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TELEPHONE 801-581-5283

February 22, 1982

Mr. David L. Reese, Manager
Geothermal Operations
Phillips Petroleum Company
655 East 4500 South
Salt Lake City, Utah 84107

Re: Seismic Monitoring, RHSU

Dear Mr. Reese:

I have received your letter dated February 12, 1982 informing us of the decision by the Roosevelt Hot Springs Unit (RHSU) not to financially support the continuation of the seismic monitoring project at Roosevelt Hot Springs (RHS).

We are disappointed to see the project terminated particularly when 1) seismic swarm activity was recorded in the production area last summer coupled with the probability of additional seismic activity in the future and 2) seismic monitoring data could provide very valuable information legally as well as technically concerning the geothermal development of the production area.

There is a misunderstanding you have concerning our proposal being in response to your RFP regarding the seismic monitoring program at RHS. The first time we saw a copy of the RFP was the copy attached to your February 12, 1982 letter. Our proposal was unsolicited and not in response to any RFP. The intent of our unsolicited proposal was to 1) request additional DOE funding for our DOE Contract No. AS07-78ID01821, and 2) provide a transition vehicle for industry to enter cooperatively with DOE on an established DOE seismic monitoring project that without industry participation, DOE will not continue to fund.

We had some initial contact with Phillips Petroleum Company concerning the project. A meeting was held at the Earth Science Laboratory (ESL) on January 6, 1982 to discuss the seismic project at RHS and our pending proposal. Our January 15, 1982 proposal was submitted in response to this meeting. However, I talked to Mr. Dick Lenzer on February 2, 1982, and we were surprised to learn that our proposal was being considered along with other proposals submitted by private sector contractors in response to an RFP you sent out on January 13, 1982. ESL, of course, cannot bid competitively against private sector contractors by proposing the use of government equipment. We have worked above-board with all concerned on our proposal. Therefore, we feel a correct understanding of our intent is necessary.

I have contacted DOE about your decision, and they have asked me to forward a copy of the enclosed DOE "Guide for Submission of Unsolicited Proposals" in the event the RHSU has a future interest in a seismic monitoring project at RHS.

We do appreciate your consideration of our proposal.

Sincerely,

W. L. Forsberg
Associate Director

WLF:gm

Enclosure
cc: W. C. Drake
R. C. Lenzer
J. Mass
S. H. Ward
P. M. Wright

Seismicity A-3

UGI
Utah Geophysical Inc.
P.O. Box 9344 Salt Lake City, Utah 84109 (801) 272-1289

December 10, 1978

Attached is a short paper in reply to some questions that have justifiably been raised about Seismic Emission (groundnoise correlation) surveys. The principal question involved is whether geothermal reservoirs generate predominantly P-wave or Rayleigh (surface) motion. Seismic Emission surveys are based on the premise that the geothermal source generates P-waves. In the attached paper it is shown that:

1) Surface waves are generated only in special cases when the source is located at or near the surface of the earth. An example of this would be in the presence of a hot spring or geyser.

2) When the geothermal source is buried at depth the mechanism for the generation of Rayleigh waves is no longer present and, therefore, P-wave motion is being observed.

3) At distances beyond 4 km from a hot spring the surface wave energy is attenuated and no longer coherent.

4) Geophone arrays used to filter surface waves from the groundnoise data are inappropriate and ineffective in geothermal studies. Particle motion filtering (offered by UGI) provides for a more practical approach to this problem. However, the best solution is to avoid monitoring groundnoise within a 4 km radius of a hot spring.

The purpose of this paper is to avoid some of the pitfalls that have occurred in a few previous surveys that tend to discredit Seismic Emission surveys.

Very truly yours,
UTAH GEOPHYSICAL, INC.
Lewis J. Katz
Lewis J. Katz

LFK:acs
Attachment

Comments on Seismic Emission Surveys

by Lewis Katz, Utah Geophysical, Inc.

Introduction

Controversy on the subject of geothermally generated Body (P) versus Rayleigh (R) waves was raised by McEvilly (Univ. Calif.) as a result of work he took part in at Leach Hot Springs, Nevada (Beyer et al., 1976). McEvilly's group was able to use frequency-wave number correlation processing to show that apparent Rayleigh wave solutions of his analysis pointed toward the geothermal hot springs. He also suggested that P-wave solutions to groundnoise source locations derived at other areas were actually biased surface waves.

As a result of McEvilly's allegations both the University of Tulsa and the U.S.G.S. have sponsored studies using geophone arrays to suppress the Rayleigh waves that McEvilly claims are being monitored. Unfortuanately, the approach of using geophone arrays in a seismic noise study appears to be inappropriate and ineffective, as will be explained later. Also, the generation of surface waves from a source located on the earth's surface is to be expected (Lamb, 1904). However, as the depth of burial of the noise source is increased, the amplitude of surface waves are greatly attenuated (Dobrin, et al., 1951; Ricter, 1958). This means that at areas not having surface hot springs or geysers, coherent Rayleigh wave microseisms should not be expected since the mechanism for their generation is not present. Furthermore, Rayleigh wave microseisms have been seen to attenuate quite quickly with distance from the source. At Grass Valley, McEvilly had 16 arrays (Liaw, 1977), of which only four showed coherent Rayleigh wave microseisms generated from the hot springs. These four arrays were all located within 4 kilometers of the hot springs. This suggests that beyond 4 kms. Rayleigh wave energy is greatly attenuated. Similarly, the findings of Iyer (1974) at East Mesa found that groundnoise generated from canals and water drops were attenuated at about the same distance (3 kms.)

Therefore, by staying a distance of 4 km from surface hot springs, interference from coherent Rayleigh waves can possibly be avoided.

Rayleigh waves

Rayleigh waves differ from body waves in that their particle motion is retrograde elliptical. Rayleigh motion occurs in the vertical and horizontal radial planes. For poissons ratio of 0.25, Rayleigh wave velocity is approximately half of the P-wave velocity.

Theoretically, from the work of Rayleigh the amplitude of surface waves falls off as the source or hypocenter is displaced to greater depth (Ricter, 1958). Banerji (1925) and Jeffreys (1929) have also shown the amplitude of Rayleigh waves to decrease with the source depth (z) as

$$e^{-K\, z/\lambda}$$

Where, λ is wavelength.

K is 5.8 for a purely compressional (P) wave and 2.4 for a purely distortional wave.

These results have been observed by Dobrin et al. (1951) in generating Rayleigh waves from small explosions and are shown in Figure 1. It can be seen from Figure 1 that increasing the source depth severely attenuates the amplitude of Rayleigh waves. In this example the wavelength was 300 feet and therefore the relationship stated above is

$$A = Ce^{-3.6\, z/\lambda}\ .$$

In summary, Rayleigh waves propagate with retrograde elliptical particle motion. For surface sources they occur within 4 kms of the source and for buried geothermal sources they probably do not appear because of the short wavelengths (high frequencies) used in geothermal analysis.

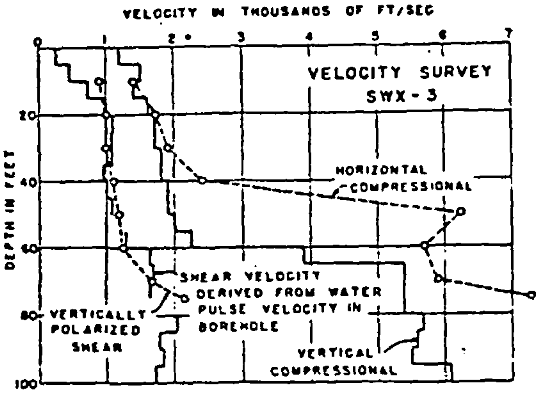

Fig. 3--Logs of compressional and shear interval velocities at SWX-3

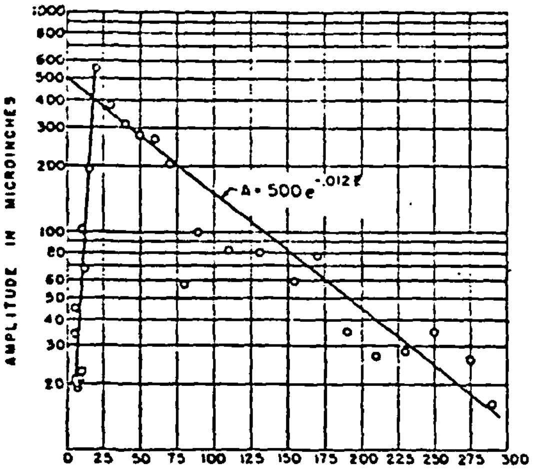

Fig. 9--Variation of Rayleigh-wave amplitude from five-pound explosion as function of depth of shot; data from T-218

Fig. 1. After Dobrin et al., 1951

Methods of Filtering Rayleigh Wave Motion

(1) Geophone Arrays:

As mentioned previously a few geothermal groundnoise surveys using geophone arrays have been used inappropriately to suppress Rayleigh wave motion. Geophone arrays such as these have proved effective in seismic reflection exploration. The difference between its use in geothermal noise studies and exploration seismology is that in exploration seismology the P-waves arrive at the geophones with vertical incidence thus having infinite apparent velocity. In the groundnoise case we have a small geophone array focusing at a source a distance from the array. The first arrival is either a refracted body wave or a reflected wave having a large angle of incidence and the apparent velocity is no longer infinite. This results in the P-wave of interest being distorted or attenuated as well as the surface wave.

Improper field procedures in designing the array is another problem. In exploration geophysics a preliminary noise survey is performed to design the array. In the two geothermal experiments using geophone arrays, the arrays were designed in a haphazard manner with no previous field investigation. Results of this procedure appear to have caused the pass band of the arrays to pass both P and Rayleigh waves. Let us expand upon this since it will exemplify the impracticality of these arrays in geothermal groundnoise exploration.

Liaw (1977) has shown that coherent surface waves at Grass Valley had a velocity of about 1 km/sec (3300 fps) at a frequency of about 4 Hz. Page and Houck (1978) report using a multi-element geophone array with 12 phone diagonals at 10 feet geophone intervals. The wave number (K) for a surface wave is

$$K = \frac{\text{frequency}}{\text{velocity}}$$

$$= \frac{4}{3300} = .0012$$

for a P-wave having an apparent velocity of 10,000 fps

$$K = \frac{4}{10,000} = .0004$$

The response of the geophone array can be approximated as

$$\text{response} = 0, \text{ at } \frac{I}{(N)\ (\Delta L)}$$

where, $I = 1, 2, 3, \ldots, N-1$

N = number of geophones in array

ΔL = geophone spacing

Thus, the response curve for the above geophone array is shown in Figure 2. It can be seen that wave numbers (K) less than 1/120 (.008) are passed. Thus, the array used previously by Page and Houck appears to be failing to filter out the Rayleigh waves.

(2) Spatial (Distance) filtering:

We have shown above that coherent Rayleigh waves generated from surface hot springs can be expected to be attenuated at a distance of about 4 km from the source. By designing surveys so that monitoring is greater than 4 km from a spring, Rayleigh wave motion generated from the spring can be avoided.

(3) Particle Motion filtering:

Since Rayleigh wave particle motion is retrograde elliptical, seismic noise data from a 3-component (vertical, radial, horizontal) seismometer can be combined to filter data with retrograde elliptical particle motion.

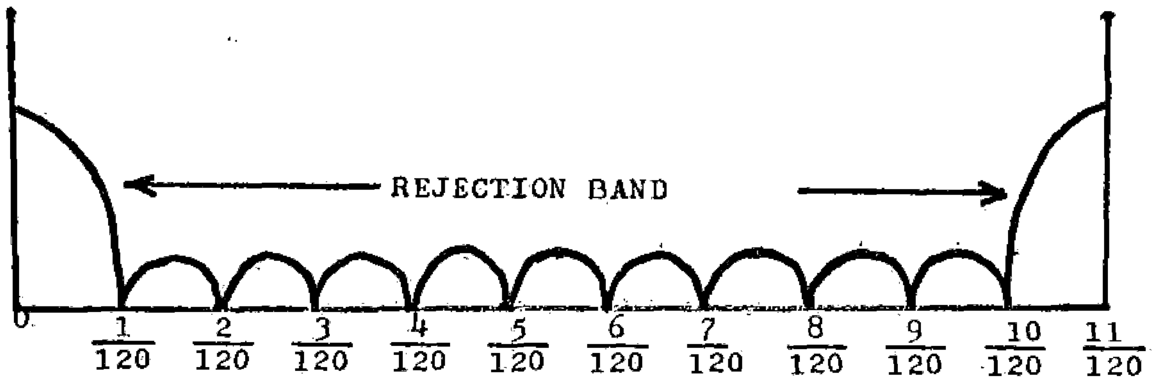

Fig. 2. Geophone array response. Twelve phone diagonal at ten feet spacing.

REFERENCES

Banerji, S.K. (1925). On the depth of earthquake focus, Phil. Mag., v. 49, pp. 65-80.

Beyer, H., Dey, A., Liaw, A., Majer, E., McEvilly, T.V., Morrison, H.F., and H. Wollenberg (1976). Preliminary open file report geological and geophysical studies in Grass Valley, Nevada, LBL-5262, Univ. Calif./Berkeley.

Dobrin, M.B., Simon, R.F., and P.L. Lawrence (1951). Rayleigh waves from small explosions, Trans. Am. Geophy. Un., v. 32, no. 6, pp. 822-32.

Jeffreys, H. (1929). The Earth (2nd ed.), Cambridge Univ. Press.

Lamb, H. (1904). On the propagation of tremors over the surface of an elastic solid, Phil. Trans. Roy. Soc. (London A, v. 203, pp. 1-42.

Liaw, A.L. (1977). Microseisms in geothermal exploration: Studies in Grass Valley, Nevada, LBL-7002, (Ph.D. thesis).

Nakano, H. (1925). On Rayleigh waves, Japan. J. Astron. Geophys., v. 2, pp. 233-326.

Page, E.A. and R.T. Houck (1978). Geothermal groundnoise benchmark experiment, Contract # P.O. 38730, Univ. of Tulsa.

Ricter, C.F. (1958). Elementary seismology, W.H. Freeman and Co., p. 306.