Shear Wave Conversion in Reservoir Rocks*

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Abstract

Converted shear waves (P- to S-) are clearly seen at large offsets in conventional seismic reflection profiling using 3-component seismometers. However, at normal or near normal incidence it is unusual. One such observation where the horizontal component signal was more pronounced than the corresponding vertical component prompted this inquiry. Possible explanations are scattering and anisotropy. A different possibility considered here is the conversion due to lateral motion of fluids in the reservoirs. This lateral motion of fluids induces shearing forces on the rock matrix due to a combination of viscous drag and pressure differences.

An experiment investigated the influence of fluids on the transmitted wave. Compression and shear motion in two orthogonal directions were induced on one face of the core sample and for each set-up all three motions were recorded on the opposite face. The data suggests that the converted shear is enhanced by the presence of fluids, in this instance, water. This transmission experiment was repeated using oil and a very significant difference between the amplitudes was observed. One has to realize that this demonstration is made at MHz frequencies. However, the original field observation was made at seismic frequencies of ~ 20 Hz; and, hence it behooves us to investigate the relationship between converted shear wave amplitudes and reservoir fluids at seismic frequencies. This may be considered analogous to "bright spot" technology for detection of gas.

Shear Wave Conversion in Reservoir Rocks

By
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Eastern Section AAPG, Kalamazoo, Sep. 10

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- Conversion from compressional waves to shear waves takes place at all interfaces with acoustic impedance contrasts – reflection – and varies with angle/offsets
- It is also converted in layers that are heterogeneous by scattering

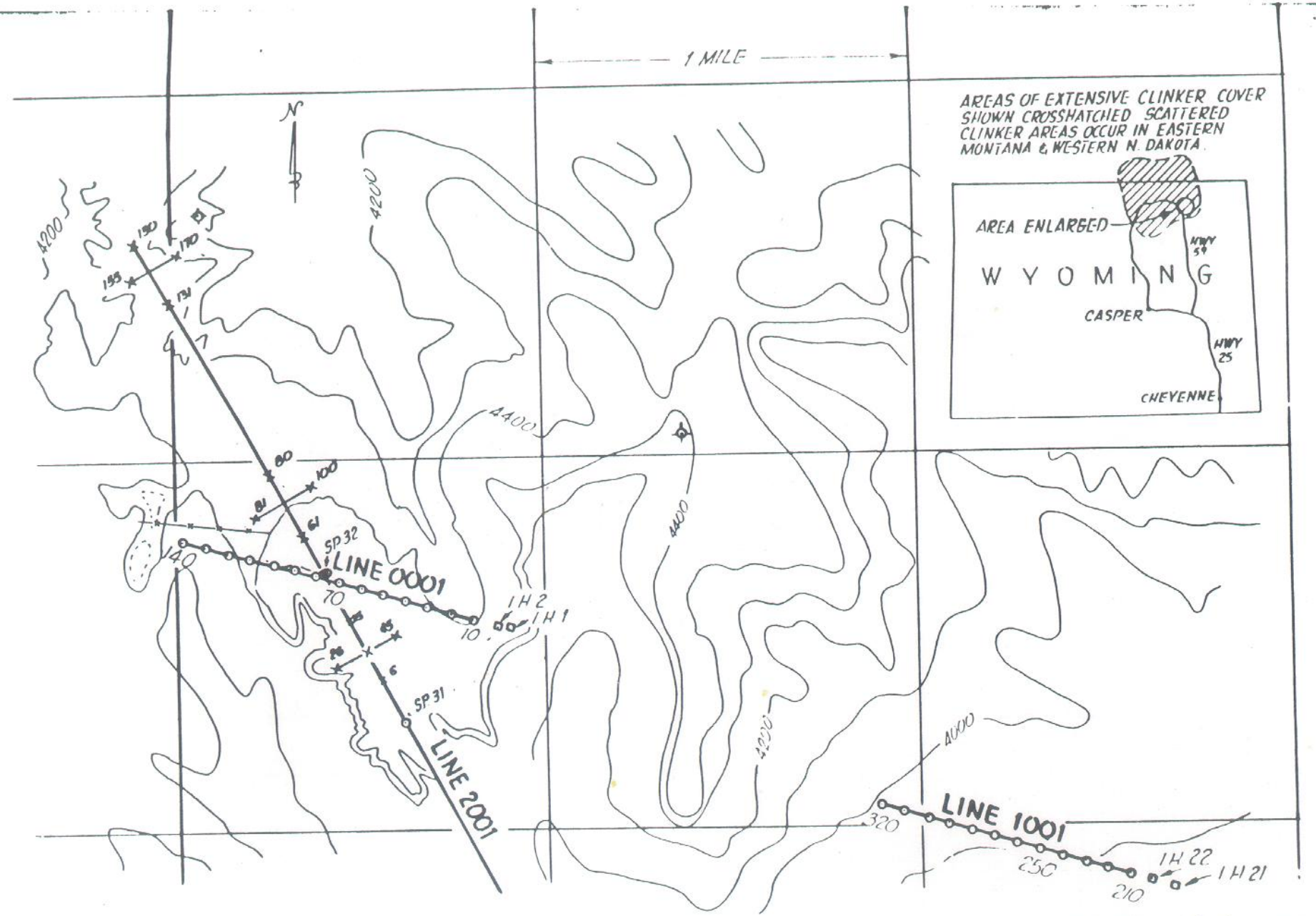


Fig. 1. Area of detailed study. The inset map of Wyoming shows the location of the enlarged area and the appro mate extent of clinker-covered areas. Tests conducted along Lines 0001 and 1001 are semitransposed wave test These lines show the shot locations and the locations of the Instrument Holes (IH). The test along Line 2001 in

Hammer Blow Experiment
Powder River Basin

X X … X O O O … O

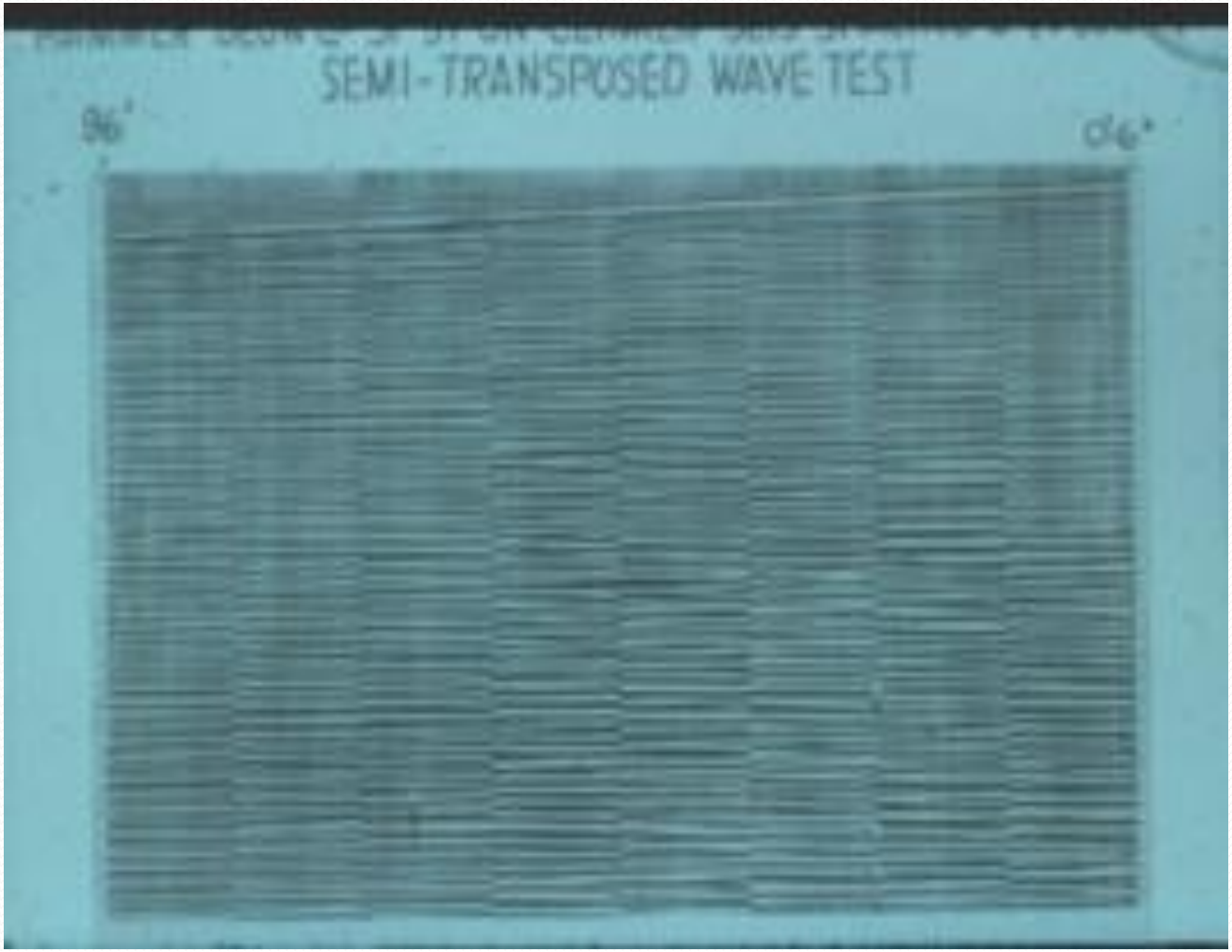
R1 … R24 S1 S2 S3 S8

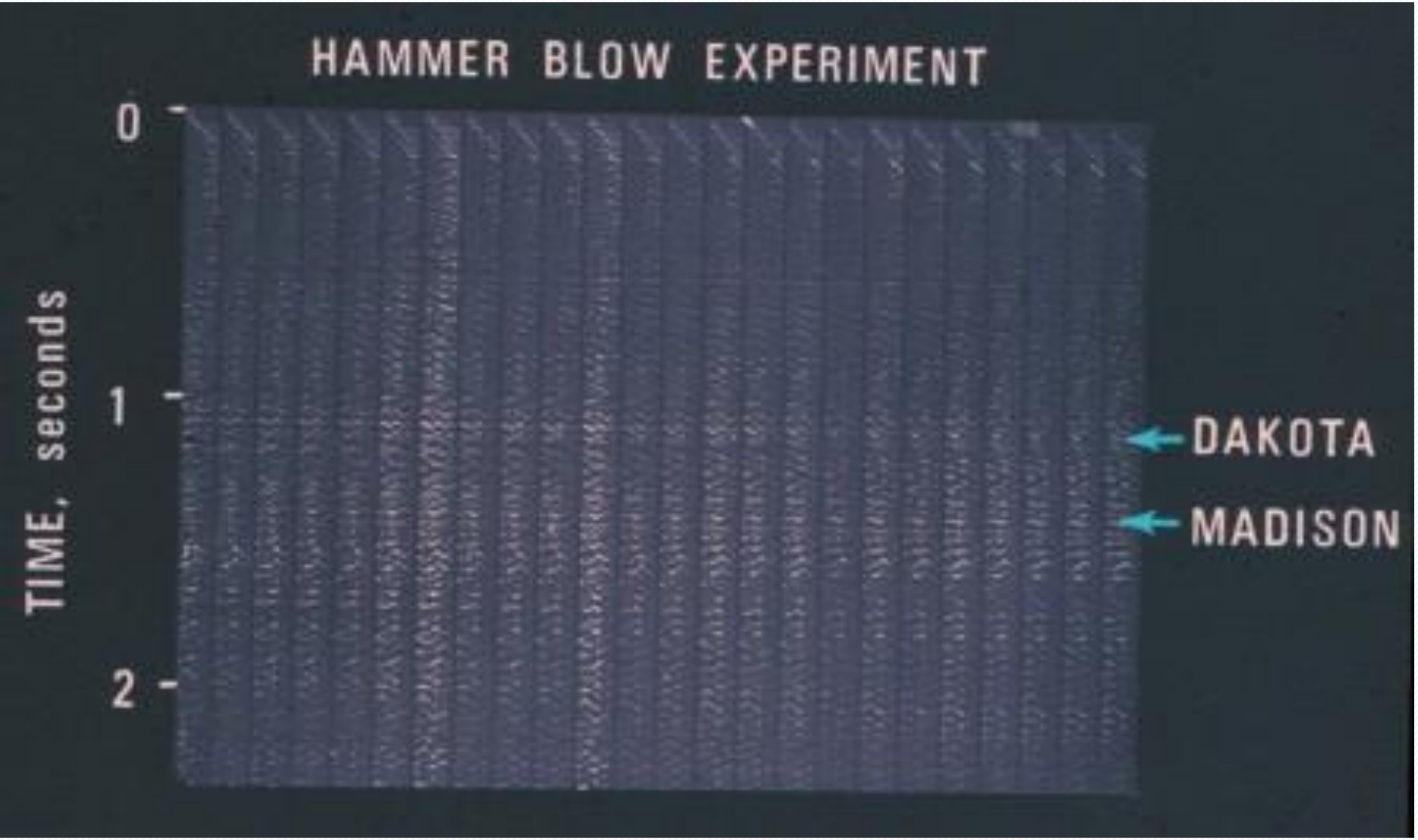
R1 – R 24: 6 in. (15 cm) spacing

S1 – S8: 12 ft (3.66 m) spacing

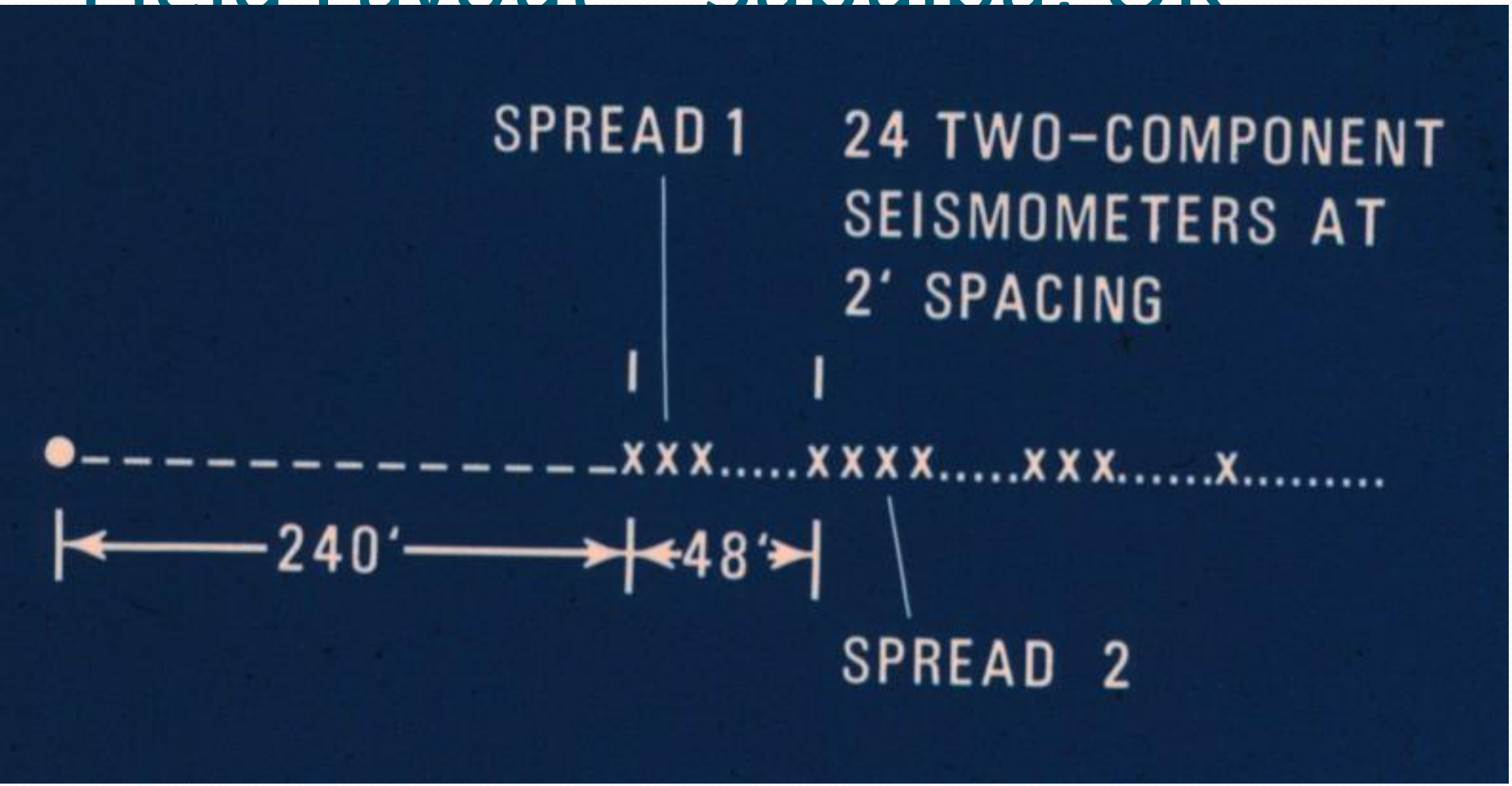
S – R offset: 6 in. to 96 ft (29.3 m)

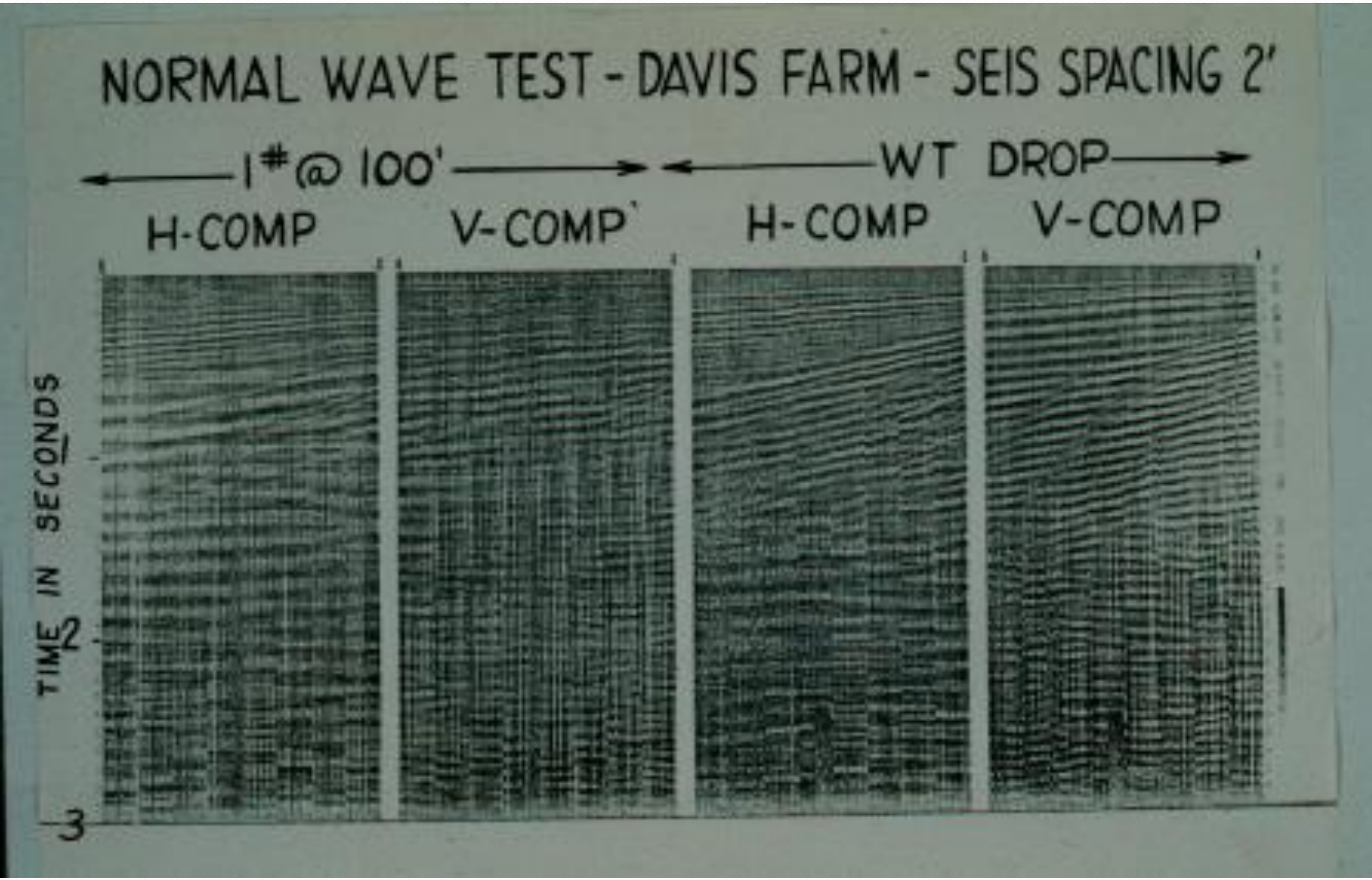
HAMMER BLOW EXPERIMENT
On a clinker mesa
Powder River Basin




HAMMER BLOW EXPERIMENT
TIME, seconds
0
1
2
DAKOTA
MADISON

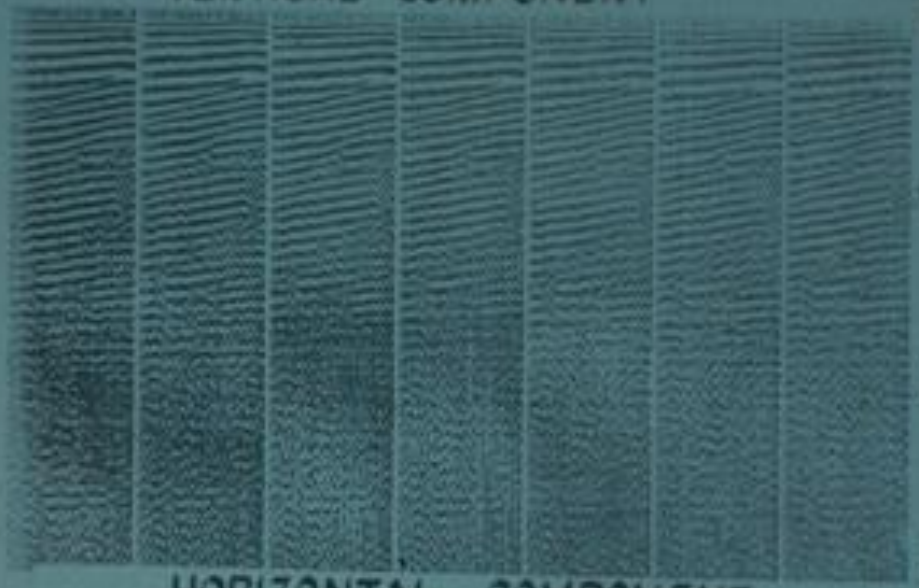
Field Layout – Sapulpa, OK




NORMAL WAVE TEST - DAVIS FARM - SEIS SPACING 2'
1# @ 100'
WT DROP
H-COMP
V-COMP
H-COMP
V-COMP
TIME IN SECONDS
1
2
3

TRANSPOSED WAVE TEST - DAVIS FARM

VERTICAL COMPONENT



HORIZONTAL COMPONENT

SOURCE: WT. DROP, SOURCE IS MOVED AT 2' INCREMENTS FROM 240' TO 324' FROM SPREAD.

Experiments

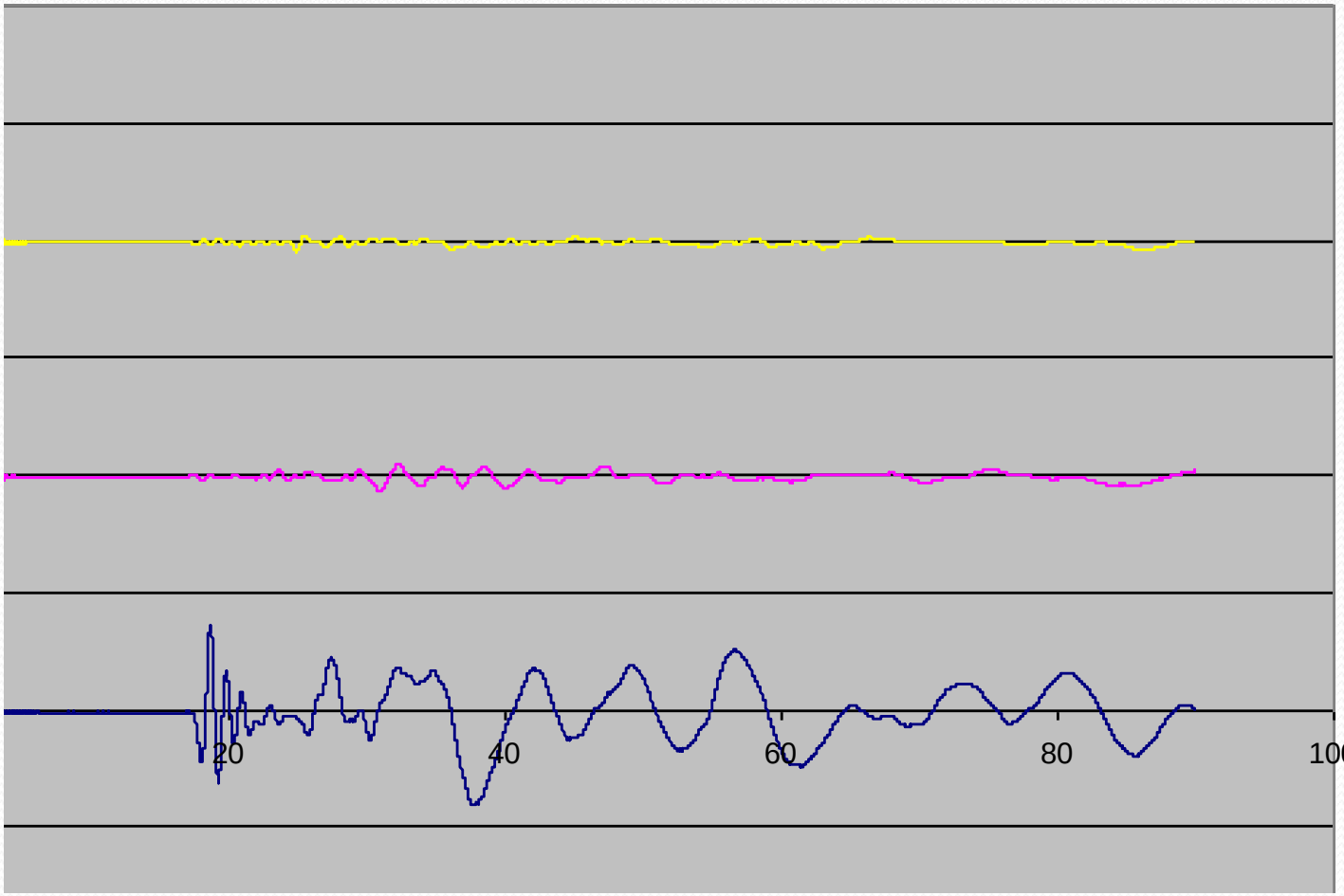
- Comparatively strong horizontal component signature was recorded at near normal incidence at a field site near Tulsa, Oklahoma which led to this investigation.
- A simple set-up simulating a two-layer medium was constructed using a thick block of aluminum glued to a slab of Berea sandstone.

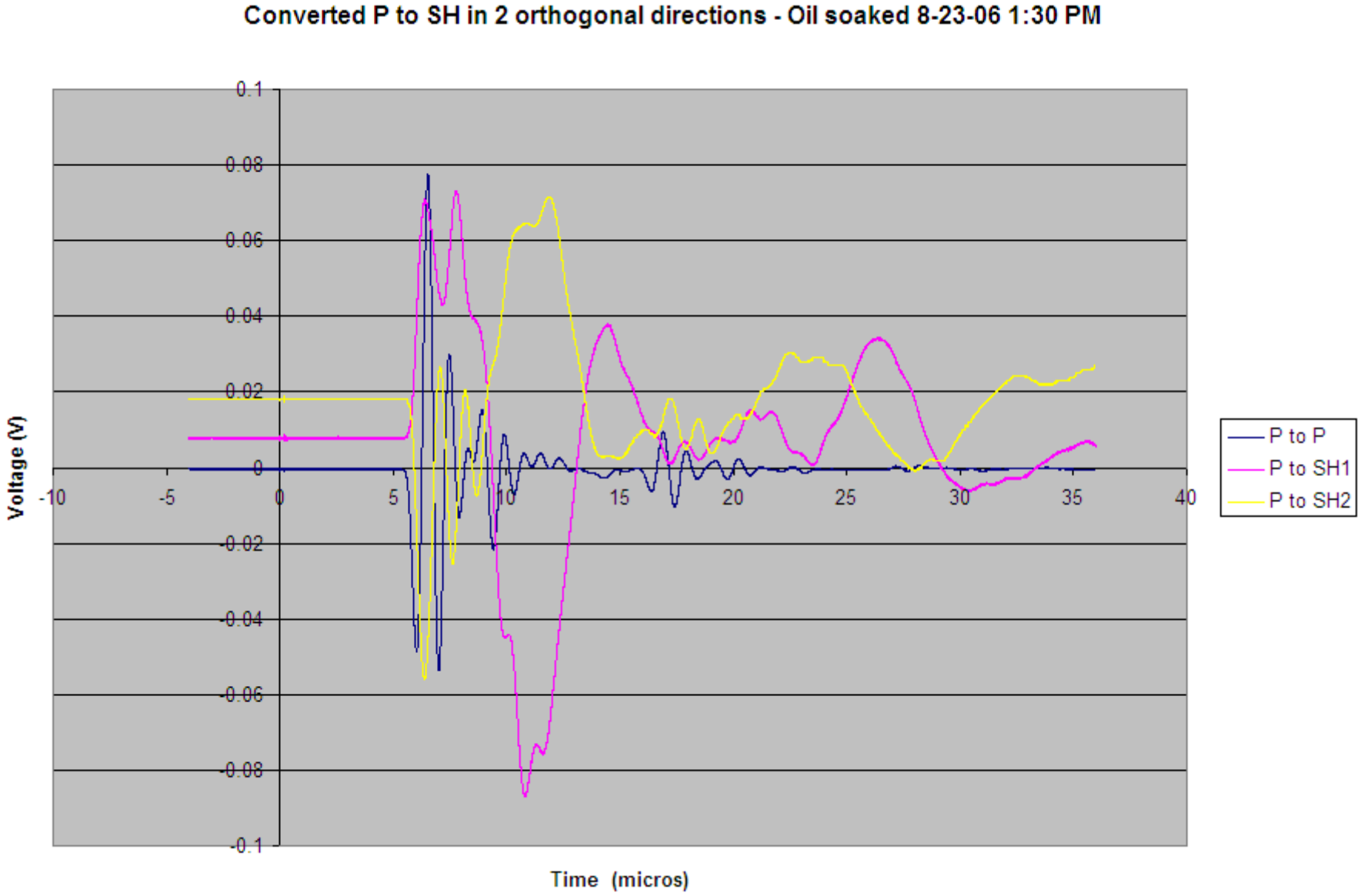
Experiments (contd.)

- A P-transducer was placed on top of the Al block to generate the P-waves that were reflected at the interface. Both P- and SV-reflected waves were recorded at various offsets.
- The experiment was done with dry rock first.
- It was repeated with the rock in a bath of water.
- Results were mixed.
- So transmission experiment was done which provided some excitement.

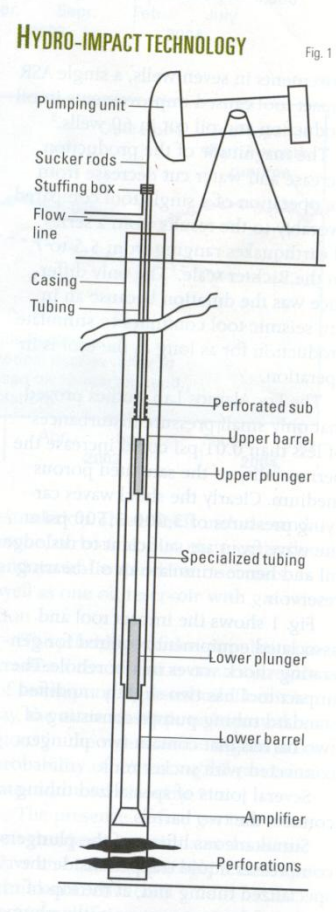

28 10:50 AM

Transmission Data _ DRY Sample

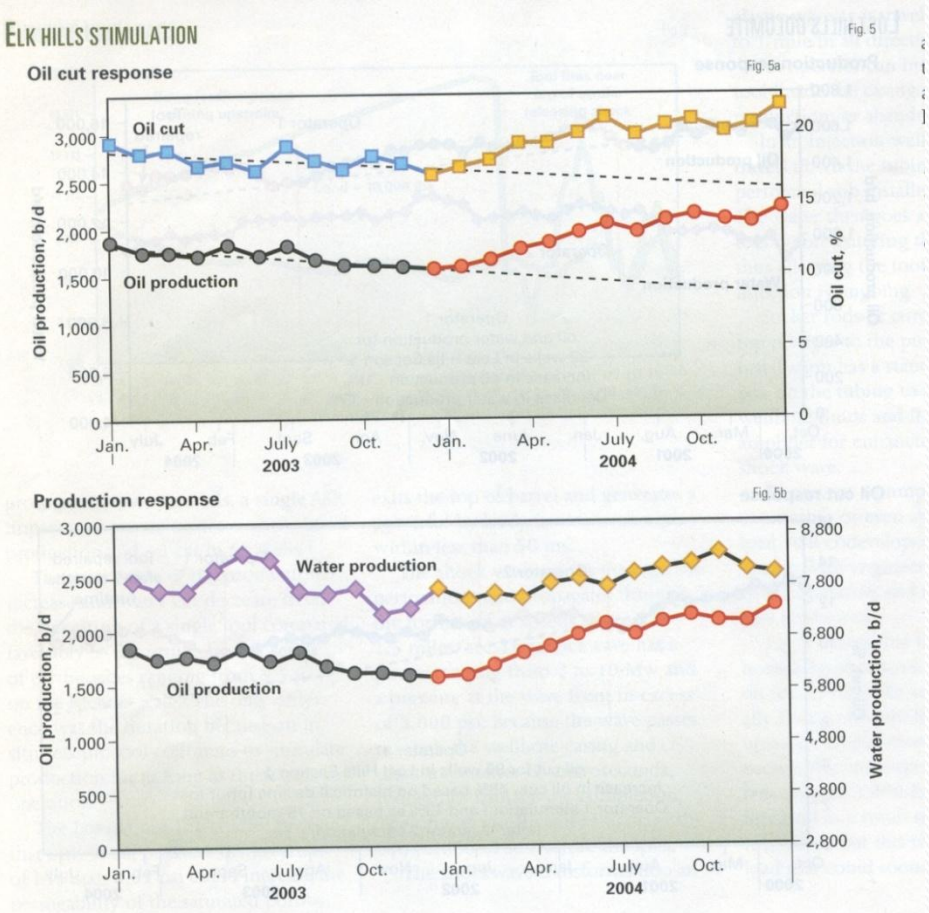



Converted P to SH in 2 orthogonal directions - Oil soaked 8-23-06 1:30 PM
Voltage (V)
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
-10
-5
0
5
10
15
20
25
30
35
40
Time (micros)
P to P
P to SH1
P to SH2

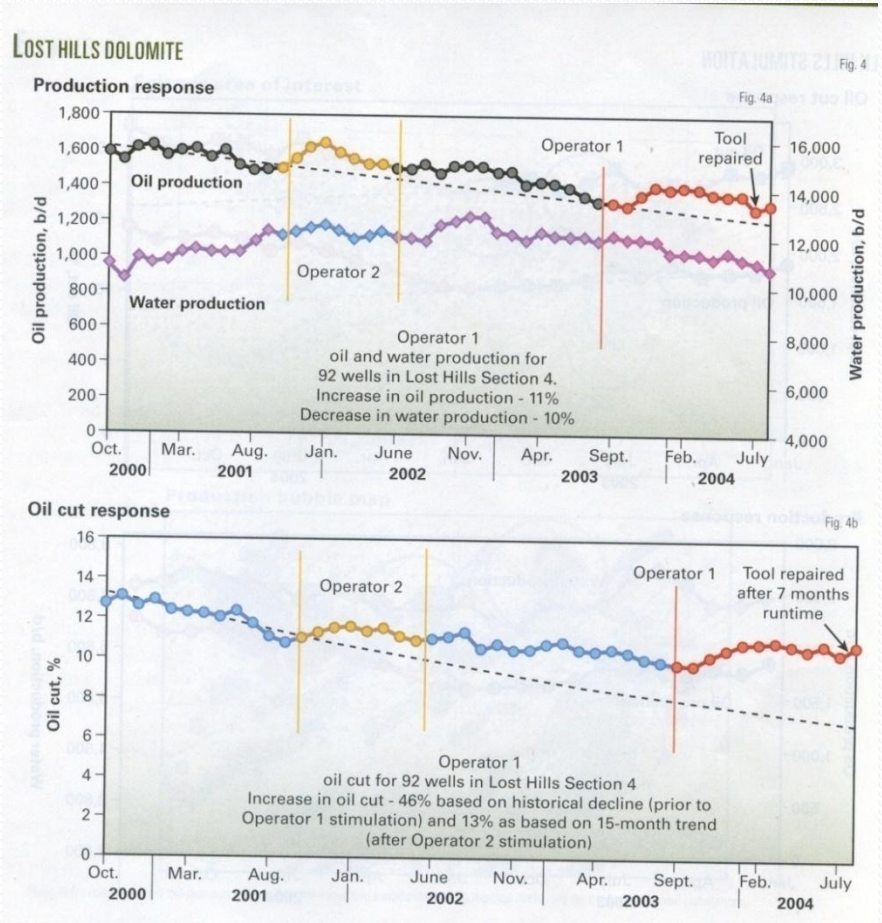
Use of the same concept in increasing OIL production!



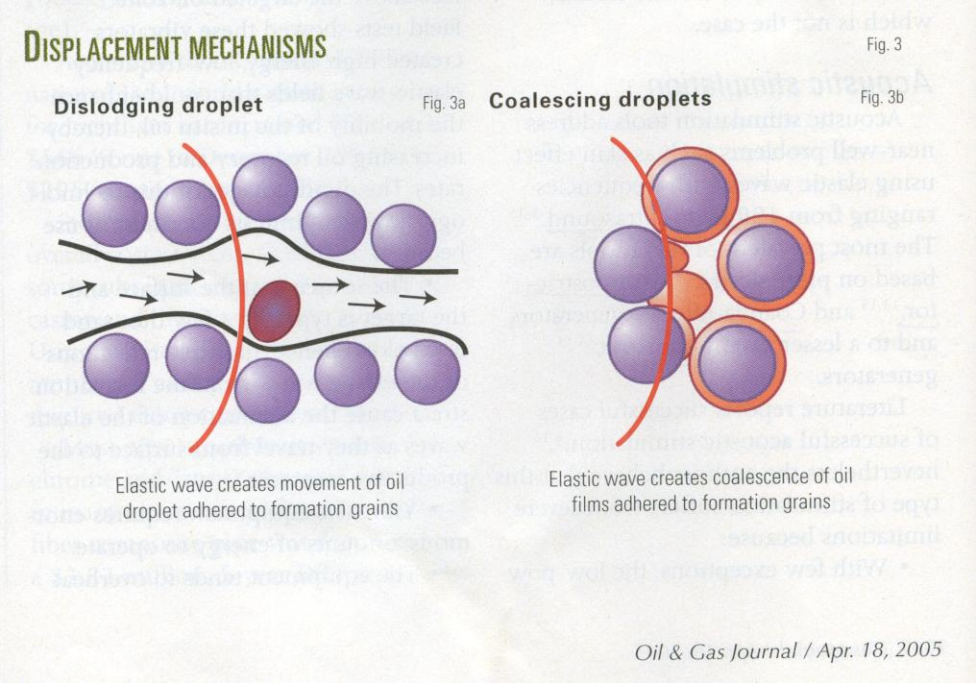
Improvement in production

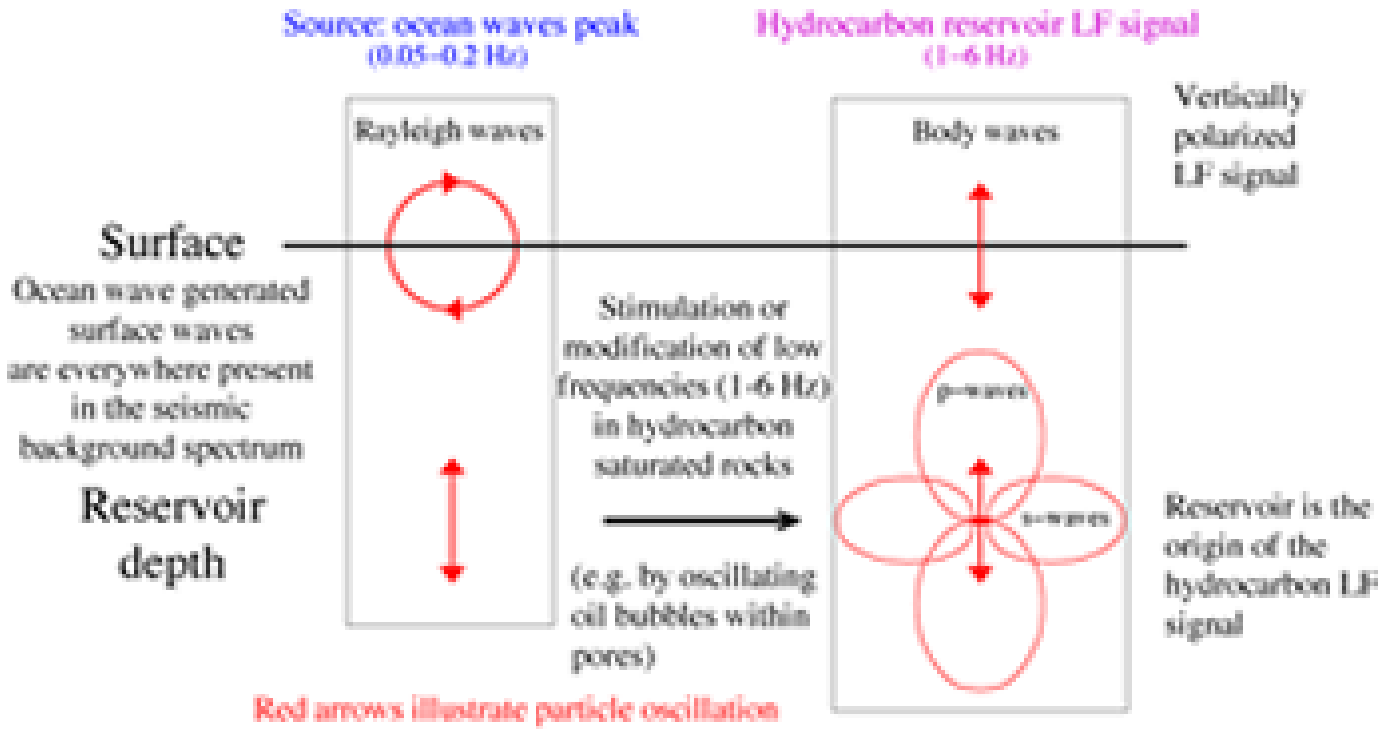


Another case of improvement



Seismic effect on oil in reservoirs




Source: ocean waves peak
(0.05–0.2 Hz)
Hydrocarbon reservoir LF signal
(1–6 Hz)
Rayleigh waves
Body waves
Vertically polarized LF signal
Surface
Ocean wave generated surface waves are everywhere present in the seismic background spectrum
Reservoir depth
Stimulation or modification of low frequencies (1-6 Hz) in hydrocarbon saturated rocks
(e.g. by oscillating oil bubbles within pores)
p-waves
s-waves
Reservoir is the origin of the hydrocarbon LF signal
Red arrows illustrate particle oscillation

References

Horizontal Component Seismograms, The Annual Meeting of the Society of Petroleum Engineers in Houston, TX, October 1978 (SPE preprint 7437).

The Seismic Problem in the Clinker Areas: Midwestern meeting of the Society of Exploration Geophysicists, March 1987, Dallas, TX.

Noninterchangeability of sources and receivers, 1974 Geophysics, Soc. of Exploration Geophysicists, **39**, 73 - 80.

See also:
http://classes.kvcc.edu/kbalachandran