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Volume II

**ENVIRONMENTAL BASELINE MONITORING IN THE AREA OF GENERAL CRUDE OIL--
DEPARTMENT OF ENERGY PLEASANT BAYOU NUMBER 1--
A GEOPRESSURED-GEOTHERMAL TEST WELL--1978**

by

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MASTER

**APPENDIX I:
MICROSEISMIC MONITORING
TELEDYNE GEOTECH
GARLAND, TEXAS**

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TECHNICAL REPORT NO. 78-12

MICROSEISMIC MONITORING NEAR THE BRAZORIA COUNTY
WELL TEST SITE

TELEDYNE GEOTECH
3401 Shiloh Road
Garland, Texas 75041

12 December 1978

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ABSTRACT

The Department of Energy has recently initiated a program to assess the economic potential of producing fluids from geopressured formations. A key element of this program is to evaluate and, if possible, minimize the environmental risks accruing from geopressured brine production. Inducement of localized seismic activity is one of the anticipated risks. An essential first step in evaluating the magnitude of this hazard is to develop a local seismic history prior to the onset of production. This document is an interim report on a project to monitor microseismic activity in the vicinity of a future geopressured well test site in Brazoria County, Texas. The data collected to date indicate that numerous weak seismic sources are intermittently active in the vicinity of the test site. However, all of these sources appear to be related to cultural or industrial activity of undetermined origin. At the present time there is no evidence for naturally occurring seismic activity within 4 kilometers of the future test site with local magnitudes in excess of 0.25.

MICROSEISMIC MONITORING NEAR THE BRAZORIA COUNTY WELL TEST SITE

1. BACKGROUND

Economic recovery of the energy resources stored in geopressured formations beneath the Texas and Louisiana Gulf Coast regions will require the withdrawal of massive volumes of fluid at relatively high rates. At the present time, economic production rates are estimated to be approximately 4×10^4 barrels per day. Since recharge into the geopressured formations is expected to be negligible in comparison to the withdrawal, substantial pressure drops and subsequent reservoir compaction are anticipated. In particular, it is estimated that the reservoir compaction resulting from one year's production from a single well could result in internal volumetric losses of the order of 10^7 cubic meters. Volume changes of this order when concentrated in an area with maximum dimensions of only a few kilometers will impose a significant additional load upon the rocks surrounding the reservoir. Based upon a disc approximation to the reservoir the cumulative deviatoric component of this additional load will be roughly of the order of a 100 bars or so within a few hundred meters of the reservoir and of the order of 10 bars as far as 2 kilometers away, after one year's production from a single well. Deviatoric stress perturbations of this magnitude are sufficient to trigger substantial non-elastic deformation of the rocks surrounding the reservoir. This deformation may well be manifested through multiple discrete slips on both pre-existing and newly created fracture planes, thus releasing part of the stored strain energy as seismic waves. Since the release of seismic energy can potentially pose a risk to the local environment the possible correlation between the production of geopressured brines and the occurrence of microearthquakes deserves serious consideration. In order to unambiguously relate geopressured brine production to the occurrence of seismic activity it is desirable to obtain a local seismic history prior to the onset of the withdrawal of fluids.

Consequently, the Texas Bureau of Economic Geology under the sponsorship of the Division of Geothermal Energy of the Department authorized Teledyne Geotech to monitor seismic activity in the vicinity of the Brazoria County geopressured well test site. The results of a reconnaissance microseismic survey in the same region have been documented in an earlier publication (Teledyne Geotech Staff, 1978). The objective of this report is to summarize the principal results obtained through November 1978, from the operation of semi-permanent microseismic monitoring network installed near the well test site.

2. DESCRIPTION OF MONITORING SYSTEM

2.1 INSTRUMENTATION

The monitoring system instrumentation consists of five separate units, each with a standard moving-coil seismometer (Geotech S-13) followed by a low-noise amplifier/filter. The seismometers are installed in sealed containers at a depth of approximately four feet.

As illustrated in figure 1, data from four of the sites are transmitted via radiotelemetry to a collection point in Liverpool, Texas. Here they are multiplexed together with the data from a nearby sensor and then transmitted via commercial telephone circuits to the Garland laboratory. At this point, the signals are discriminated and the seismic outputs are recorded on both magnetic tape and 16 mm film.

Figure 2 shows the total frequency response of the monitoring system. The solid line represents the tape recorder velocity response, while the dashed line represents the film recorder velocity response.

2.2 SITE LOCATIONS

Figure 3 is a local map showing the location and configuration of the Brazoria microseismic monitoring array, and the location of the geopressured test well. The geographic coordinates of the individual sensor sites are listed in table 1.

Table 1. Site coordinates

Site	Latitude			Longitude			Elevation Feet
	Deg	Min	Sec	Deg	Min	Sec	
1	29	17	27	95	16	52	15
2	29	17	32	95	14	01	15
3	29	16	54	95	15	23	5
4	29	15	54	95	14	45	12
5	29	15	15	95	16	11	18

The five sensor site locations were selected to avoid obvious cultural noise sources while maintaining an appropriate spacing between array elements, and distance from the source of anticipated seismic activity. The diameter of the monitoring array is shown in figure 3 to be roughly 4 kilometers, which is on the same order as the distance from the center of the array to the well location.

Figure 1. Block diagram of Brazoria County, Texas, microseismic monitoring system

Figure 2. Response of survey system to a constant input

Figure 3. Location of sensor sites of Brazoria County field program

3. DATA ANALYSIS PROCEDURES

3.1 ESTIMATION OF SIGNAL PARAMETERS

The basic sequence of data processing is shown by the flow chart of figure 4. The first step of the processing is to discriminate the multiplexed data as received at Garland by telephone from Liverpool, and to record the de-multiplexed data directly to magnetic tape and 16 mm film. In this manner, the Develocorder film record can be reviewed immediately as it is received, thus maintaining continuous quality control over the data.

The film records are reviewed by a seismologist to detect microseismic activity and to evaluate the background noise levels for the purpose of determining detection thresholds.

Hypocenter locations and magnitudes are estimated for the microseismic activity observed during the film analysis.

3.1.1 Estimation of Source Coordinates

The signal arrival time data tabulated during the film review is processed by MEHYPO (Johnson, et al 1977), a digital computer program which determines hypocenter, magnitudes, and reliability parameters of local events. The hypocenter, or focus of the microearthquake, is the location of the subterranean point of initial rupture of the rocks.

The location program utilizes both compressional and shear arrivals, tracing the refracted paths through an appropriate earth model consisting of horizontal layers with constant velocities. The solution is based upon a conventional least squares minimization criteria for the estimation of hypocenter coordinates.

The program computes several hypocenter reliability estimates, including the standard error of the computed epicenter, standard error of the computed depth, and also computes a confidence epicenter reliability ellipse and depth reliability interval, based on the variance of observed travel-time residuals. Hypocenters are computed only for events observed at three or more stations because of ambiguities of solution based on data from fewer stations.

3.1.2 Magnitude Estimation

Local seismic magnitudes calculated for the microseismic events are based upon maximum P wave amplitude and are calculated as:

$$M_L = \log_{10} \left(\frac{A}{2} \right) - 1.75 + 0.8 \log_{10} (X) \quad (1)$$

where

M_L is local magnitude

A is the peak-to-peak compressional wave amplitude in millimicrons ($\mu\mu$)

$$X = [(\text{epicentral distance in km})^2 + (\text{hypocentral depth in km})^2]^{1/2}$$

and

X must be ≥ 1.0 .

DATA PROCESSING FLOW CHART

Figure 4. Microseismic data processing flow chart

The body wave magnitude of an earthquake is defined as $\log_{10}$ of the amplitude expressed in microns normalized to a distance of 100 kilometers from the source.

Magnitude, therefore, is a measure of energy released at the focus, independent of the place of observation.

The empirically derived constants within the local magnitude formula (M_L), adjust the amplitude of the recorded arrival to compensate for energy lost in transmission across the distance (X) from the source to the recording station, and adjust the locally observed value to conform with the standard magnitude definition.

3.2 ESTIMATE OF DETECTION CAPABILITIES

The time variant amplitudes of the microseismic background noise within the range of 10 to 15 Hz were evaluated to obtain an estimate of the array detection threshold. This was done by first taking systematic noise amplitude measurements at each site from the film records. The measurements were taken from a period of time that included several days in order to reduce bias caused by weather conditions, etc., and were classified as either daytime or nighttime samples to facilitate separate analysis.

It was assumed that if a signal arrived coincidental with the noise measurement, its compressional wave amplitude would have to be approximately a factor of 2 above the observed background in order to be detected. Based upon this assumption, a local magnitude was calculated which represents the lowest detectable magnitude at that point in time.

When all noise measurements were tabulated and related to a minimum detectable magnitude, a graph showing frequency of occurrence as a function of magnitude was constructed for each site. From these frequency of occurrence graphs, the computed magnitudes were ranked according to percentage of occurrence in the sample set to obtain estimated detection probability density distributions for each site.

4. PRESENTATION AND DISCUSSION OF RESULTS

4.1 SIGNAL DETECTION THRESHOLDS

The graphs of the frequency of occurrence of lowest detectable magnitudes, resulting from the background noise evaluation discussed in section 3.2, are shown in figure 5.

Both day and night sample sets shown in this figure appear to indicate two separate distributions. The first distribution centers about magnitudes near -1.0, and apparently represents detection capabilities during periods of normal low background. The second distribution centers about -0.25, and results from measurements associated with cultural activity. Notice that the peak near -0.25 magnitude diminishes relative to the peak near -1.0 during the quiet night hours as cultural noise subsides. During these quiet periods (in the absence of cultural noise) the background noise level may be regarded as a composite of system noise and natural earth noise.

Figure 6 compares the cumulative probability density distributions of day and night sample sets for each site. The probability of detecting small magnitude events is shown to be significantly higher for all sites during the night hours.

Figure 7 then regroups the probability curves shown in figure 7 for more convenient comparison of day and night sets. Note that approximately 40 percent of events of magnitude -0.5 and greater can be detected during the night hours while only 20 percent of events of magnitude -0.5 and greater can be detected during the day hours.

A summary of the comparison of day and night probability of detection estimates is given below in table 1.

Table 2. Summarized comparison of daytime
to nighttime detection capabilities

Magnitude	Probability of Detection (%)	
	Day	Night
-1.5	0	0
-1.0	4	14
-0.75	9	24
-0.5	20	40
-0.25	42	65
0.0	66	80
0.25	86	94
0.5	95	99
0.75	100	100

Figure 5. Frequency of occurrence of lowest detectable magnitudes

Figure 6. Comparison of detection probability estimates for daytime and nighttime at the five sensor sites

Figure 7. Comparison of daytime to nighttime detection capabilities

The noise evaluation of the current site locations revealed several things that should be noted.

a. Cultural noise significantly raises the detection thresholds of all sites during both day and night hours, although to a much greater extent during day hours.

b. The 95 percent detection level for both day and night sample sets is shown to be near a magnitude of 0.25. Relative to other microseismic detection networks, this is a fairly high detection threshold.

4.2 OBSERVED MICROSEISMIC ACTIVITY

Microseismic activity has been observed sporadically since the monitoring system was brought up to a continuous operational status in late August 1978. The arrival times of these events at each station in the array, their maximum amplitudes and the coordinates of their sources, when they can be determined, are routinely tabulated and published elsewhere on a monthly basis. Therefore, the list will not be repeated in this report. Film seismograms of some of the events detected during September and October 1978 are reproduced in figures 8 through 10. Notice, in particular, the emergent character of these signals. This makes it difficult to estimate the onset times of the compressional and shear waves with a precision sufficient to justify computation of the coordinates of the source. Unfortunately this has been a characteristic common to all of the events observed through October 1978. Therefore, precise estimation of source coordinates has not been possible.

The microseismic data observed to date also share other common characteristics which permits us to classify their occurrence as being the result of either natural or culturally derived processes. For example, all observed activity has exclusively occurred during normal working hours. Since the seismicity resulting from natural processes is not likely to suffer from such a constraint, this behavior indirectly argues that the observed activity is the result of culturally derived processes. Similarly, the frequency of occurrence of events within a given suite as well as the distribution of local magnitudes as a function of the cumulative number of occurrences provide additional indirect evidence for culturally derived source mechanisms. Seismic events generated by natural processes generally tend to occur randomly in time and their local magnitudes are invariably related to the cumulative number of occurrences through an equation of the form

$$M_L = \frac{1}{B} (\log_{10} N - A) \quad (2)$$

where N is the cumulative number of events with local magnitudes greater than or equal to M_L , B is a constant with a value between -0.8 and -1.5 and A/B is the local magnitude of the largest event in the sequence. A segment of the record of a typical suite of events is reproduced in figure 11. This sequence began at approximately 3:10 p.m. (local time), 17 November 1978, with events occurring near 2 minute intervals.

MAG @ 10 Hz

-14-

Figure 8. A typical event recorded by the Brazoria monitoring system during the month of October 1978

MAG @ 10 Hz

1 SECOND

17 05

SITE 1

178.18 k

SITE 2

165.45 k

SITE 3

165.48 k

SITE 4

152.73 k

SITE 5

159.09 k

-15-

Figure 9. Acoustic wave recorded by the Brazoria monitoring system

MAG

1 SECOND

SITE 1

159 k

SITE 2

159 k

SITE 3

166 k

SITE 4

403 k

SITE 5

269 k

-16-

Figure 10. A typical event recorded by Brazoria monitoring system during the month of November 1978

17 NOVEMBER 1978

3:10 PM

2 MINUTES

3:20 PM

SITE 3

SITE 4

SITE 5

-17-

Figure 11. Typical series of events recorded during November 1978

Notice, first, that instead of being randomly distributed in time, the events tend to occur at more or less regular intervals. Additionally, note that all the events are of a similar intensity. This would indicate that not only are the signals being generated in the same area but that they are of approximately the same local magnitude. Since the compressional waves associated with the events in this suite fell below the detection threshold of the monitoring system it was not possible to calculate local magnitudes using the relationship given in section 3.1.2. However, an approximate local magnitude can be determined by noting the duration of each event and using the following relationship

$$M_L = -1.0 + 1.8 \log_{10} T \quad (3)$$

where T is the duration in seconds. When this is done it is found that the distribution of local magnitudes for this particular sequence is given by

$$M_L = C \quad (4)$$

where $C = -0.96 \pm 0.05$

The magnitude distribution for all other sequences observed to date are described by the same relationship. However, the value of C changes slightly from suite to suite. Comparison of equation 4 with equation 2 demonstrates that the magnitude distributions characterizing the microseismic activity observed thus far are significantly different from those produced by a naturally occurring process. This result, coupled with the fact that all events within a given suite tend to occur at more or less regular intervals and occur only during normal working hours, leads us to conclude that all of the microseismic activity detected to date in the vicinity of Brazoria Co. well site is the result of undetermined cultural processes.

5. REFERENCES

Teledyne Geotech Staff, 1978, A reconnaissance microseismic survey of the Brazoria County geopressured well test region, TR 78-6, Garland, Texas, Teledyne Geotech, 23 p.

Johnson, J. L., Clawson, G. E., and Swanson, J. G., 1977, Program MEHYPO with 1977 modifications: TN 3/77, Garland, Texas, Teledyne Geotech, 25 p.

**MICROSEISMIC MONITORING NEAR THE
BRAZORIA COUNTY GEOPRESSURED WELL TEST SITE
SEPTEMBER 1978**

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1. INTRODUCTION

The Department of Energy plans to conduct long term flow tests of a well in Brazoria County, Texas which penetrates into the geopressured zone. Preliminary calculations indicate that the production of fluids from geopressured formations can introduce relatively large cumulative shearing strains into the surrounding rocks. It is reasonable to anticipate that these strains will be at least partially dissipated through localized, brittle failure of intact rock and renewed movement along dormant growth faults. Both processes may result in the emission of perceptible seismic energy which could pose a potential threat to the local environment. At the present time there is no rational basis for assessing the magnitude of this risk. Therefore, plans have been made to monitor the microseismic activity in the vicinity of the test site both before and during production tests. This report briefly describes the monitoring instrumentation and procedures and lists the seismic activity observed during the month of September 1978.

2. DATA COLLECTION

Figure 1 shows the location and configuration of the microseismic monitoring system array and the test well. The geographical coordinates of the individual sensor sites are listed in table 1.

Table 1. Site coordinates

Site	Latitude			Longitude			Elevation feet
	Deg	Min	Secs	Deg	Min	Secs	
1	29	17	27	95	16	52	15
2	29	17	32	95	14	01	15
3	29	16	54	95	15	23	5
4	29	15	54	95	14	45	12
5	29	15	54	95	16	11	18

The monitoring system instrumentation consists of five separate units, each with a standard moving-coil seismometer (Geotech S-13) followed by a low-noise amplifier/filter. In order to reduce background noise levels, the seismometers are installed in sealed containers at a depth of approximately four feet.

As shown in the block diagram of the monitoring system in figure 2, data from 4 of the sites are transmitted via radiotelemetry to a collection point in Liverpool, Texas. Here these input are multiplexed together with the support from the Liverpool site. The multiplexed signals are then transmitted via commercial telephone circuits to our Garland laboratory. At this point, the signals are discriminated and the seismic outputs are recorded on both magnetic tape and 16 mm film.

Figure 3 shows the total response of the monitoring system. The solid lines represent the tape recorder velocity and displacement response while the dashed lines represent the film recorder velocity and displacement response.

3. DATA ANALYSIS PROCEDURES

The film records are continuously reviewed to tabulate microseismic activity, assess the general quality of the data, and obtain information on detection thresholds.

During the review of these film records, incoming signals which are observed at three or more sites are listed and later, high speed playouts of the magnetic tape records of the signals are made in order to obtain high precision in the measurement of phase arrival times.

The arrival time data is processed by MEHYPO (Johnson, et al, 1977) a digital computer program which determines hypocenter, magnitude and reliability parameters of the local events. This program utilizes both compressional and shear arrivals, and is based upon the conventional least squares minimization criteria for the estimation of hypocentral coordinates.

Hypocenters are computed only for events observed at three or more stations because of possible ambiguities of solutions based on data from fewer stations.

Local seismic magnitudes are based upon maximum P wave amplitude and are calculated as:

$$M_L = \log_{10} (A/2) - 1.75 + 0.8 \log_{10} (X)$$

where M_L is the local magnitude

A is the peak to peak compressional wave amplitude in nanometers
(10^{-9} meters)

$$X = \left[\frac{(\text{epicentral distance})^2}{(\text{in kilometers})} + \frac{(\text{hypocentral depth})^2}{(\text{in kilometers})} \right]^{\frac{1}{2}}$$

and X = must be ≥ 1.0

4. RESULTS

Microseismic events detected during the month of September 1978 are listed in table 2. Hypocenter locations have not been determined because signal arrival times cannot be reliably measured at three or more stations.

Notice that the occurrence of these events is somewhat regular and generally confined to the daylight hours. This suggests that they may be the result of cultural or industrial activity.

No events were detected during the nighttime hours during September.

5. REFERENCES

Johnson, J. L., Clawson, G. E, and Swanson, J. G., 1977, program MEHYPO with 1977 modifications: TN 3/77, Garland, Texas, Teledyne Geotech, 25 p.

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Figure 1. Location of sensor sites of Brazoria County field program

Figure 2. Block diagram of Brazoria County, Texas, array system

Figure 3. Response of survey system to a constant input

Table 2. Microseismic events

Event No.	Site	P Arrival Time				S Arrival Time				P-Amplitude (μ)
		Day	Hr	Min	Sec	Day	Hr	Min	Sec	
1	1	256	17	22	40.20	256	17	22	40.90	133.7
	2									
	3			22	38.90			22	39.50	213.46
	4			22	37.50			22	37.92	134.82
	5			22	38.76			22	39.54	160.09
2	1	256	17	32	49.68	256	17	32	50.22	164.08
	2									
	3				48.00				48.58	192.11
	4				47.30				48.05	185.37
	5				48.10				48.85	106.73
3	1	256	17	39	37.63	256	17	39	38.09	133.69
	2									
	3				35.39				36.50	170.77
	4				35.04				35.75	151.67
	5				35.82				36.60	106.73
4	1	256	17	52	32.15	256	17	52	32.95	121.54
	2									
	3				30.64				31.16	362.88
	4				29.94				30.60	185.37
	5				30.65				31.45	213.45
5	1	256	18	04	15.72	256	18	04	15.49	97.23
	2									
	3				13.78				14.40	170.77
	4				13.40				14.15	168.52
	5				14.17				15.00	106.73
6	1	256	18	11		256	18	11	24.30	
	2									
	3				22.05				22.75	234.80
	4				21.30				22.05	143.24
	5				22.07				22.90	71.15
7	1	256	18	22	08.80	256	18	22	09.51	97.23
	2									
	3				07.30				07.94	277.50
	4				06.45				07.17	92.68
	5				07.20				08.00	88.94

Table 2. Continued.

Event No.	Site	P Arrival Time				S Arrival Time				P-Amplitude (mu)
		Day	Hr	Min	Sec	Day	Hr	Min	Sec	
8	1	256	19	12	49.58	256	19	12	50.23	291.70
	2				48.50				48.88	256.15
	3									
	4				47.07				47.87	67.41
	5				47.89				48.65	88.94
9	1	257	14	21	04.30	257	14	21	05.20	60.77
	2									
	3				04.00				04.40	64.04
	4				02.40				03.10	84.26
	5				02.00				03.40	177.88
10	1	257	14	30	47.80	257	14	30	48.40	60.77
	2									
	3				46.10				47.00	149.42
	4				45.20				46.00	101.11
	5				46.20				46.80	124.52
11	1	257	14	38	03.00	257	14	38	03.08	72.92
	2									
	3				01.90				02.40	149.42
	4				00.00				00.08	101.11
	5				01.10				02.30	106.73
12	1	260	16	13						
	2									
	3				26.00					
	4				23.00					
	5				25.00					
13	1	260	16	32	16.10	260	16	32	17.20	121.54
	2									
	3				15.00				15.80	149.42
	4				12.10				13.9	117.96
	5				14.90				15.50	284.60
14	1	260	16	40	37.40	260	16	40	38.00	121.54
	2									
	3				36.80				37.5	234.80
	4				35.00					109.54
	5				36.00				37.00	284.61
15	1	260	16	49	11.40	260	16	49	12.00	170.15
	2									
	3				9.90				11.00	170.77
	4				7.60				9.20	101.11
	5				10.00				10.90	231.24

Table 2. Continued.

Event No.	Site	P Arrival Time				S Arrival Time				P-Amplitude (mμ)
		Day	Hr	Min	Sec	Day	Hr	Min	Sec	
16	1	260	17	01	21.20	260	17	01	22.30	121.54
	2									
	3				20.00				20.90	192.11
	4				18.00				19.20	134.83
	5				19.90				21.20	302.40
17	1	260	17	09	11.50	260	17	09	12.00	109.38
	2									
	3				10.00				10.90	213.46
	4				06.30				07.80	101.11
	5				09.30				10.20	266.82
18	1	260	17	16	44.80	260	17	16	05.90	72.92
	2									
	3				43.70				44.50	256.15
	4				41.40				43.00	84.26
	5									
19	1	260	17	27	21.00	260	17	27	21.70	243.08
	2									
	3				19.80				20.60	256.15
	4				16.80				17.90	107.38
	5				19.90				20.70	177.88
20	1	260	18	11	58.70	260	18	11	59.20	97.23
	2									
	3				57.00				58.00	192.11
	4				55.00				56.00	117.96
	5				57.3				58.20	177.88
21	1	260	18	22	12.00	260	18	22	13.00	72.92
	2									
	3				11.00				12.00	149.42
	4				08.80				10.00	101.11
	5				11.00				12.00	160.09
22	1	260	18	32	46.80	260	18	32	48.00	97.23
	2									
	3				45.90				46.70	106.73
	4				43.70				44.80	75.83
	5				47.00				48.00	142.30
23	1	260	18	40	00.00	260	18	40	01.00	145.85
	2									
	3			39	59.70			39	60.80	213.46
	4				57.60				58.90	117.96
	5				58.80				60.30	177.88

Table 2. Continued.

Event No.	Site	P Arrival Time				S Arrival Time				P-Amplitude (mμ)
		Day	Hr	Min	Sec	Day	Hr	Min	Sec	
24	1	260	18	48	52.90	260	18	48	53.80	145.85
	2									
	3				51.00				52.20	192.11
	4				49.00				50.90	126.39
	5				51.00				52.00	177.88
25	1	260	18	57	07.00	260	18	57		
	2									
	3				06.20				07.80	213.46
	4				03.50				04.80	109.54
	5				05.10				06.20	213.45
26	1	260	19	07	32.50	260	19	07	33.20	121.54
	2									
	3				31.00				32.00	213.46
	4				29.50				31.00	101.11
	5				31.20				32.30	160.09
27	1	260	19	15	10.90	260	19	15	11.80	121.54
	2									
	3				09.80				10.80	149.42
	4				07.60				09.00	101.11
	5				09.00				10.00	142.30
28	1	260	19	50	26.50	260	19	50	27.60	182.31
	2									
	3				25.00				26.20	213.46
	4				22.00				23.60	92.68
	5				25.20				26.30	249.03
29	1	260	20	32	51.20	260	20	32	52.00	97.23
	2									
	3				49.80				50.90	128.07
	4				46.				48.00	
	5				50.00				51.00	231.24
30	1	260	20	40	45.00	260	20	40	46.00	145.85
	2									
	3				44.30				55.20	192.11
	4				41.8				43.00	84.26
	5				44.00				45.00	266.82
31	1	262	18	11	35.60	262	18	11	36.40	160.50
	2				33.80				34.10	
	3				34.00				35.10	106.73
	4				30.50				33.00	84.26
	5				34.7				35.80	195.67

Table 2. Continued.

Event No.	Site	P Arrival Time				S Arrival Time				P-Amplitude (mu)
		Day	Hr	Min	Sec	Day	Hr	Min	Sec	
32	1	262	18	01	15.00	262	18	01	16.50	145.85
	2									
	3									
	4				10.00				12.00	84.26
	5				13.50				14.20	160.09
33	1	262	17	52	43.20	262	17	52	44.30	97.23
	2									
	3									
	4									
	5				41.90				43.00	177.88
34	1	262	17	18	44.50	262	17	18	45.30	243.08
	2				42.90				43.50	
	3				42.8				43.4	106.73
	4				41.80				42.20	168.52
	5				43.80				44.60	142.30
35	1	262	17	09	17.80	262	17	09	18.60	121.54
	2									
	3									
	4				15.40				16.10	151.67
	5				17.00				17.60	213.45
36	1	262	17	02	00.07	262	17	02	01.70	194.46
	2			01	59.30				02.05	
	3			01	59.20				02.04	128.07
	4			01	59.00				02.00	210.65
	5			02	00.00				02.08	177.88
37	1	262	16	54	14.70	262	16	54	16.3	121.54
	2				12.00				13.70	
	3				12.20				13.50	128.07
	4				08.80				11.10	126.39
	5				13.20				15.00	177.88
38	1	262	16	23	41.20	262	16	23	42.00	60.77
	2				39.50				40.00	
	3				39.30				40.00	128.07
	4				36.40				37.80	143.24
	5				39.10				40.00	177.88
39	1	262	16	16	26.00	262	16	16	27.60	145.85
	2				24.00				25.50	
	3				24.30				25.70	149.42
	4				23.40				24.30	134.82
	5				25.00				26.30	142.30

Table 2. Continued.

Event No.	Site	P Arrival Time				S Arrival Time				P-Amplitude (mμ)
		Day	Hr	Min	Sec	Day	Hr	Min	Sec	
40	1	262	16	05	10.00	262	16	05	11.50	97.23
	2				08.80				10.00	
	3				09.00					106.73
	4				07.90				08.70	277.50
	5				10.00				10.90	177.88

MICROSEISMIC MONITORING NEAR THE
BRAZORIA COUNTY GEOPRESSURED WELL TEST SITE
OCTOBER 1978

TELEDYNE GEOTECH
3401 Shiloh Road
Garland, Texas 75041

1. INTRODUCTION

The Department of Energy plans to conduct long term flow tests of a well in Brazoria County, Texas which penetrates into the geopressured zone. Preliminary calculations indicate that the production of fluids from geopressured formations can introduce relatively large cumulative shearing strains into the surrounding rocks. It is reasonable to anticipate that these strains will be at least partially dissipated through localized, brittle failure of intact rock and renewed movement along dormant growth faults. Both processes may result in the emission of perceptible seismic energy which could pose a potential threat to the local environment. At the present time there is no rational basis for assessing the magnitude of this risk. Therefore, plans have been made to monitor the microseismic activity in the vicinity of the test site both before and during production tests. This report briefly describes the monitoring instrumentation and procedures and lists the seismic activity observed during the month of October 1978.

2. DATA COLLECTION

Figure 1 shows the location and configuration of the microseismic monitoring system array and the test well. The geographical coordinates of the individual sensor sites are listed in table 1.

Table 1. Site coordinates

<u>Site</u>	<u>Latitude</u>			<u>Longitude</u>			<u>Elevation feet</u>
	<u>Deg</u>	<u>Min</u>	<u>Secs</u>	<u>Deg</u>	<u>Min</u>	<u>Secs</u>	
1	29	17	27	95	16	52	15
2	29	17	32	95	14	01	15
3	29	16	54	95	15	23	5
4	29	15	54	95	14	45	12
5	29	15	54	95	16	11	18

The monitoring system instrumentation consists of five separate units, each with a standard moving-coil seismometer (Geotech S-13) followed by a low-noise amplifier/filter. In order to reduce background noise levels, the seismometers are installed in sealed containers at a depth of approximately four feet.

As shown in the block diagram of the monitoring system in figure 2, data from 4 of the sites are transmitted via radiotelemetry to a collection point in Liverpool, Texas. Here these input are multiplexed together with the support from the Liverpool site. The multiplexed signals are then transmitted via commercial telephone circuits to our Garland laboratory. At this point, the signals are discriminated and the seismic outputs are recorded on both magnetic tape and 16 mm film.

Figure 3 shows the total response of the monitoring system. The solid lines represent the tape recorder velocity and displacement response while the dashed lines represent the film recorder velocity and displacement response.

3. DATA ANALYSIS PROCEDURES

The film records are continuously reviewed to tabulate microseismic activity, assess the general quality of the data, and obtain information on detection thresholds.

During the review of these film records, incoming signals which are observed at three or more sites are listed and later, high speed playouts of the magnetic tape records of the signals are made in order to obtain high precision in the measurement of phase arrival times.

The arrival time data is processed by MEHYPO (Johnson, et al, 1977) a digital computer program which determines hypocenter, magnitude and reliability parameters of the local events. This program utilizes both compressional and shear arrivals, and is based upon the conventional least squares minimization criteria for the estimation of hypocentral coordinates.

Hypocenters are computed only for events observed at three or more stations because of possible ambiguities of solutions based on data from fewer stations.

Local seismic magnitudes are based upon maximum P wave amplitude and are calculated as:

$$M_L = \log_{10} (A/2) - 1.75 + 0.8 \log_{10} (X)$$

where M_L is the local magnitude

A is the peak to peak compressional wave amplitude in nanometers
(10^{-9} meters)

$$X = \left[\frac{(\text{epicentral distance})^2}{(\text{in kilometers})} + \frac{(\text{hypocentral depth})^2}{(\text{in kilometers})} \right]^{\frac{1}{2}}$$

and X = must be > 1.0

4. RESULTS

Microseismic events detected during the month of October 1978 are listed in table 2. Hypocenter locations have not been determined because signal arrival times cannot be reliably measured at three or more stations.

Event number 15 of table 2 is a signal from the Houston pipeline explosion of 24 October, which is apparently an acoustic wave or an air-coupled Rayleigh wave. Figure 4 is a photograph of the signal as recorded by the Brazoria array. Delay time between station arrivals indicate an apparent velocity of approximately 310 meters/sec.

Two other acoustic waves were recorded by the monitoring system during October, events 14 and 23, an example of which is shown in the photograph of figure 5.

The majority of events observed during October, however, are similar to the typical example shown in figure 6. In many instances the recorded amplitudes of the initial arrival were very weak, resulting in uncertain phase identification and arrival time measurements. These events propagate from northeast to southwest of the array at an apparent velocity of approximately 1.09 km/sec. Notice that the occurrence of these events is somewhat regular and generally confined to the daylight hours. This suggests that they may be the result of cultural or industrial activity.

No events were detected during the nighttime hours during October.

5. REFERENCES

Johnson, J. L., Clawson, G. E., and Swanson, J. G., 1977, program MEHYPO with 1977 modifications: TN 3/77, Garland, Texas, Teledyne Geotech, 25 p.

G10260

Figure 1. Location of sensor sites of Brazoria County field program

Figure 2. Block diagram of Brazoria County, Texas, array system

Figure 3. Response of survey system to a constant input

08 01

MAG AT 10 Hz

122.73K

118.18K

113.63K

104.54K

109.09K

Figure 4. Signal from the Houston pipeline explosion (Event No. 15) recorded by the Brazoria monitoring system.

17 05

MAG AT 10 Hz

178.18K

165.45K

165.48K

152.73K

159.09K

Figure 5. Acoustic wave (Event No. 14) recorded by the Brazoria monitoring system.

8 10 10

MAG AT 10 Hz

165.45K

159.09K

159.09K

146.36K

171.82K

Figure 6. A typical event recorded by the Brazoria monitoring system during the month of October 1978.

Table 2. Microseismic events

Event No.	Site	P Arrival Time				S Arrival Time				P-Amplitude (mu)
		Day	Hr	Min	Sec	Day	Hr	Min	Sec	
1	1	277	19	10	59.90					60.87
	2									
	3				58.80					37.50
	4				48.70					36.39
	5				59.80					68.68
2	1	277	19	19	0.02					20.29
	2				0.00					28.22
	3				1.50					31.25
	4				0.01					72.78
	5				0.03					44.15
3	1	277	19	31	52.50					67.64
	2				48.50					40.32
	3									
	4				49.80					50.03
	5				52.00					98.11
4	1	277	19	35	42.00					
	2				38.00					52.42
	3				41.00					46.87
	4				40.00					54.58
	5				42.00					53.96
5	1	277	19	51						
	2				08.00					48.38
	3				10.00					31.25
	4									
	5				12.00					31.43
6	1	277	20	36	28.00					67.64
	2				24.80					40.32
	3				25.80					31.25
	4				26.00					100.07
	5				27.70					88.30
7	1	277	20	44						
	2				19.00					40.32
	3				18.00					
	4				18.20					93.75
	5				19.10					112.83
8	1	277	20	53	18.00					
	2				14.00					64.51
	3				16.20					53.12
	4				15.90					78.23
	5									

Table 2 (continued)

Event No.	Site	P Arrival Time				S Arrival Time				P-Amplitude (mu)
		Day	Hr	Min	Sec	Day	Hr	Min	Sec	
9	1	278	17	35	39.40					50.73
	2									
	3				36.50					68.75
	4				38.00					118.27
	5				38.50					107.93
10	1	278	17	51	16.00					74.40
	2									
	3				14.50					87.50
	4				13.80					100.07
	5				15.00					132.45
11	1	278	17	55						
	2									
	3				07.00					78.12
	4				06.50					90.97
	5				08.00					98.11
12	1	278	19	14	49.00					74.40
	2				46.00					80.64
	3				47.40					56.25
	4									
	5				48.50					98.11
13	1	285	15	12	08.00					303.57
	2				05.00					288.46
	3				03.50					138.46
	4			11	58.80					145.83
	5			12	00.00					52.00
* 14	1	296	17	04	47.80					31.60
	2				52.80					44.80
	3				47.20					40.00
	4				43.00					43.48
	5				41.00					37.04
* 15	1	297	08	00	46.50					60.71
	2				49.00					34.61
	3				50.70					96.15
	4				56.50					70.83
	5				55.20					60.00
16	1	297	21	06	07.00					132.20
	2									
	3				13.80					115.38
	4				19.80					62.49
	5				14.00					100.00

*Time and amplitude of initial arrival

Table 2 (continued)

Event No.	Site	P Arrival Time				S Arrival Time				P-Amplitude (mu)
		Day	Hr	Min	Sec	Day	Hr	Min	Sec	
17	1	298	04	26						
	2				3.90					44.80
	3				3.20					35.60
	4				0.00					30.42
	5				1.80					36.96
18	1	298	18	22	02.00					89.29
	2				04.00					34.62
	3				01.00					69.23
	4			21	55.50					79.17
	5				55.00					80.00
19	1	299	17	16	20.00					34.61
	2									
	3				19.50					40.00
	4				20.20					47.82
	5				21.00					29.63
20	1	299	17	28	32.00					30.77
	2				29.50					44.00
	3				31.50					40.00
	4				32.20					43.48
	5				32.80					25.93
21	1	299	17	31	30.00					53.85
	2									
	3				31.00					40.00
	4									
	5				31.90					25.93
22	1	299	17	34	42.20					46.15
	2									
	3				42.80					36.00
	4									
	5				43.80					37.04
* 23	1	299	18	10	1.70					88.46
	2									
	3				0.60					20.00
	4				1.90					30.43
	5				2.60					18.52
24	1	299	18	22	32.50					38.45
	2									
	3				32.30					28.00
	4									
	5				34.00					17.20

*Time and amplitude of initial arrival

Table 2 (continued)

Event No.	Site	P Arrival Time				S Arrival Time				P-Amplitude (mm)
		Day	Hr	Min	Sec	Day	Hr	Min	Sec	
25	1	299	18	32						
	2									
	3				12.00					40.00
	4				13.00					43.48
	5				13.50					22.22
26	1	299	18	40						
	2									
	3				58.00					40.00
	4				56.70					30.43
	5				58.20					25.93
27	1	299	18	54	20.00					38.46
	2									
	3				19.80					48.00
	4				10.50					47.82
	5				10.90					51.86
28	1	299	18	57						
	2				05.60					40.00
	3				06.80					36.00
	4				10.00					26.09
	5				08.00					18.52
29	1	299	19	06	07.40					49.93
	2									
	3				07.20					40.00
	4				08.00					73.91
	5				09.00					55.56
30	1	299	19	12	10.50					57.60
	2									
	3				09.90					44.00
	4				11.00					65.22
	5				11.50					74.08
31	1	299	19	14	55.00					46.15
	2									
	3				54.00					48.00
	4				55.50					65.22
	5				56.00					55.56
32	1	299	19	12	10.40					76.92
	2									
	3				10.00					64.00
	4				11.00					86.96
	5				11.50					74.08

Table 2 (continued)

Event No.	Site	P Arrival Time				S Arrival Time				P-Amplitude (mu)
		Day	Hr	Min	Sec	Day	Hr	Min	Sec	
33	1	299	22	53	21.30					49.92
	2				20.00					40.00
	3				22.00					44.00
	4				22.50					69.50
	5				22.90					51.86
34	1	300	17	22						
	2				22.50					28.00
	3				23.50					32.00
	4				24.50					43.47
	5				24.90					37.04
35	1	301	15	28	29.20					57.73
	2				27.50					112.00
	3				28.50					52.00
	4				29.90					65.22
	5				30.00					
36	1	301	15	32						
	2				4.00					48.00
	3				43.20					60.00
	4				44.30					43.47
	5				44.40					
37	1	301	15	53	47.60					38.46
	2				45.90					80.00
	3				46.50					68.00
	4				48.50					43.48
	5				49.00					37.04
38	1	301	15	56	53.50					49.92
	2				51.70					88.00
	3				52.80					68.00
	4				53.90					65.22
	5				54.00					37.04
39	1	301	15	59	04.00					57.60
	2				02.60					100.00
	3				03.80					56.00
	4				04.90					69.12
	5				05.80					66.67
40	1	301	16	03	52.00					
	2				49.00					48.00
	3				51.20					28.00
	4				52.30					43.48
	5									

Table 2 (continued)

Event No.	P Arrival Time					S Arrival Time				P-Amplitude (μ)
	Site	Day	Hr	Min	Sec	Day	Hr	Min	Sec	
41	1	301	16	10	33.00					107.52
	2				30.00					100.00
	3				33.20					48.00
	4				33.50					86.88
	5				35.00					37.04
42	1	301	16	31	34.30					69.12
	2				32.70					80.00
	3				30.60					88.00
	4				28.20					86.88
	5									
43	1	301	16	42	59.50					38.48
	2									
	3				59.00					60.00
	4			43	00.00					86.88
	5				05.00					29.60
44	1	301	17	04	41.50					76.80
	2				40.00					80.00
	3				41.50					44.00
	4				42.50					78.19
	5				43.40					
45	1	301	17	11	42.00					38.46
	2				40.00					80.00
	3				41.90					40.00
	4				42.40					56.47
	5				43.50					37.04
46	1	301	17	17	29.00					
	2				26.00					80.00
	3				27.90					40.00
	4				28.50					69.12
	5				29.90					37.04
47	1	301	17	25	08.50					
	2				07.70					80.00
	3				09.40					40.00
	4				09.90					51.84
	5				11.00					37.04
48	1	301	17	36	20.60					76.80
	2				18.00					40.00
	3				20.20					40.00
	4				21.40					56.48
	5				22.10					25.92

Table 2 (continued)

Event No.	Site	P Arrival Time				S Arrival Time				P-Amplitude (mμ)
		Day	Hr	Min	Sec	Day	Hr	Min	Sec	
49	1	301	19	02	35.30					46.24
	2				33.70					100.00
	3				34.80					24.00
	4				35.30					21.76
	5				37.00					55.52
50	1	301	19	10	19.30					57.60
	2				17.00					80.00
	3				19.40					60.00
	4									
	5				21.20					55.56
51	1	301	19	18	30.00					42.24
	2				28.40					
	3				30.50					60.00
	4				32.00					43.48
	5				32.50					59.28
52	1	301	19	23	20.00					38.48
	2				19.00					52.00
	3				21.00					40.00
	4				21.60					60.88
	5				22.70					66.67

**MICROSEISMIC MONITORING NEAR THE
BRAZORIA COUNTY GEOPRESSURED WELL TEST SITE
NOVEMBER 1978**

**TELEDYNE GEOTECH
3401 Shiloh Road
Garland, Texas 75041**

1. INTRODUCTION

The Department of Energy plans to conduct long term flow tests of a well in Brazoria County, Texas which penetrates into the geopressured zone. Preliminary calculations indicate that the production of fluids from geopressured formations can introduce relatively large cumulative shearing strains into the surrounding rocks. It is reasonable to anticipate that these strains will be at least partially dissipated through localized, brittle failure of intact rock and renewed movement along dormant growth faults. Both processes may result in the emission of perceptible seismic energy which could pose a potential threat to the local environment. At the present time there is no rational basis for assessing the magnitude of this risk. Therefore, plans have been made to monitor the microseismic activity in the vicinity of the test site both before and during production tests. This report briefly describes the monitoring instrumentation and procedures and lists the seismic activity observed during the month of November 1978.

2. DATA COLLECTION

Figure 1 shows the location and configuration of the microseismic monitoring system array and the test well. The geographical coordinates and the Y(north-south) and X (east-west) coordinates of the individual sensor sites are listed in table 1. X, Y coordinates for flat earth are calculated relative to sensor site 3.

Table 1. Site coordinates

Site	Latitude			Longitude			Y(km)	X(km)	Elevation feet
	Deg	Min	Secs	Deg	Min	Secs			
1	29	17	27	95	16	52	1.027	-2.422	15
2	29	17	32	95	14	01	1.171	2.242	15
3	29	16	54	95	15	23	0.000	0.000	5
4	29	15	54	95	14	45	-1.872	1.032	12
5	29	15	54	95	16	11	-1.898	-1.284	18

The monitoring system instrumentation consists of five separate units, each with a standard moving-coil seismometer (Geotech S-13) followed by a low-noise amplifier/filter. In order to reduce background noise levels, the seismometers are installed in sealed containers at a depth of approximately four feet.

As shown in the block diagram of the monitoring system in figure 2, data from 4 of the sites are transmitted via radiotelemetry to a collection point in Liverpool, Texas. Here these input are multiplexed together with the support from the Liverpool site. The multiplexed signals are then transmitted via commercial telephone circuits to our Garland laboratory. At this point, the signals are discriminated and the seismic outputs are recorded on both magnetic tape and 16 mm film.

Figure 3 shows the total response of the monitoring system. The solid lines represent the tape recorder velocity and displacement response while the dashed lines represent the film recorder velocity and displacement response.

3. DATA ANALYSIS PROCEDURES

The film records are continuously reviewed to tabulate microseismic activity, assess the general quality of the data, and obtain information on detection thresholds.

During the review of these film records, incoming signals which are observed at three or more sites are listed and later, high speed playouts of the magnetic tape records of the signals are made in order to obtain high precision in the measurement of phase arrival times.

The arrival time data is processed by MEHYPO (Johnson, et al, 1977) a digital computer program which determines hypocenter, magnitude and reliability parameters of the local events. The location program utilizes both compressional and shear arrivals, tracing the refracted paths through an appropriate earth model consisting of horizontal layers with constant velocities. The solution is based upon a conventional least squares minimization criteria for the estimation of hypocenter coordinates.

The earth model presently used by MEHYPO for epicenter determination is shown in table 2.

Hypocenters are computed only for events observed at three or more stations because of possible ambiguities of solutions based on data from fewer stations.

Local seismic magnitudes are based upon maximum P wave amplitude and are calculated as:

$$M_L = \log_{10} (A/2) - 1.75 + 0.8 \log_{10} (X)$$

where M_L is the local magnitude

A is the peak to peak compressional wave amplitude in nanometers
(10^{-9} meters)

$$X = \left[\frac{(\text{epicentral distance})^2}{(\text{in kilometers})} + \frac{(\text{hypocentral depth})^2}{(\text{in kilometers})} \right]^{\frac{1}{2}}$$

and X = must be ≥ 1.0

Table 2. Velocity model utilized by MEHYPO for epicenter determination

<u>Layer</u>	<u>Thickness (km)</u>	<u>Velocity (km/sec)</u>
1	.4000	1.8000
2	.4000	1.9000
3	.3000	2.1000
4	.3000	2.3000
5	.3000	2.4000
6	.3000	2.5000
7	.3000	2.9000
8	.3000	2.6500
9	.2700	2.4000
10	.1300	1.6500
11	.2500	2.8000
12	.3000	3.3500
13	.3000	3.4000
14	1000.0000	3.5000

4. RESULTS

A total of two hundred forty-nine microseismic events occurring within the test well area has been detected during the month of November 1978. Seventy of the recorded events have distinct P and S arrivals at three or more stations, facilitating reasonably reliable hypocenter location and magnitude estimates. The estimated hypocenter locations and magnitudes calculated by program MEHYPO for these events are listed in table 3.

Figure 4 is a local map of the test well area showing the distribution of the calculated epicenter locations. Note that the epicenters generally lie in clusters which locate very near accessible roadways. Notice also (from table 2) that the occurrence of the events composing a cluster is somewhat regular in time and that the events are near equal in magnitude and are confined to the same general epicentral region.

All microseismic events detected during November have occurred during daylight hours. This fact combined with the regularity of occurrence and similarity of magnitudes indicates that the activity observed during this recording period results from cultural activity. No naturally occurring microseismic activity has been identified.

5. REFERENCES

Johnson, J. L., Clawson, G. E., and Swanson, J. G., 1977, program MEHYPO with 1977 modifications: TN 3/77, Garland, Texas, Teledyne Geotech, 25 p.

Table 3. Microseismic events

Event Number	Date			Origin Time			Coordinates		Depth (km)	Magnitude
	Yr	Mo	Day	Hr	Min	Sec	Y(km)	X(km)		
1	78	11	03	0	2	59.35	-1.356	.583	.005	.54
2	78	11	03	0	5	44.573	-.479	1.571	.005	.85
3	78	11	03	0	31	38.371	-1.248	.280	.005	.59
4	78	11	03	0	14	32.866	-.533	1.622	.005	1.00
5	78	11	03	0	18	37.315	-.569	1.689	.005	.89
6	78	11	03	0	43	48.914	-.552	1.588	.005	.94
7	78	11	03	0	30	35.037	-1.142	.349	.005	.86
8	78	11	03	0	0	47.492	-.589	1.801	.005	.67
9	78	11	03	0	0	36.125	-.522	1.471	.005	.59
10	78	11	03	0	0	38.417	-1.269	.203	.005	.23
11	78	11	03	0	22	37.577	-.612	2.261	.005	1.03
12	78	11	03	0	0	40.275	-.358	1.495	.005	.60
13	78	11	03	0	14	32.669	-.824	2.207	.005	1.10
14	78	11	03	0	18	37.318	-.306	1.223	.005	.90
15	78	11	03	0	30	35.096	-1.165	.498	.005	.90
16	78	11	03	0	43	48.864	-.648	1.784	.005	.97
17	78	11	03	0	0	47.493	-.580	1.717	.005	.65
18	78	11	03	0	0	38.399	-1.147	.247	.005	.77
19	78	11	03	0	0	40.279	-.346	1.490	.005	.60
20	78	11	07	0	0	28.766	1.453	1.098	.005	1.07
21	78	11	07	0	0	44.631	1.499	.990	.005	.96
22	78	11	07	0	0	25.334	1.326	1.211	.005	.99
23	78	11	07	0	0	47.995	1.201	1.319	.005	1.11
24	78	11	07	0	21	48.022	1.579	1.630	.005	1.33
25	78	11	13	0	0	30.164	1.032	1.335	.001	.90
26	78	11	13	0	0	17.530	1.093	1.315	.005	.98
27	78	11	13	0	0	39.161	1.056	1.329	.005	1.21
28	78	11	13	0	0	56.092	1.024	1.325	.005	1.04
29	78	11	13	0	0	40.960	1.144	1.324	.005	1.17
30	78	11	13	0	0	25.264	1.059	1.360	.005	.92
31	78	11	13	0	0	09.430	1.214	1.322	.005	.84
32	78	11	14	0	2	33.046	1.522	.948	.001	.85

Table 3 continued.

<u>Event Number</u>	<u>Date</u>			<u>Origin Time</u>			<u>Coordinates</u>		<u>Depth (km)</u>	<u>Magnitude</u>
	<u>Yr</u>	<u>Mo</u>	<u>Day</u>	<u>Hr</u>	<u>Min</u>	<u>Sec</u>	<u>Y(km)</u>	<u>X(km)</u>		
33	78	11	14	0	51	30.636	1.247	1.055	.005	.89
34	78	11	14	0	45	39.472	1.490	1.028	.005	.81
35	78	11	14	0	33	51.552	1.225	1.106	.005	.79
36	78	11	14	0	27	52.296	1.473	1.033	.005	1.07
37	78	11	14	0	24	17.608	1.386	.957	.005	.94
38	78	11	14	0	19	56.510	1.573	1.085	.005	1.06
39	78	11	14	0	0	56.200	1.507	.950	.005	.84
40	78	11	14	0	0	0.992	1.694	.923	.005	.84
41	78	11	14	0	0	39.289	1.688	.914	.005	.84
42	78	11	14	0	0	13.717	1.453	1.008	.005	1.07
43	78	11	14	0	0	10.046	1.609	.861	.005	.98
44	78	11	14	0	0	37.464	1.553	.932	.005	1.03
45	78	11	14	0	0	3.486	1.572	.835	.005	.95
46	78	11	15	0	37	6.386	1.338	.930	.005	.80
47	78	11	15	0	6	33.225	1.997	.857	.005	.90
48	78	11	15	0	13	31.009	1.739	.832	.005	.86
49	78	11	15	0	16	0.403	1.871	.851	.005	1.14
50	78	11	15	0	51	55.802	1.877	.781	.001	.90
51	78	11	15	0	3	5.861	1.790	.673	.005	.98
52	78	11	15	0	28	14.143	1.822	.653	.005	.86
53	78	11	15	0	32	34.409	2.200	.625	.005	.94
54	78	11	15	0	54	35.348	2.887	.511	.005	1.31
55	78	11	15	0	59	37.378	2.897	.613	.005	1.20
56	78	11	15	0	0	20.099	1.059	1.325	.005	1.10
57	78	11	15	0	0	31.602	1.044	1.375	.005	1.10
58	78	11	16	0	0	46.836	.186	1.591	.001	.75
59	78	11	16	0	0	11.448	.261	1.525	.005	.84
60	78	11	16	0	0	16.040	.178	1.591	.005	.79
61	78	11	16	0	39	34.874	.278	1.717	.005	.76
62	78	11	16	0	44	54.561	.317	1.615	.005	.85
63	78	11	16	0	46	36.566	.231	1.722	.005	1.00
64	78	11	16	0	10	11.284	-.041	2.156	.005	.95
65	78	11	21	0	36	3.873	-.641	1.776	.005	.78

Table 3 continued.

<u>Event Number</u>	<u>Date</u>			<u>Origin Time</u>			<u>Coordinates</u>		<u>Depth (km)</u>	<u>Magnitude</u>
	<u>Yr</u>	<u>Mo</u>	<u>Day</u>	<u>Hr</u>	<u>Min</u>	<u>Sec</u>	<u>Y(km)</u>	<u>X(km)</u>		
66	78	11	21	0	23	3.873	-1.040	2.624	.005	1.05
67	78	11	21	0	49	1.576	-0.450	1.591	.005	.73
68	78	11	21	0	36	57.084	-0.271	2.138	.005	1.07
69	78	11	21	0	51	24.700	-0.455	1.578	.005	.87
70	78	11	21	0	57	10.990	-0.395	1.403	.005	.91

Figure 1. Location of sensor sites of Brazoria County field program

Figure 2. Block diagram of Brazoria County, Texas, array system

Figure 3. Response of survey system to a constant input

Figure 4. Epicenter locations of microseismic activity detected during November 1978

**MICROSEISMIC MONITORING NEAR THE
BRAZORIA COUNTY GEOPRESSURED WELL TEST SITE
DECEMBER 1978**

**TELEDYNE GEOTECH
3401 Shiloh Road
Garland, Texas 75041**

1. INTRODUCTION

The Department of Energy plans to conduct long term flow tests of a well in Brazoria County, Texas which penetrates into the geopressured zone. Preliminary calculations indicate that the production of fluids from geopressured formations can introduce relatively large cumulative shearing strains into the surrounding rocks. It is reasonable to anticipate that these strains will be at least partially dissipated through localized, brittle failure of intact rock and renewed movement along dormant growth faults. Both processes may result in the emission of perceptible seismic energy which could pose a potential threat to the local environment. At the present time there is no rational basis for assessing the magnitude of this risk. Therefore, plans have been made to monitor the microseismic activity in the vicinity of the test site both before and during production tests. This report briefly describes the monitoring instrumentation and procedures and lists the seismic activity observed during the month of December 1978.

2. DATA COLLECTION

Figure 1 shows the location and configuration of the microseismic monitoring system array and the test well. The geographical coordinates and the Y(north-south) and X (east-west) coordinates of the individual sensor sites are listed in table 1. X, Y coordinates for flat earth are calculated relative to sensor site 3.

Table 1. Site coordinates

Site	Latitude			Longitude			N-S (km)	E-W (km)	Elevation feet
	Deg	Min	Secs	Deg	Min	Secs			
1	29	17	27	95	16	52	1.027	2.422	15
2	29	17	32	95	14	01	1.171	2.242	15
3	29	16	54	95	15	23	0.000	0.000	5
4	29	15	54	95	14	45	-1.872	1.032	12
5	29	15	54	95	16	11	-1.898	-1.284	18

The monitoring system instrumentation consists of five separate units, each with a standard moving-coil seismometer (Geotech S-13) followed by a low-noise amplifier/filter. In order to reduce background noise levels, the seismometers are installed in sealed containers at a depth of approximately four feet.

As shown in the block diagram of the monitoring system in figure 2, data from 4 of the sites are transmitted via radiotelemetry to a collection point in Liverpool, Texas. Here these input are multiplexed together with the support from the Liverpool site. The multiplexed signals are then transmitted via commercial telephone circuits to our Garland laboratory. At this point, the signals are discriminated and the seismic outputs are recorded on both magnetic tape and 16 mm film.

Figure 3 shows the total response of the monitoring system. The solid lines represent the tape recorder velocity and displacement response while the dashed lines represent the film recorder velocity and displacement response.

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The film records are continuously reviewed to tabulate microseismic activity, assess the general quality of the data, and obtain information on detection thresholds.

During the review of these film records, incoming signals which are observed at three or more sites are listed and later, high speed playouts of the magnetic tape records of the signals are made in order to obtain high precision in the measurement of phase arrival times.

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The earth model presently used by MEHYPO for epicenter determination is shown in table 2.

Hypocenters are computed only for events observed at three or more stations because of possible ambiguities of solutions based on data from fewer stations.

Local seismic magnitudes are based upon maximum P wave amplitude and are calculated as:

$$M_L = \log_{10} (A/2) - 1.75 + 0.8 \log_{10} (X)$$

where M_L is the local magnitude

A is the peak to peak compressional wave amplitude in nanometers
(10^{-9} meters)

$$X = \left[\frac{(\text{epicentral distance})^2}{(\text{in kilometers})} + \frac{(\text{hypocentral depth})^2}{(\text{in kilometers})} \right]^{\frac{1}{2}}$$

and X = must be ≥ 1.0

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9	.2700	2.4000
10	.1300	1.6500
11	.2500	2.8000
12	.3000	3.3500
13	.3000	3.4000
14	1000.0000	3.5000

4. RESULTS

A total of seventy four microseismic events which occurred within the test well area has been detected during the month of December 1978. None of these events were recorded with distinct compressional (P) or shear (S) arrivals, therefore no reliable hypocenter locations or magnitudes have been calculated by program MEHYPO. A rough estimate of the location of these events, however, places the epicenter 0.91 km south and 1.65 km west of Site 3, with an estimated average magnitude of 1.0.

Figure 4 is a typical example of the events observed during December, and illustrates the difficulty in determining arrival times and phase identification from the recorded signals.

All microseismic events detected during this monitoring period have occurred during the daylight hours. This fact combined with the regularity of occurrence and similarity of magnitudes indicates that the activity observed during December is of cultural origin.

No definite naturally occurring microseismic activity from within the test well vicinity has been identified since the beginning of the monitoring program.

5. REFERENCES

Johnson, J. L., Clawson, G. E, and Swanson, J. G., 1977, program MEHYPO with 1977 modifications: TN 3/77, Garland, Texas, Teledyne Geotech, 25 p.

Figure 1. Location of sensor sites of Brazoria County field program

Figure 2. Block diagram of Brazoria County, Texas, array system

graph 1
3 x 3

Figure 3. Response of survey system to a constant input

Figure 4. A typical event recorded by the Brazoria monitoring system during the month of December 1978.