72-0002-SMRI

NEW BRINE FIELD PROGRAM FOR
MORTON SALT COMPANY

SENTURION SCIENCES, INC.

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INTRODUCTION

The Hydrofrac Connection Project assignment was primarily to investigate the ability of microearthquake detection equipment to determine the depth, location and extent of injected fluids used in hydrofrac operations to affect a connection between two wells. The injections under high pressures were released in the salt beds being mined. The seismic events set up by stresses released by fracturing were expected to be the origin of seismic noise data used in computing the extent of the invading fluids. An important secondary object was to detect any faults in the area which might affect the hydrofrac operation.

The project was in operation from January 18th to January 23rd, 1972.

SUMMARY OF RESULTS

The first objective, to locate fracture occurrences both horizontally and vertically as a direct result of the injection of fluid pressures, was not attained. The most reasonable conclusion to draw from this is that the random and coherent noise levels constantly recurring at the surface had considerably more power than expected, and overrode weaker frac signals. This subject is discussed below. (See Discussion)

The secondary objective of fault detection in the area was successful. Referring to the DEPTH TO FAULT PLANE MAP, it can be seen that a series of microearthquake epicenters occur in a southeasterly direction from a point south of Wells Number Ten and Eleven. The hypocenters indicating the depths to the microearthquake origins describe three faults. The disposition of the faults may be interpreted somewhat differently, but their strikes would be similar. Based on the quantity and distribution of data, Fault "A" is the most accurate, whereas Faults "B" and "C" appear to be relief faults and have less supporting data as illustrated by Fault Profiles X-X' and Y-Y', Figure Five. By projecting the contours of the fault planes, it can be seen that Well Number Ten penetrates Fault "B" at a depth of about 1360 feet. Well Number Eleven penetrates Fault "B" at 2400 feet and Fault "A" at a depth of 1400 feet. On Well Number Eleven, the plane of Fault "B" at the injection level of 2735 feet is about one hundred and twenty feet east of the well, and the plane of Fault "A" is about two hundred and fifty feet east of the well.

Bearing in mind that the above locations of the fault planes are by projection, there may be some discrepancy in the measured distances. However, Fault "A" has a three point control pattern of hypocenters (J, L, and Q) only three hundred feet south of Well Number Eleven. Consequently, in this case, the distance should be reasonably accurate.

The fault juncture lines may be of more importance than the fault planes in acting as a porosity pipe allowing the escape of injection fluids. The junction of Faults "A" and "B" at the 2700 foot depth is four hundred and sixty feet north 23^{o} east of Well Number Eleven, and the junction of Faults "A" and "C" is two hundred and ninety feet north 108^{o} east of Well Number Eleven.

The close proximity of both the fault planes and the juncture lines of the intersecting planes acting as escape routes for fluid under pressure may be the explanation for the difficulty in affecting a connection between Wells Number Ten and Number Eleven. This would depend on the porosity and permeability of the fault breccia.

DISCUSSION

The occurrence of the microearthquakes is not directly related to the hydrofraction activities in Wells Number Ten and Eleven. Four of the fourteen events computed for hypocenter locations occurred on January 18th, the day preceding the commencement of injection activity, and one additional event was recorded less than an hour prior to injection in Well Number Ten. Referring to Figure Six, it can be seen that the only comparable period of recognizable seismicity is on January 20th at three thirty p.m., during a long shutdown period of the hydrofrac operation. In either case, the lack of intervening events between hydrofrac activity does not necessarily mean that microearthquakes did not occur, but that their power was likely below that of the noise. The following short periods of shutdown time did not happen coincidentally with periods of strong seismicity.

Referring to the epicenter locations and hypocenter depths on the map, it will be noted that a hiatus of fault seismicity occurs in the vicinity of the two wells and, in general, the events became shallower as this area is approached. The reason for this may be that in areas of hydrofrac activity the nature of the seismic signals generated by faulting changes in power and frequency, and this modified signal may be in the same power-frequency spectrum as the noise; hence, it is not definable. Reasons for this could be due to lubricating action of invading fluids on movement along the fault planes and changes in the natural rock pressures caused by the induced hydrofrac pressures. Distance is not a factor in event signal attenuation in the vicinity of the wells since signals are recorded to the south at greater distances from the network stations.

It was hoped to record a signal from the perforation shot prior to the injection operations. These signal arrival times at the seismometer locations of Station Three would be used in calculating the velocity to the perforation depth, and calibrating the network stations to the known perforation depth and location. The playback data using various filter band pass widths failed to produce the desired signals. In all probability, the signal energy was too low to override the surface noise at the geophone stations. The simultaneous discharge of nineteen shots with a load of twenty grains each, or a total of 0.053 pounds of explosive, would cause the casing to ring and produce tube waves within the casing fluid, but the signal at the geophone stations would be very low in power after being subjected to transmission loss in traveling from shot to seismometer, particularly since it would traverse the large velocity inversion at the interfaces of the Big Lime.

Coherent and incoherent noise has controlled the effectiveness of the recording and processing systems used in the project. The producing and hydrofrac operations will necessarily have to continue through seismic monitoring at the well sites. Consequently, a method will have to be devised to attenuate the noise and enhance the signals. The Power Spectral Density Charts in Appendix One show the density of signal frequencies up to thirty-five Hz with samples taken on three days at the seismometer locations of each station. These show a decline of power through the three days, commencing on the 18th before the hydrofrac operation started, at Wells Number Ten and Eleven. Consequently, this evidence shows there is no increase of ground noise due to the hydrofrac process. The PSD Charts have an input signal power of eight hundred milivolts at fifty-four db.

In order to bring the microearthquake signals out of the miasma of noise, various narrow band pass filters were used. The band pass frequencies were selected to avoid the noise peaks shown on the PSD Analysis Charts. The most effective was an LP10 Hz-HP8 Hz filter. Figure Seven shows a playback of two events, H and I, using this system. Three signature seismograms are shown at the top of the illustration showing a wide band pass of LP100 Hz, HP0.8 Hz, a narrow band pass of LP5 Hz, HP0 Hz, and the narrow band pass of LP10 Hz, HP8 Hz. In the last example, the improvement of the signal to noise ratio is outstanding. The playback at a faster camera speed is shown at the bottom of the illustration, and was used for timing the H and I events. The four seismometers of Station Three were used for this example. The traces from top to bottom of the seismograms represent the Z1, Z2, Z3, and Z4 geophone locations. The H signal arrival times clearly show that it originates southeast of the station location. The inclusion of data from Stations One and Two confirmed the depth and location of the microearthquake hypocenter. The arrival times of Event I show the hypocenter