NON-TECHNICAL ABSTRACT

Award Number: 1434-HQ-97-GR-03136

HIGH-RESOLUTION P- AND SH-WAVE SEISMIC REFLECTION INVESTIGATIONS OF THE REELFOOT AND KENTUCKY BEND FAULT SCARPS IN THE NEW MADRID SEISMIC ZONE

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The purpose of this study was to investigate the extent and trend of a suite of faults that cross the southwest corner of Kentucky, from northwestern Tennessee to area about New Madrid, Missouri. It has been suggested that movement occurred along the faults during the great New Madrid earthquake of Feb. 7, 1812. If this is in fact the case, then the extent and orientation of the faulting will help us to more clearly understand that earthquake, and the seismic hazard the faults currently pose to the central United States.

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Program Element I
Neotectonics, Reflection Seismology

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Approximately 12.5 km of conventional P-wave and 1.2 km of SH-wave, CDP seismic reflection data were acquired in the southwest corner of Kentucky, and adjacent areas in Tennessee and Missouri. The objective of acquiring the data was to establish the density, strike and sense of movement along a suite of suspected northwest trending faults in the New Madrid seismic zone that lie to the northeast of the Reelfoot and Kentucky Bend Scarps. The style and geometry of the faults are consistent with the geomorphic documentation (i.e., the Kentucky Bend Scarp), and the contemporary seismicity. The reflection profiles are interpreted as imaging high-angle transpressional faults that strike between N30°W and N45°W.

SH-wave data were used to establish the fact that many of the faults can be traced from the top of the Paleozoic bedrock upwards into the Quaternary sediments. Such data provides physical evidence for causative faults associated with contemporary seismicity, as well as, lend corroborative evidence for the magnitudes of the great New Madrid earthquakes that occurred during the winter of 1811-1812.

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INTRODUCTION

This study is a continuation of another study of the same title (USGS award number 1434-HQ-97-GR-02988), and many of the general comments and results of this study were included in the final report for that study. The common objectives of the two studies were to: (a) continue mapping the series of NW-SE trending faults in the Kentucky Bend area shown in Figure 1, and (b) attempt to verify their continuation in the northwesterly direction across the Mississippi river into Missouri and in the southeasterly direction across Donaldson Point (Mo.) and into northwestern Tennessee. General procedures used in the data collection, processing, and interpretations are common to both studies, and are described in detail in Woolery *et al.* (1998).

Figure 2 illustrates the locations of the seismic lines proposed as part of this study. Of the seismic lines shown in Figure 2, lines F-F', L-L', J-J', D-D', and a short section of E-E' were completed. Lines C-C' and the majority of line E-E' were not shot due to our inability to gain landowner permission to do the lines. Seismic line K-K' has been started, but will not be completed until late in the Fall of this year. Access to the road along which the line is to be shot lies outside of the levee along the Mississippi river. It has been inaccessible throughout much of the year due to high water resulting from excessive rainfall in the upper Mississippi embayment. In addition, the road along which we are collecting P-wave data is private, and our permission to work in the area is restricted to the late fall after harvesting, until before planting in the early spring.

P-wave data collected along seismic line F-F' are of very poor quality. Possible reasons for the lack of quality include noise from the nearby interstate (I-55), and/or the lack of solid road bed for the energy source, a vacuum assisted weight drop (described below), to hit on. SH-wave CDP seismic reflection data collected along the line, however, and do indicate neoteconic deformation (Harris *et al.*, 1998)

Seismic line L-L' was extended to the Kentucky/Tennessee border because of conflicting suggestions as to the strike of the faulting from the Kentucky Bend area, through Donaldson Point, Mo., and into northwestern Tennessee. In all, about 12.5 km of high-resolution P-wave CDP lines were acquired as a result of this grant, exceeding the 11.5 km outlined in the proposal. Approximately 2.5 km additional CDP work will be done late this Fall along line K-K', after the crops have been harvested in the Donaldson Point area. It is not anticipated that the seismic data acquired along line K-K' will change any of the conclusions arrived at in this study.

SEISMIC DATA ACQUISITION, PROCESSING, AND INTERPRETATIONS

Seismic data collected for this study were acquired using an EG&G StrataView RX engineering seismograph with 48-channels. The common-depth-point (CDP) seismic profiling method was used, and acquisition parameters were established from the optimal window of walkaway tests (Hunter *et al.*, 1984; Musgrave, 1962). In addition to determining the optimal window, the walkaway tests were also used for: 1) distinguishing reflections from other coherent events; 2) the determination of stacking velocities to reflecting horizons; 3) doing depth calculations to reflecting horizons (using the X^2-T^2 method); and 4) for calculating interval velocities between horizons (Dix, 1955).

P-wave data were collected using 12-fold in-line spreads of twenty four 40 Hz vertically polarized geophones. The energy source used for the P-wave acquisition was an EG&G WDA-T885 weight drop. This device utilizes vacuum assistance to accelerate a 45 kg steel slug vertically downward from a height of approximately 2.0 m onto a hardened aluminum anvil. Typically, four vertical stacks were applied at each shotpoint location. Data were collected along the hard-packed shoulders of existing roadways in order to enhance coupling of the energy source to the ground, and to facilitate the movement of vehicles and the trailer mounted weight drop. Energy of the weight striking the anvil when the anvil is resting on a well compacted ground, such as the shoulder of a road, is far more impulsive in character then when the anvil is resting on poorly consolidated ground. The impulsive character of the signal results in better resolution of the P-wave reflections.

The seismic data were processed on an IBM-compatible microcomputer using the commercial software package VISTA 7.0 (Seismic Image Software Ltd., 1995). The general procedure for processing the walkaway data included: 1) converting raw field data into a format (SEG-Y) acceptable to the processing software; 2) combining the various offsets into a composite seismic sounding; and 3) applying various filters, automatic gain control (AGC) windows, etc to improve the appearance of the desired seismic signal. The standard processing sequence for the CDP data is shown in Table 1. Signal muting and F-K filtering were given special attention to ensure that coherent events (i.e., refractions, ground roll, air waves, etc.) not corresponding to reflection events were not inadvertently stacked.

Figures 3 through 12 illustrate the P- and SH-wave data acquired specifically as part of this study. A detailed explanation of the lines and their interpretations were included in the final report for USGS award number 1434-HQ-97-GR-02988 of the same title as this study, as well as in Woolery *et al.* (1998). They are included herein for completeness. In Woolery *et al.* (1998), the following convention is used: line D-D' in Figure 2 is the northern half of what is referred to as line UK-2C in Woolery *et al.*, line J-J' in Figure 2 is line UK-4 in Woolery *et al.*, and line L-L' is included in line UK-5 in Woolery *et al.*

DISCUSSION AND SUMMARY

The principal conclusion that has been drawn from the interpretations of the seismic lines for this study is the observation that there is widespread evidence of N 30°

to 45° W faulting throughout the area (Fig. 3). The strikes of these faults are coincident to, and consistent with geomorphic evidence (i.e., Kentucky Bend Scarp [VanArsdale *et al.*, 1995]), the contemporary seismicity (i.e., linear epicentral trend [Stauder, 1982]), focal mechanism solutions (Herrmann and Canas, 1978), and lineaments defined by aerial photography by Marple and Schweig (1992).

The flexures and numerous faults are indicative of and consistent with an overall compressive stress. Specifically, the faults seen on the reflection profiles are interpreted as predominantly high-angle reverse faults with a transpressive component. The principal faults are often accompanied with compensating antithetical and synthetical structure. These transpressional features are consistent with the predominant stress regime associated with the complex focal mechanism solutions in the central New Madrid Seismic Zone (Herrmann and Canas, 1978; Chiu et al., 1992)

The widespread and complex neotectonic structure in the inferred epicentral area of the February 7, 1812 New Madrid earthquake, and this study's ability to correlate structures in the area establishes the physical evidence for causative faults associated with the great 1811-1812 earthquakes. The approximately N 30°W to N 45° W strike of the faulting is coincident to and consistent with contemporary geomorphic evidence, contemporary seismicity, and focal mechanism solutions. These features can be interpreted to be high-angle reverse splay or imbricate thrusts from a interpreted blind master fault (Chiu *et al.*, 1992). Johnston and Schweig (1996) propose this geometry and give the Montague Island master thrust from the Alaska earthquake of 1964 as a model.

The geophysical evidence presented in this study, coupled with the seismic data gathered in the previous USGS award number 1434-HQ-97-GR-02988 of the same title, and the geomorphic evidence presented by VanArsdale *et al.* (1995), are interpreted as depicting responsive neotectonic deformation to the reorientation to the northeast trending Reelfoot Fault associated with the February 7, 1812, earthquake. The reorientation is most likely controlled by a deep-seated NW-SE trending basement weakness (Hildenbrand and Hendricks, 1995). Consequently, the aforementioned post-Paleozoic deformation geometries of these investigations are interpreted to specifically result from torsional behavior associated with the reorientation (or bend) of the primary seismogenic fault. Kinematically, the described fault characteristics would be consistent with the expected near-surface deformation associated with the bending of a lower-angle primary thrust having secondary high-angle splay or imbricate features.

The data collected as a result of USGS award numbers 1434-HQ-97-GR-02988 and 1434-HQ-97-GR-03136 significantly improve the overall understanding of the seismicity in the central United States by establishing scientific evidence for geologic features associated with the contemporary seismicity, as well as, providing new data which helps reconcile the estimated magnitudes of historic earthquakes with the existing physical evidence.

PUBLICATIONS RESULTING FROM STUDY

Some of the seismic data collected and interpreted as part of this study have been submitted for publication in Woolery *et al.* (1998), and Harris *et al.* (1998). In addition, since the marine seismic data acquired by Shedlock *et al.* (1997) and the paper by Odum *et al.* (1998) were not published until the study was nearly completed, the seismic data collected for this are being integrated with the data published in those two studies for a paper to be submitted to the *Seismological Research Letters*. The paper should be in review by the end of the year, and will include any additional CDP data acquired along line K-K'. Copies of this paper, as well as the paper and extended abstract that have been submitted, will be forwarded to the Project Officer of the U.S. Geological Survey when they are published.

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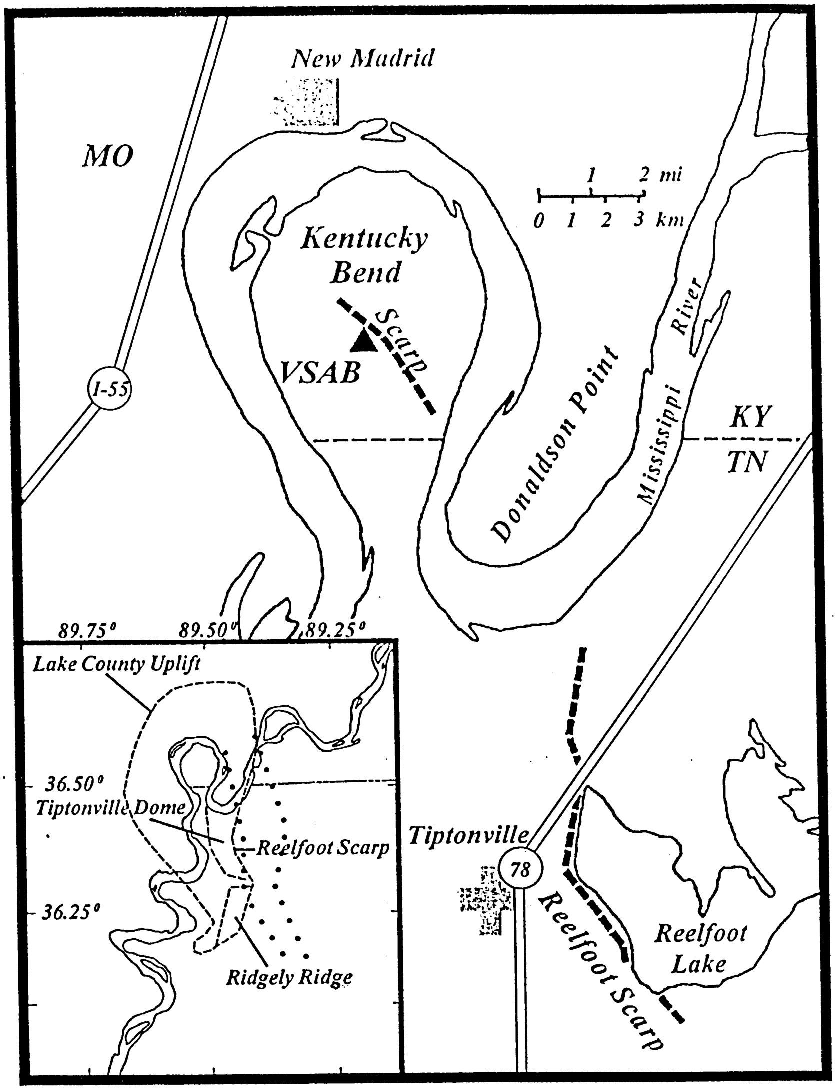

Figure 1. Generalized location map of the study area. Shown are the topographic expressions of the Kentucky Bend and Reelfoot scarps (Russ, 1982; VanArsdale *et al.*, 1995). The shaded triangle indicates the location of the University of Kentucky's strong-motion station VSAB. The inset at the bottom left defines the prominent geomorphic expressions of local geologic structure (Russ, 1982) with dashed lines. The heavy dotted lines mark the area over which the seismogenic faults are expected to intersect with the surface (Chiu *et al.*, 1992).

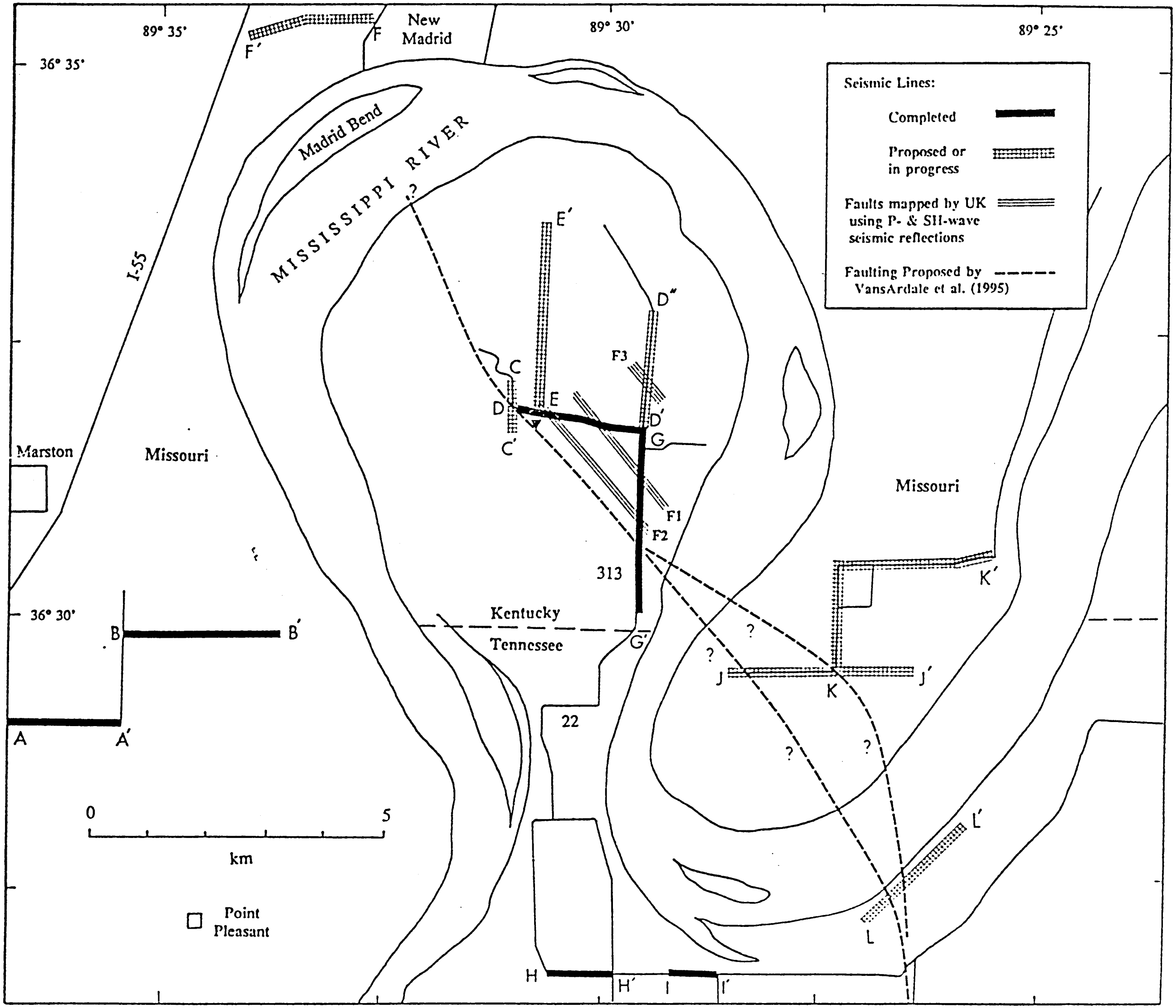

Figure 2. Study area indicating proposed seismic lines and their relationship to, what was, hypothesized northwest trending faults.

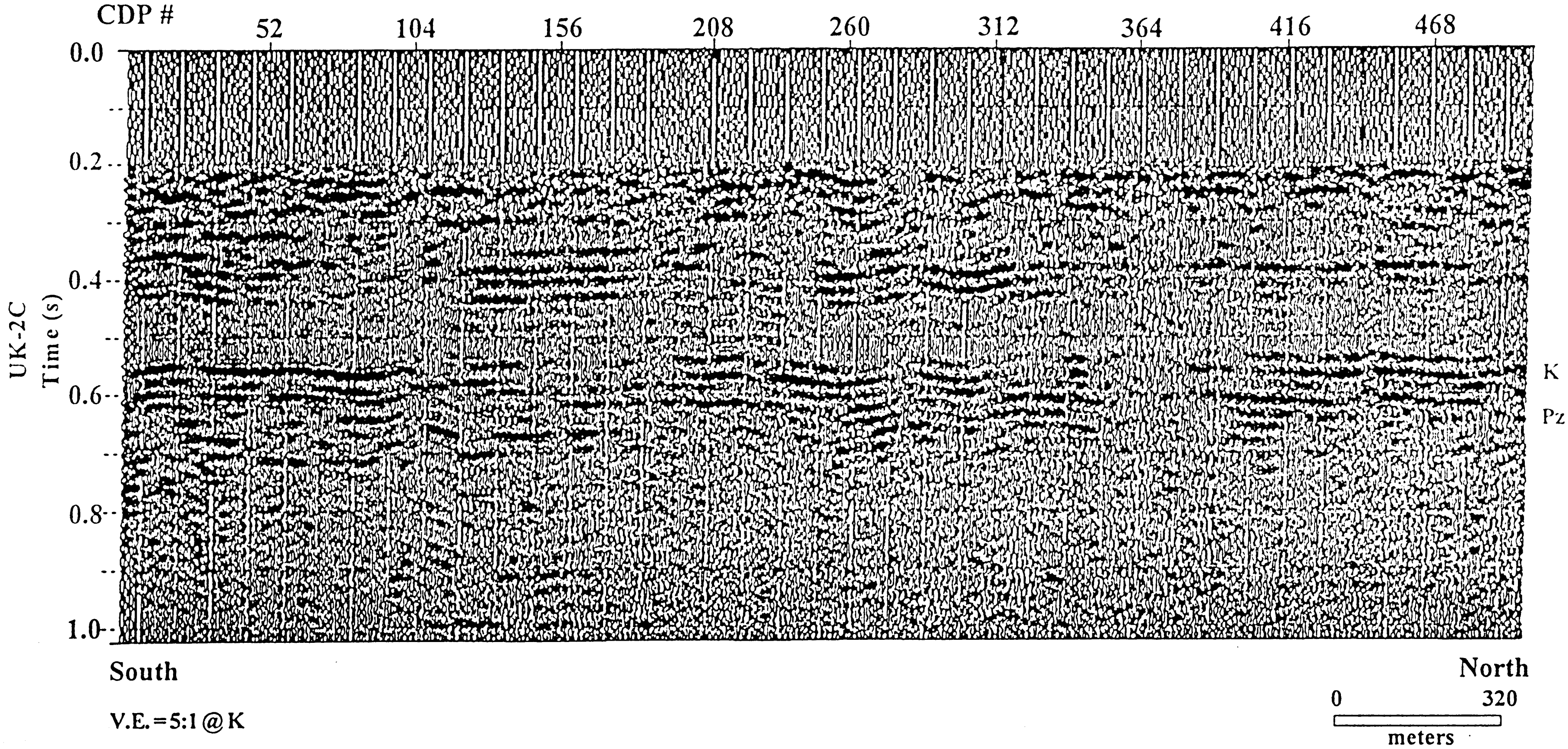

Figure 3. Uninterpreted P-wave seismic line D-D' (UK-2C in Woolery *et al.*, 1998).

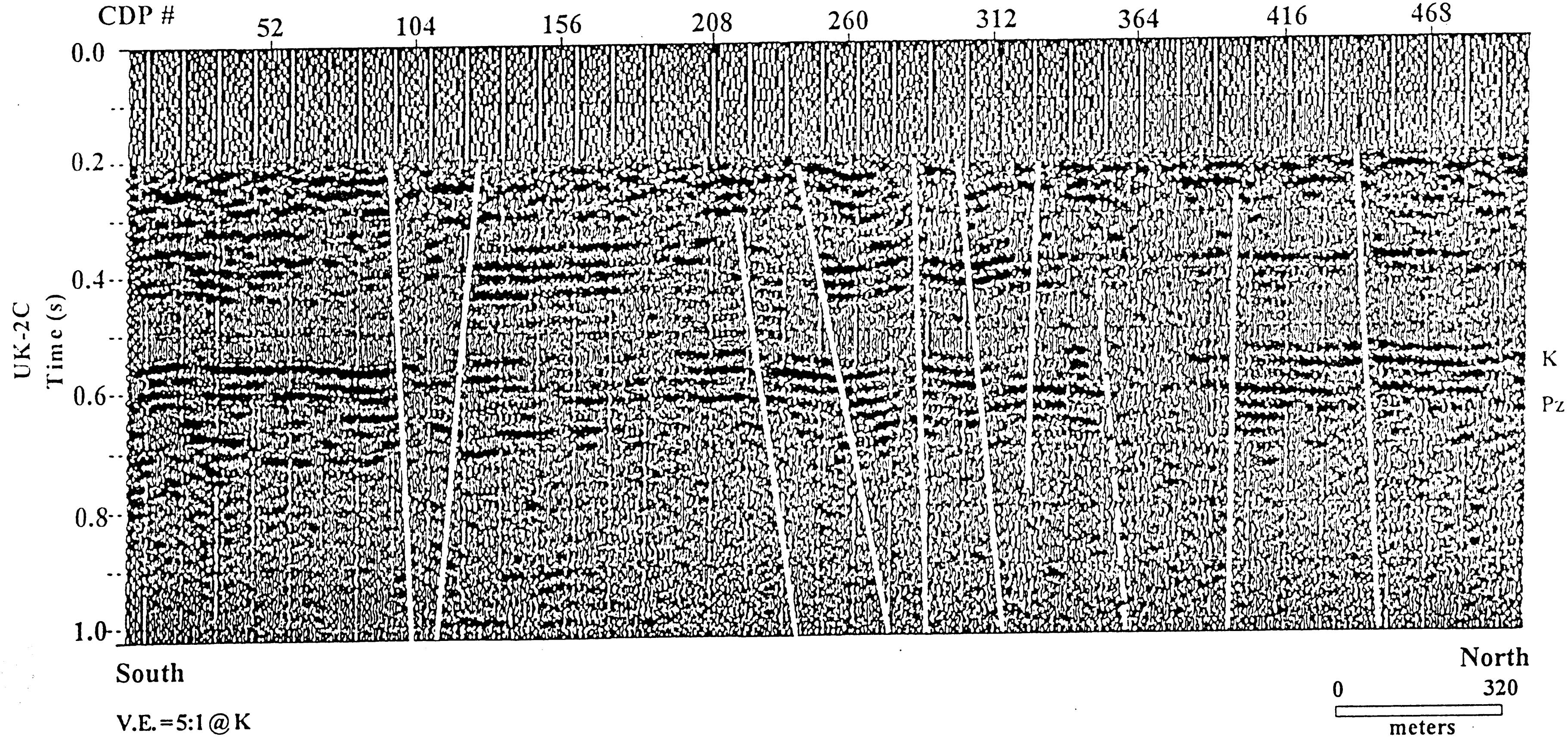

Figure 4. Interpreted P-wave seismic line D-D' (UK-2C in Woolery *et al.*, 1998).

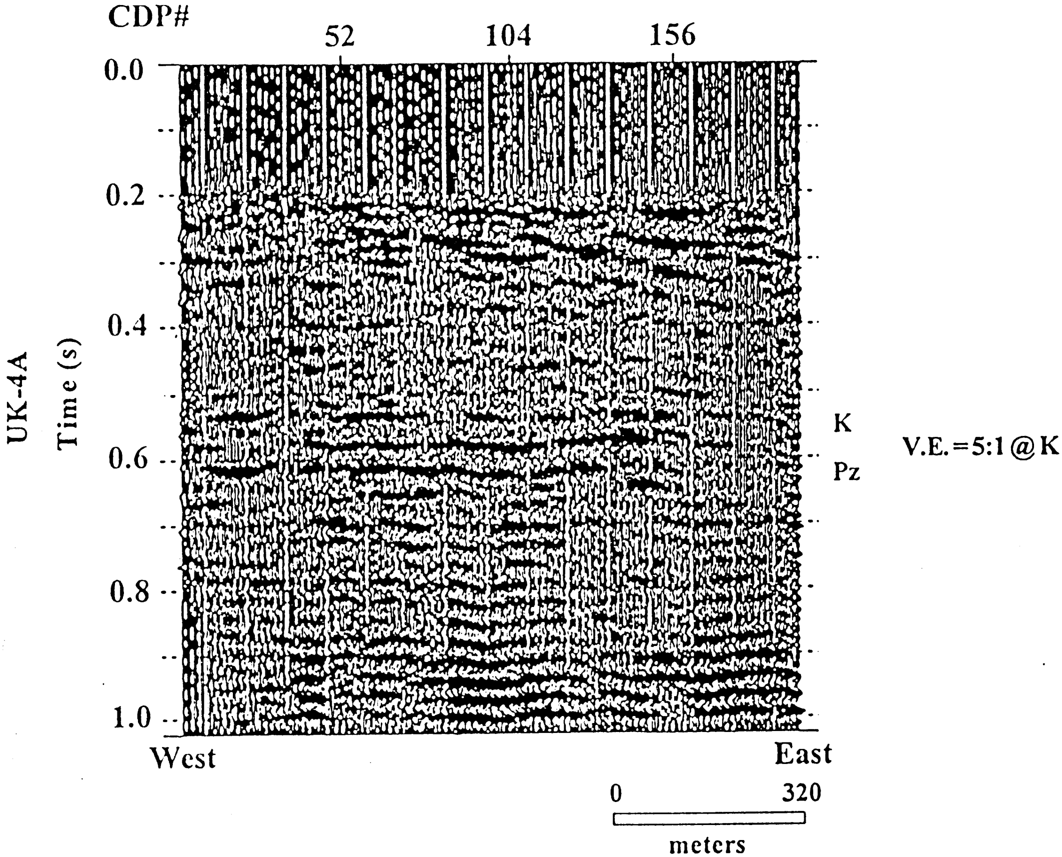

Figure 5. West end of uninterpreted P-wave seismic line J-J' (UK-4A in Woolery *et al.*, 1998).

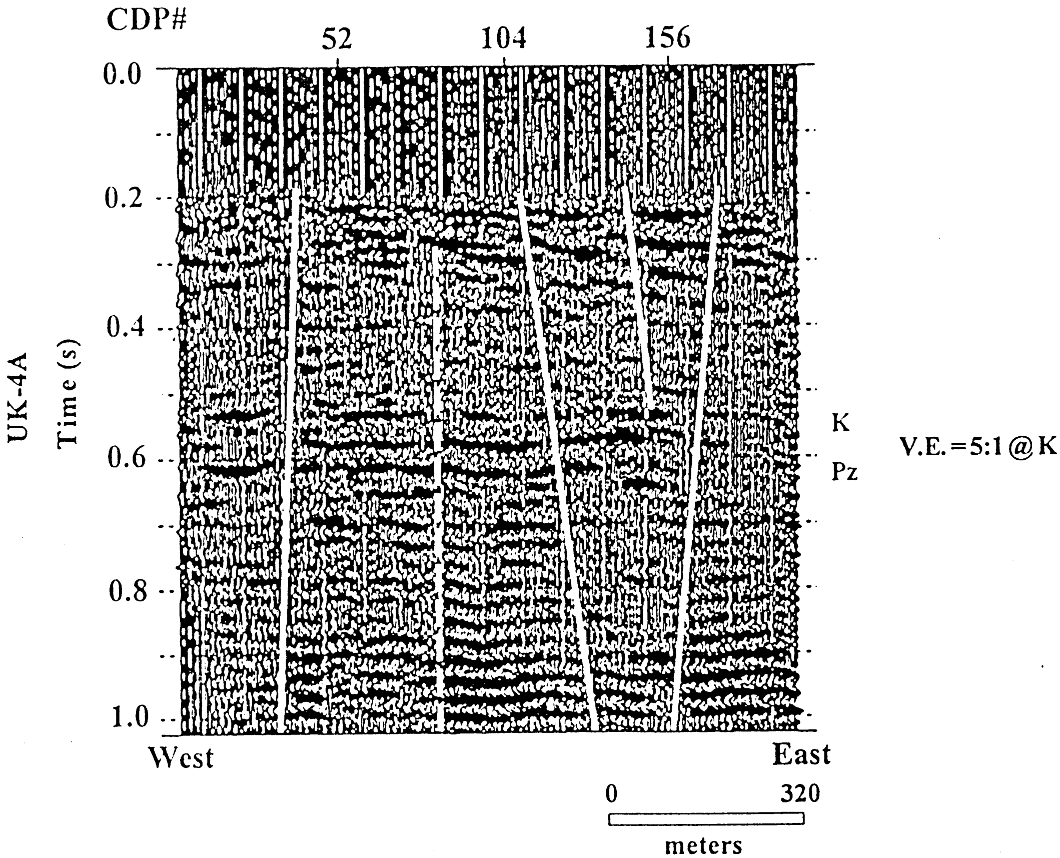

Figure 6. West end of interpreted P-wave seismic line J-J' (UK-4A in Woolery *et al.*, 1998).

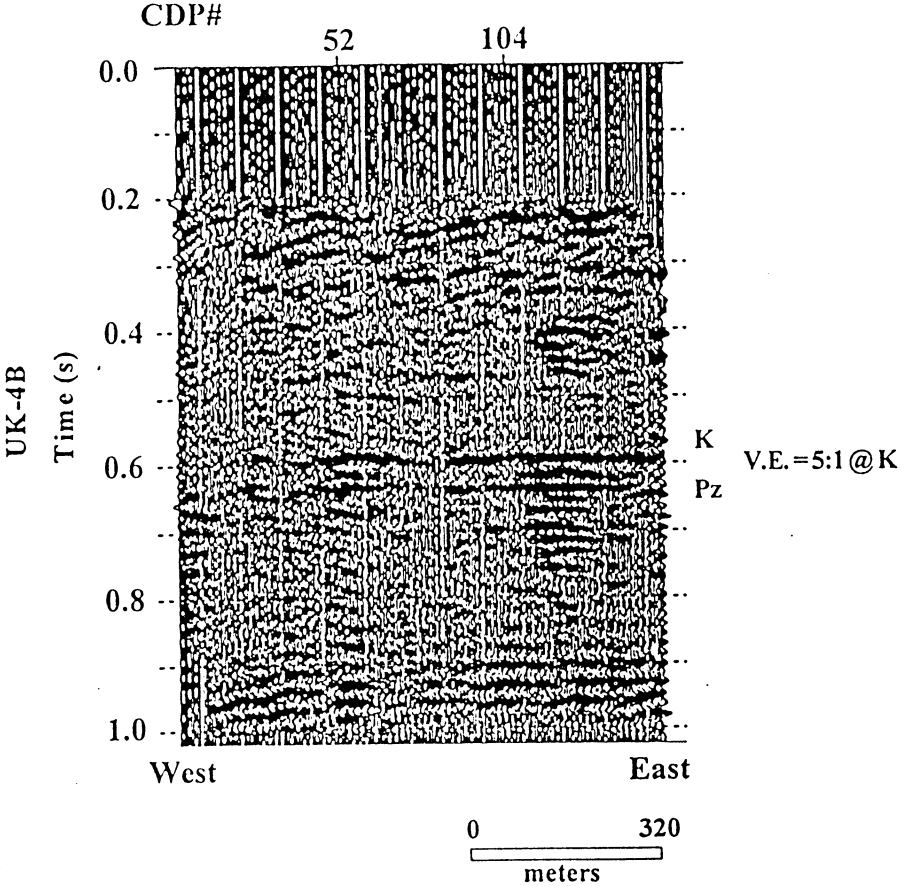

Figure 7. East end of uninterpreted P-wave seismic line J-J' (UK-4B in Woolery *et al.*, 1998).

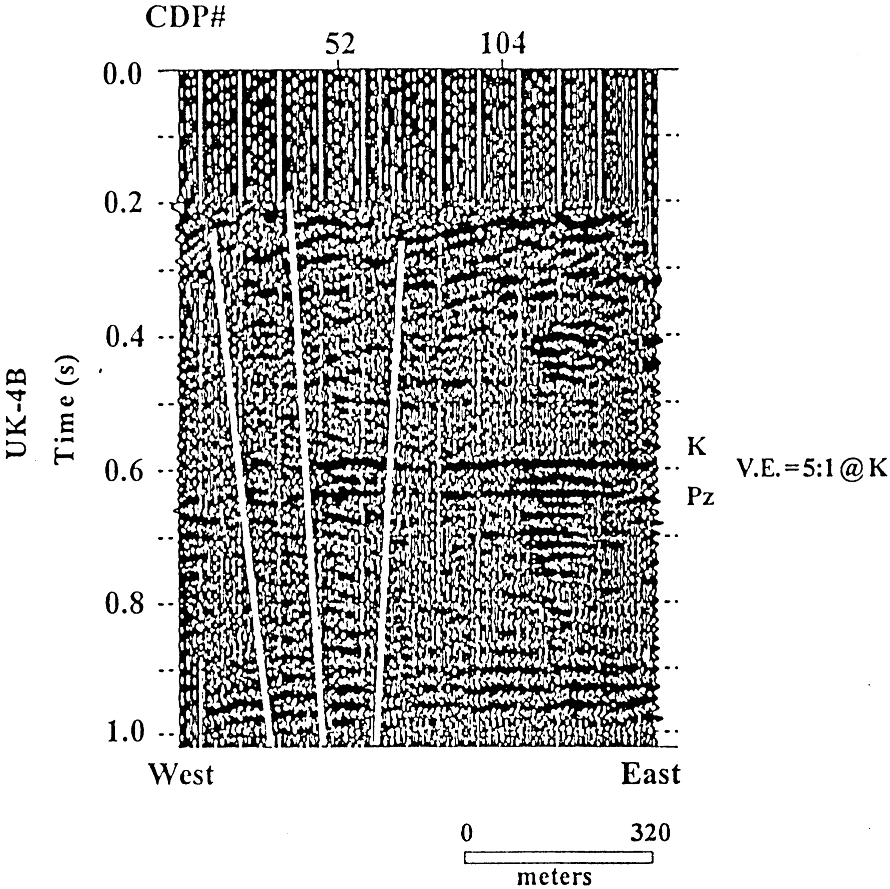

Figure 8. East end of interpreted P-wave seismic line J-J' (UK-4B in Woolery *et al.*, 1998).

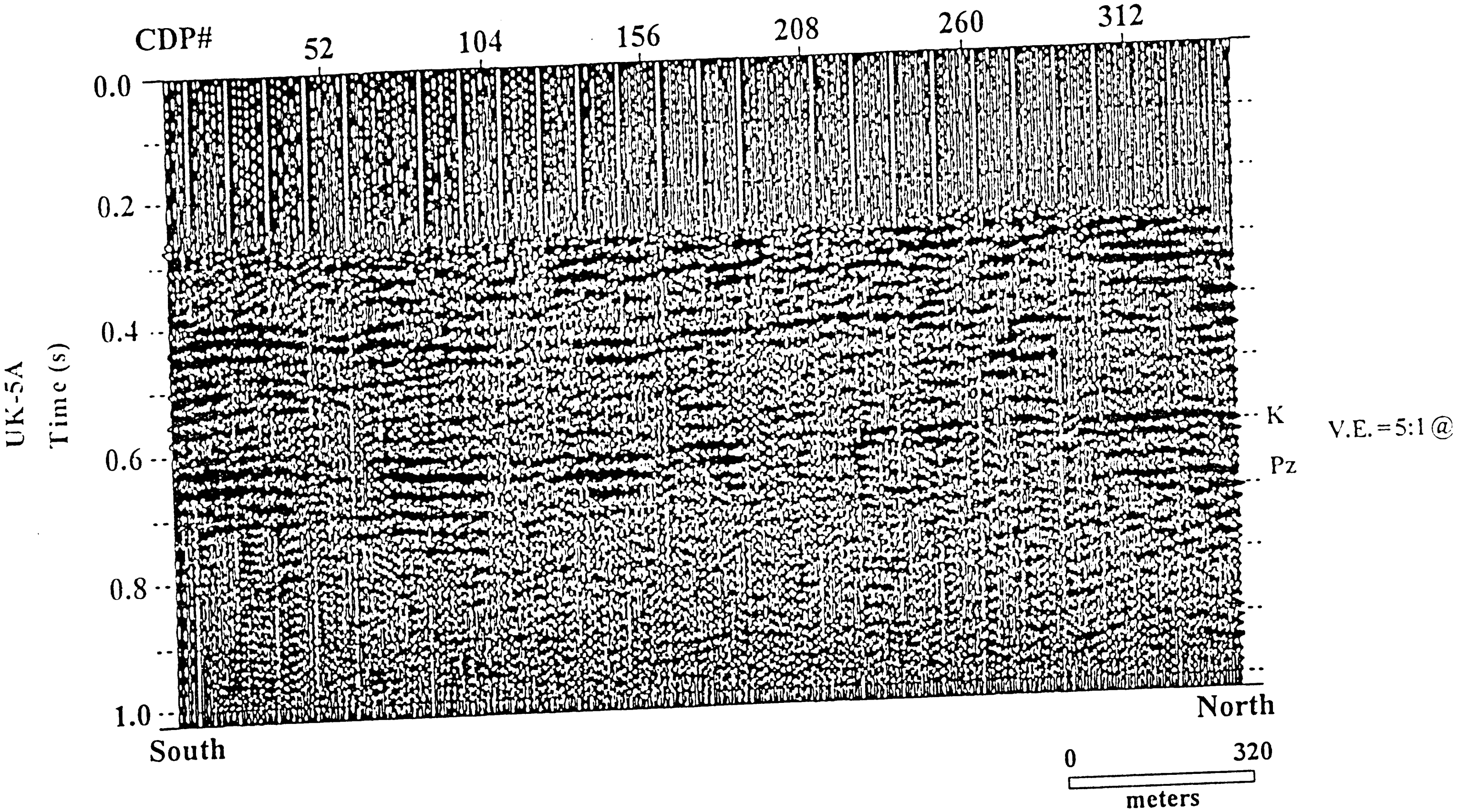

Figure 9. North end of uninterpreted P-wave seismic line L-L' (UK-5A in Woolery *et al.*, 1998).

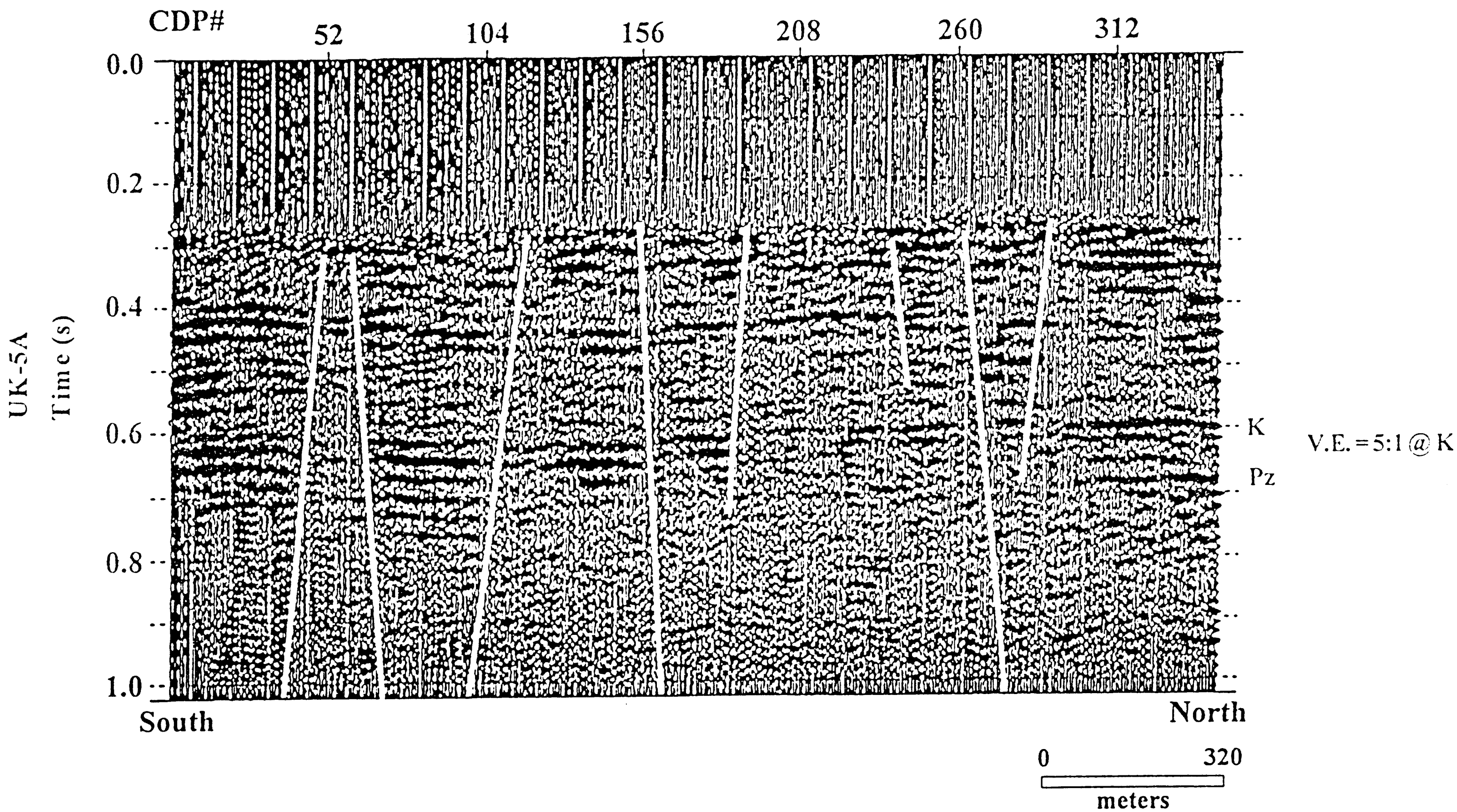

Figure 10. North end of interpreted P-wave seismic line L-L' (UK-5A in Woolery *et al.*, 1998).

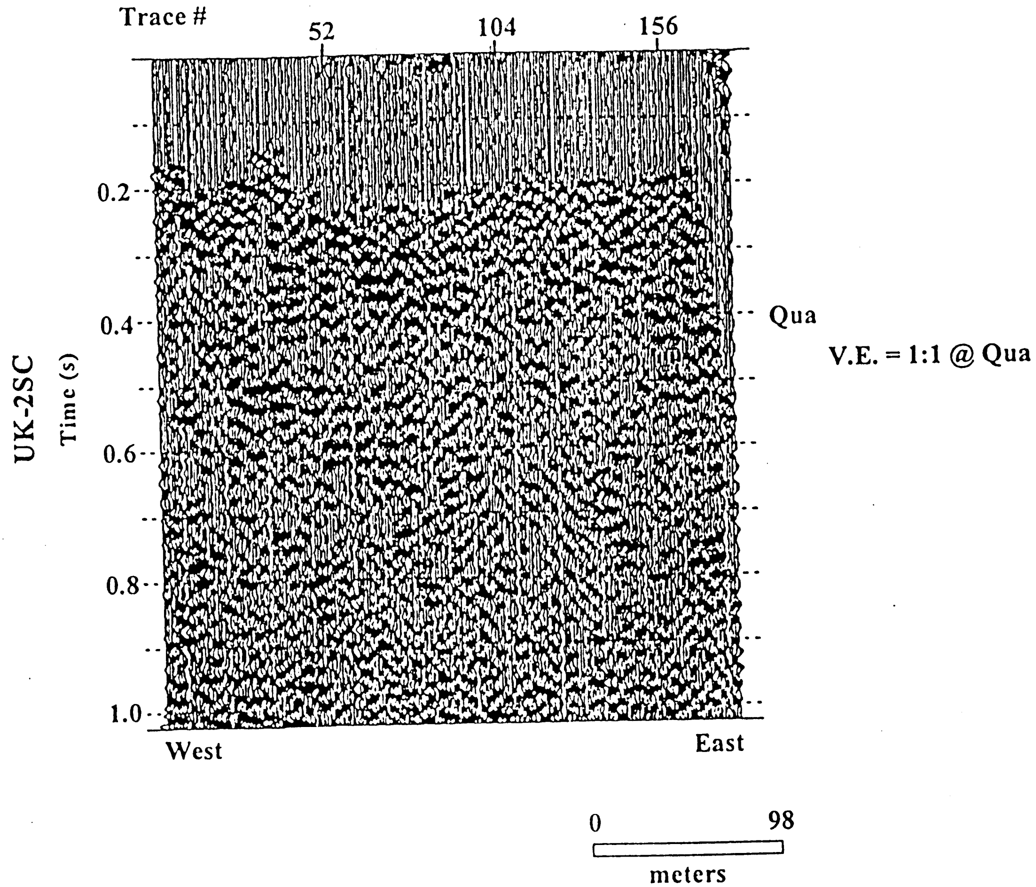

Figure 11. Uninterpreted SH-wave seismic section along line D-D' (UK-2C in Woolery *et al.*, 1998).

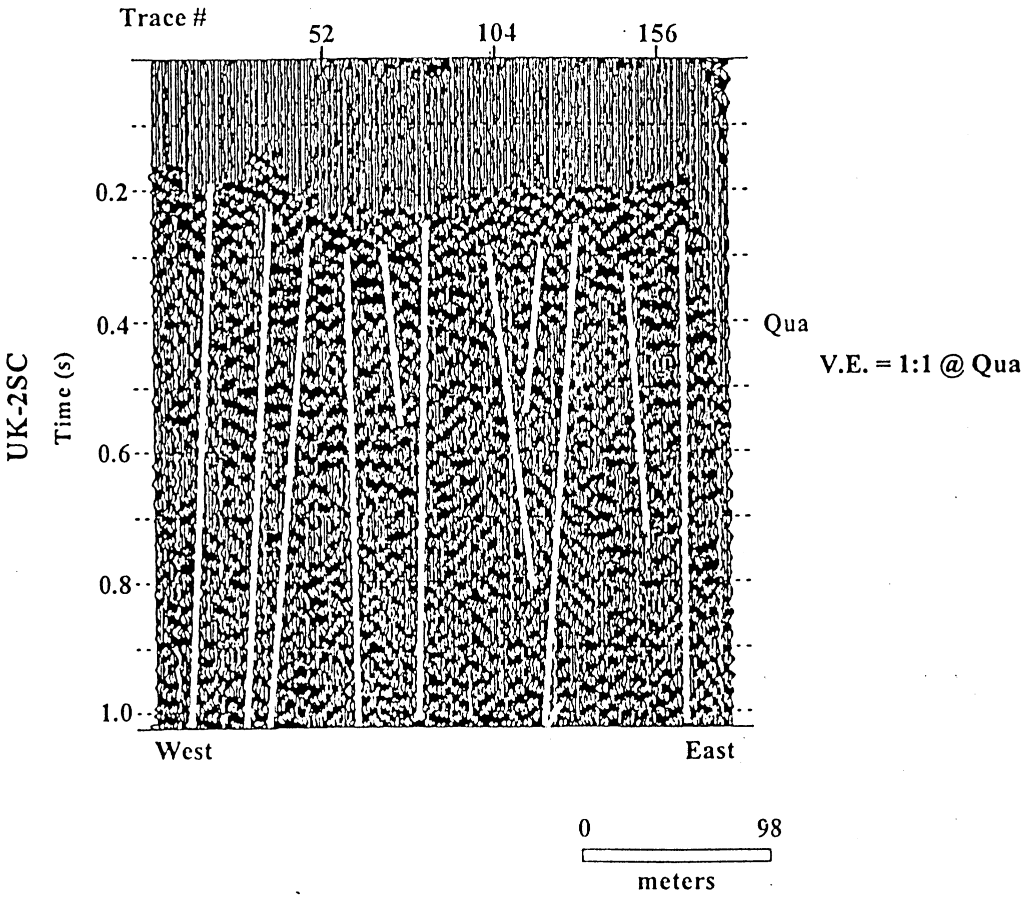

Figure 12. Interpreted SH-wave seismic section along line D-D' (UK-2C in Woolery *et al.*, 1998).

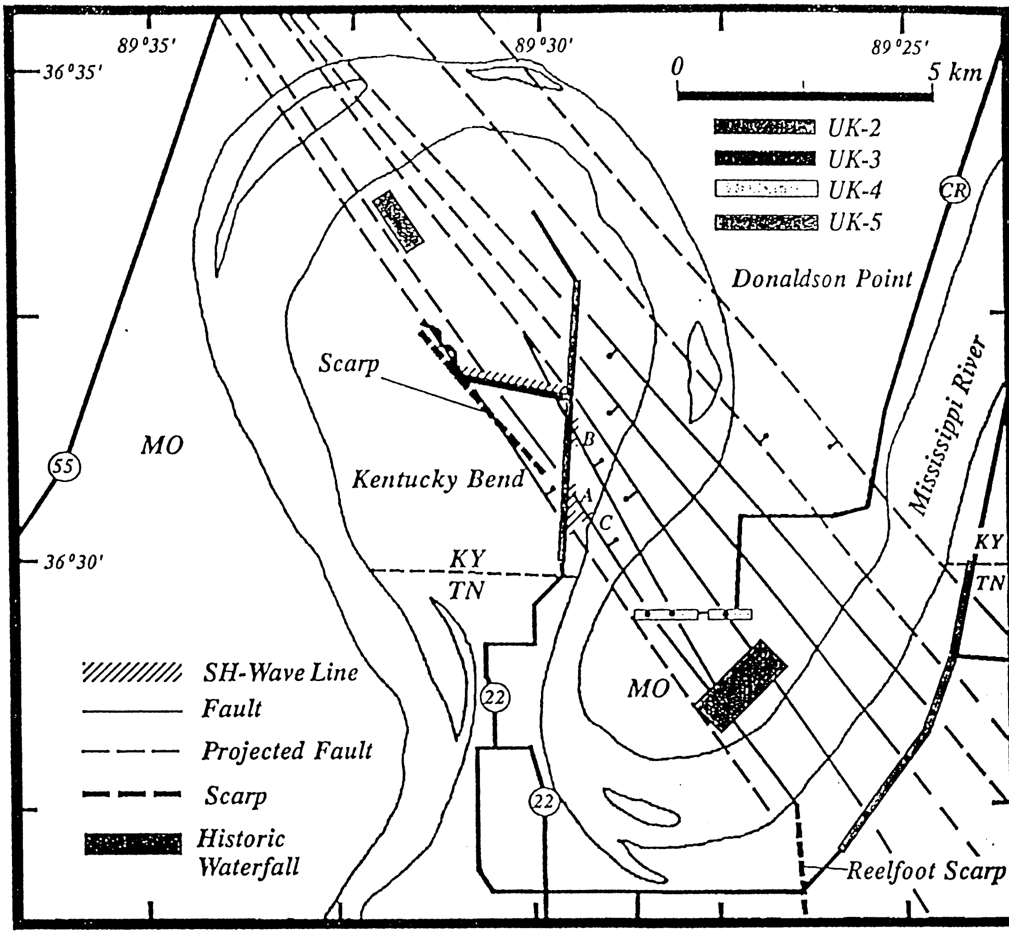

Figure 13. Detailed map showing the locations of the P- and SH-wave seismic reflection lines acquired during this study and the previous study (USGS award number 1434-HQ-97-GR-02988) of the same title. Faults indicated by solid lines are thought to be well documented, whereas dashed lines are used to indicate extensions of these faults and faults that have not been as well documented.