KANSAS GEOLOGICAL SURVEY
OPEN-FILE REPORT 97-68

Zeandale Seismic Project

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Disclaimer

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Cooperative Research between
Exploration Services Section and
Mathematical Geology Section

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One of the more significant structural features of the Midwestern United States, the Nemaha Ridge, crosses north-central Kansas. The Nemaha Ridge is almost 400 miles in north-south extent and has almost 2000 feet of uplift that has placed Precambrian basement rocks within 1200 ft of the ground surface in several places in Kansas. It is interpreted as an anticline bounded on the east by a fault or narrow fault zone.

Previous regional geophysical investigations, including both aeromagnetic and gravity studies, clearly delineate this basement high (Yarger, 1983), which also has been interpreted from regional subsurface structural mapping based on well control (Cole, 1976). Detailed stratigraphic correlations along an E-W traverse produced using the CORRELATOR program (Olea, Davis, and Merriam, 1997) across northern Kansas show dramatic evidence of structural complications on the Nemaha Ridge in the line of section near the boundary between Pottawatomie and Wabaunsee Counties. In this area, the Precambrian surface and Lower Paleozoic and Pennsylvanian-Permian sediments are uplifted as much as 2000 ft (Merriam, 1963), and the pattern of structural dips across the Ridge suggests it is a system of raised and tilted narrow fault blocks. Previous seismic reflection studies in northern Nemaha County, across the Humboldt fault zone, show extremely varied and complex structures associated with the east flank of the Nemaha anticline (Steeples, 1989).

The Zeandale Project is a high-resolution seismic reflection study whose objectives are to better resolve the position of the Nemaha Ridge and particularly its eastern side, to resolve the structural complexities of this abrupt feature, to determine the depth to basement on both sides of the Nemaha Ridge, and establish the relationships between the shallower sediments and basement. The study will be closely integrated with stratigraphic interpretations based on the CORRELATOR analysis.

Three seismic lines are planned in Wabaunsee County, along the southern edge of the Kansas River Valley and a short distance through the Flint Hills. Two of the lines will be along the river valley in an E-W direction. The first line starts southwest of St. Marys and extends 7 miles to the west. The longer, 16-mile line extends from just south of Wamego to near Manhattan. An offset in the lines is necessary to avoid a rugged part of the river valley terrace. This offset will be spanned by a small, 2 mile N-S cross line designed to allow time ties and to correlate reflections. It also will allow calculation of true structural dips for comparison with those estimated by CORRELATOR.

The data will be collected using a vibrator source, with an 80-channel asymmetric split-spread geometry, station interval of 55 feet, and offset ranging from 27 to 4400 feet. The planned maximum depth of investigation will be designed to image the basement at 3500 feet, while retaining as many of the shallower sediment reflections as possible. This will require extremely high data quality and optimized field parameters and equipment. Data will be collected in two phases: 2 miles of the shorter E-W line have been acquired so the parameters can be evaluated and adjusted before running the remainder of the short line as well as the longer line and the tie line.

Data will be processed using Winseis software developed by the KGS. To obtain high resolution sections, many common shallow seismic reflection techniques for improving signal-to-noise ratio will be used. These operations include detail and various velocity analysis methods, filtering, special muting, various types of static corrections, as well as other operations that will be dependent on the data.

The abrupt change in near-surface material expected near the center of the profile, where the line leaves the river valley and then returns to the river valley across a distance of about 5 miles, will require special attention. Maximizing the correlation process of the pilot with the uncorrelated data should be one of the necessary steps. The unique attributes of the high frequency vibrator and its energy transmitting characteristics are sufficiently unknown so that a detailed analysis will be necessary to determine whether the several ground force or synthetic pilots provide a more representative section.

The processing will focus on the delineation of subtle features and on minimizing data loss in the shallow portion of the section. The interpretation will be tied to a synthetic seismic profile calculated from an existing sonic well log and to the CORRELATOR cross-section to constrain the stratigraphic interpretations. The simultaneous consideration of both well and seismic data will be instrumental in establishing the relationship of the seismic profile to actual geology.

References:

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Merriam D. F., 1963, The Geologic History of Kansas: Kansas Geological Survey Bulletin 162, 317 p.

Steeples D. W. ed., 1989, Geophysics in Kansas: Kansas Geological Survey Bulletin 226, 311 p.

Olea, R. A., Davis, J. C., and Merriam, D. F., 1997, Automated wireline log lithostratigraphic correlation using CORRELATOR (abs.): IAMG'97, Barcelona.

Yarger H. L., 1983, Regional Interpretation of Kansas Aeromagnetic Data: Kansas Geological Survey Geophysics Series 1, 35 p.

Proposal

To support geophysical interpretation of the two-mile segment of preliminary seismic data and to design optimal processing parameters for the remainder of the seismic survey outlined above, we intend to offer a two-month appointment as Visiting Research Scientist in the Mathematical Geology Section to Dr. Marina Feroci. This will allow Dr. Feroci to extend her current CNR Fellowship for a sufficient amount of time to complete this study. She already has helped collect the initial 2-mile segment of vibrator data and will begin processing studies immediately after her appointment.

The proposed rate of pay for Dr. Feroci is $3,000 US per month for two months (September and October, 1997).

A short summary of Dr. Feroci's qualifications follows:

Name: **Marina FEROCI**
Place and date of birth: Rome, 01/27/1963
Residence in Italy: via Stanislao Cannizzaro 64, 00156 Roma
Address in U.S.: 308 16th Street, Lawrence, Kansas
Phone: c/o Geology Dept. , The University of Kansas, Lawrence, 913-864 2733 or 864 2746
Nationality: Italian

Education and Experience:
Graduated in Geological Sciences at the University "La Sapienza" of Rome in 1987 with honors (110/110), submitting a thesis titled "Characteristics of Pliopleistocenic structures of Latium area, North of Rome" (Advisor: Prof. R. Funiciello).

PhD degree in Applied Geophysics at University of Trieste in 1995, submitting a thesis titled "High resolution seismic reflection prospecting on land" (Advisor Prof. M. Bernabini).

C.N.R. Fellowship (one year from 3/1/1989) at Applied Technologies Institute for Cultural Properties. The research project concerned the application of geophysical investigations to archaeological studies.

C.N.R. Fellowship (six months from 2/28/1997) at Department of Geology, The University of Kansas, Lawrence, Kansas (USA). The research project concerns shallow seismic reflection surveys (Advisor Prof. D. Steeples).

University of Rome "La Sapienza" Post-doctoral Fellowship (two years starting November, 1997) at Engineering Dept. - Geophysical Area. The research project will concern shallow seismic reflection and georadar data processing (Advisor Prof. M. Bernabini).

HUM FILTER: POWER-LINE NOISE ELIMINATOR FOR SHALLOW SEISMIC DATA

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ABSTRACT

A unique filtering approach designed to eliminating power-line noise on shallow seismic data without affecting the frequency content of signal provides a powerful harmonic noise suppression tool for data acquired with modern large dynamic range recording systems. Amplitudes and phases of sinusoids (functions of power-line noise) present before the first arrivals can be estimated using the Levenberg-Marquardt (L-M) method. Initial amplitudes of sinusoids are determined in the frequency domain using fast Fourier transform (FFT) methods while initial phases are obtained by time domain correlation. Well-defined initial values guarantee convergence of the L-M method. Modeling results suggest the relative error of initial estimates are less than 50 percent. Calculation efficiency is achieved by simplifying the L-M solution using the singular value decomposition (SVD) technique. The approach can handle cases where power-line noise with frequencies of 60 Hz and/or its multiples exist simultaneously. Once determined, the amplitudes and phases of sinusoids can be directly subtracted from the raw data. Recorded frequencies of high-resolution shallow seismic surveys generally range from 30 to 300 Hz. Power-line noise (60 Hz) and its multiples (120 Hz, 180 Hz, and 240 Hz, etc.) are within the optimum frequency range. This filtering technique only removes harmonic noise and does not alter the spectra of signal. Real data examples demonstrate the efficiency and accuracy of this method when implemented on a normal shallow seismic data processing flow.

INTRODUCTION

Single-frequency periodic interference such as power-line noise, routinely plagues high-resolution shallow seismic surveys. The conventional tool used to eliminate power-line noise is a notch filter applied during data acquisition or data processing. A major drawback of this practice is that all frequency components around 60 Hz are muted regardless if they are signal or noise after applying a notch filter. Recorded frequencies of high-resolution shallow seismic surveys generally range from 30 to 300 Hz. Sixty hertz power-line noise and its multiples (120 Hz, 180 Hz, and 240 Hz, etc.) are within the optimum frequency range. It is not uncommon to see multiples of 60-Hz interference in high-resolution shallow seismic data (e.g., Miller et al., 1994). Application of a notch filter generally results in a saw tooth shaped spectrum with drop-outs around the notch frequency.

Black (1997) suggested that 60-Hz noise may be eliminated by *f-k* filtering techniques. If the noise is not in phase across several traces, it may be possible to save 60-Hz reflection energy near the *f* axis in *f-k* space, and suppress the majority of the 60-Hz noise at higher *k* numbers away from the *f* axis in *f-k* space. If the power-line noise is in-phase, *f-k* filtering techniques will suppress the 60-Hz component of signal as well as noise. Real data examples demonstrate that power-line noise can be in-phase for several traces and out-of-phase for other traces on one shot gather (see figure 2a). This inconsistently in trace-to-trace phase will adversely affect a *f-k* filter ability to remove power-line noise.

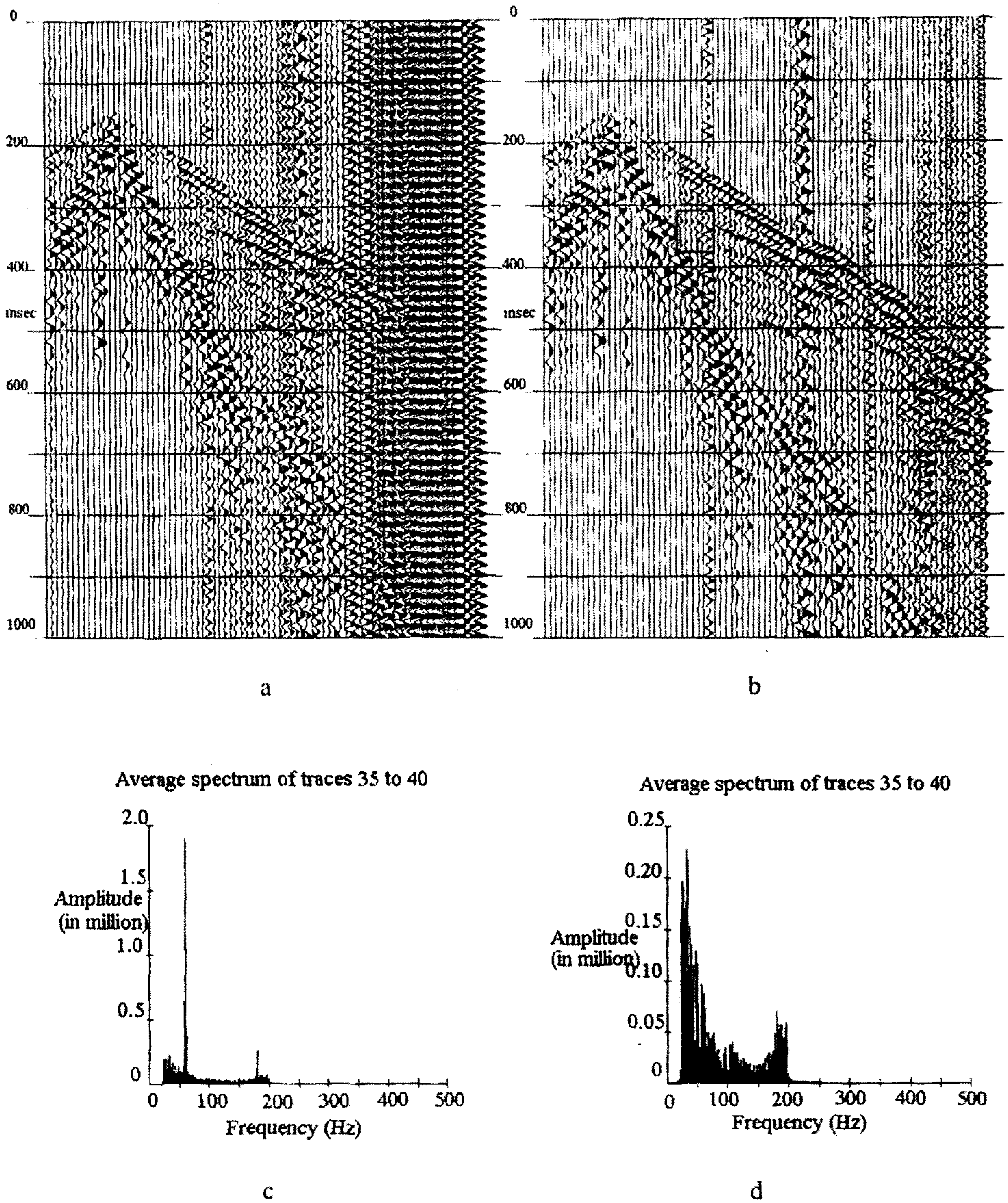

Figure 2. An 81-channel shot gather of seismic reflection data from Zeandale, Kansas with 60 Hz and 180 Hz power-line noise (a) and its spectrum (c); (b) the same shot gather after hum filtering and the spectrum (d).