (305 m) in depth are located near the eastern part of the Bayou Corne sinkhole. Microseismic activity also occurs near the dome flanks, away from any caverns or wells and is likely due to the movement of salt or growth faults in the sediments at the margins of the salt dome. Integrating cavern pressure records and specific areas of high microseismic cavern activity suggests the events are occurring during cavern salt spalls and can be used determine the time and depth of spalls. Microseismicity also results from hanging string vibrations, and was used to map a hanging string hitting near the cavern base.

Data processing from the G-01 borehole seismic array routinely yields event magnitudes ≤ -2 to a distance of about 3000 ft (914 m) from the array and magnitudes > -2 within 5,500 ft (1676 m) distance from the array. The array is more sensitive to small events near the array and the detection threshold falls off with distance due to signal attenuation. The microseismic location accuracy is a function of the location of the seismic array, the event location, and the signal quality of the seismic recording. In general, events within about 2000 feet (610 m) of the array are more accurately located than events further away.

Key words: Domal Salt, Microseismic, Geophysics, Gulf Coast of US and Mexico, Storage Cavern, Monitoring