Remote Sensing of Alluvial Terrain in a Humid, Tectonically Active Setting: The New Madrid Seismic Zone

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ABSTRACT: The first large-scale feature discovered in the New Madrid seismic zone that may be the surface expression of a seismogenic fault of the great New Madrid earthquakes of 1811-1812 is revealed by Landsat MSS imagery, SPOT XS digital data, and aerial photography. This feature, that we have named the Bootheel lineament, trends at least 80 km in a north-northeast direction through northeastern Arkansas and southeastern Missouri.

Other relatively short, northeast- and northwest-trending lineaments were located in Holocene alluvium in northwestern Tennessee. Some of these lineaments may correlate with previously published reports of subsurface faults. A west-facing scarp identified on the SPOT image in the southern part of Reelfoot Lake may represent a normal fault scarp that forms a graben structure with the Reelfoot scarp.

It was also revealed that, in addition to vegetative cover, soil moisture conditions strongly influence the contrast between differing soil types of the upper Mississippi embayment in the visible and near infrared spectral region.

INTRODUCTION

THE NEW MADRID SEISMIC ZONE (Figure 1) is the site of the greatest historical series of earthquakes in eastern North America, the New Madrid sequence of 1811 and 1812. Although it remains the most seismically active area in the central and eastern United States, very little surface evidence of faulting has been found in the region. The humid climate, intense fluvial activity, and farming in the area have worked to erase much of the evidence of ground rupture that may once have existed. The objective of this study is to use SPOT XS digital data, Landsat MSS images, and conventional black-and-white aerial photography to identify and map subtle earthquake-related features that may still remain in the region. This information is important for the mitigation of seismic hazard in the New Madrid region in that it will help identify and map subtle earthquake-related features that may still remain in the area. Additionally, this study will enhance our understanding of the use of remote sensing in similar environments elsewhere.

GEOLOGIC SETTING

The seismicity of the New Madrid seismic zone occurs along three principal trends (Figure 1): a narrow, 110-km-long trend that extends northeastward from Marked Tree, Arkansas to Caruthersville, Missouri; a broader northwest-trending zone of relatively intense seismicity from southeast of Ridgely, Tennessee to west of New Madrid, Missouri; and a northeast-trending zone that extends from just west of New Madrid to Charleston, Missouri (Stauder, 1982). The association of the 1811-1812 New Madrid earthquakes with current seismicity is strongly suggested by isoseismal maps compiled from historical accounts (Nuttli, 1973; Street and Nuttli, 1984) and the distribution of surface effects such as landslides and liquefaction deposits (e.g., Fuller, 1912; Obermeier, 1984; Jibson and Keefer, 1988) (Figures 2 and 3).

The New Madrid seismic zone is located in the northern Mississippi embayment (Figure 4), a broad southward-plunging synclinal structure forming a prominent reentrant into the North American craton. The Mississippi embayment has two main physiographic subdivisions (Saucier, 1974; Autin *et al.*, 1991).

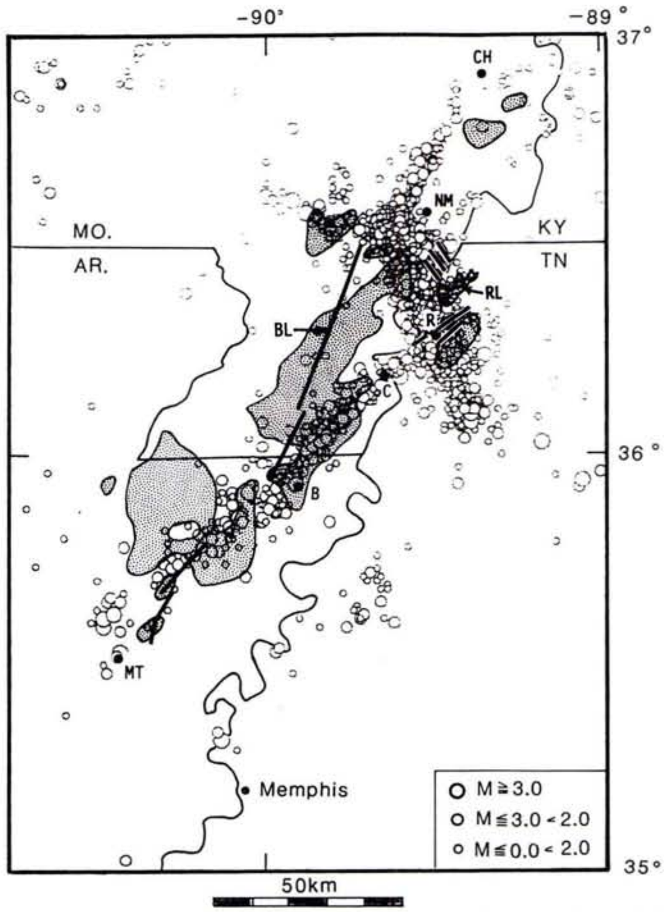

FIG. 1. The New Madrid seismic zone. Seismicity is shown for the period 1974-1987. The distribution of intense liquefaction effects (shaded areas) after Obermeier (1984) and lineaments interpreted in this study (dark lines) are also shown. Other features shown: B, Blytheville; BL, Bootheel lineament; C, Caruthersville; CH, Charleston; MT, Marked Tree; NM, New Madrid; R, Ridgely; RL, Reelfoot Lake.

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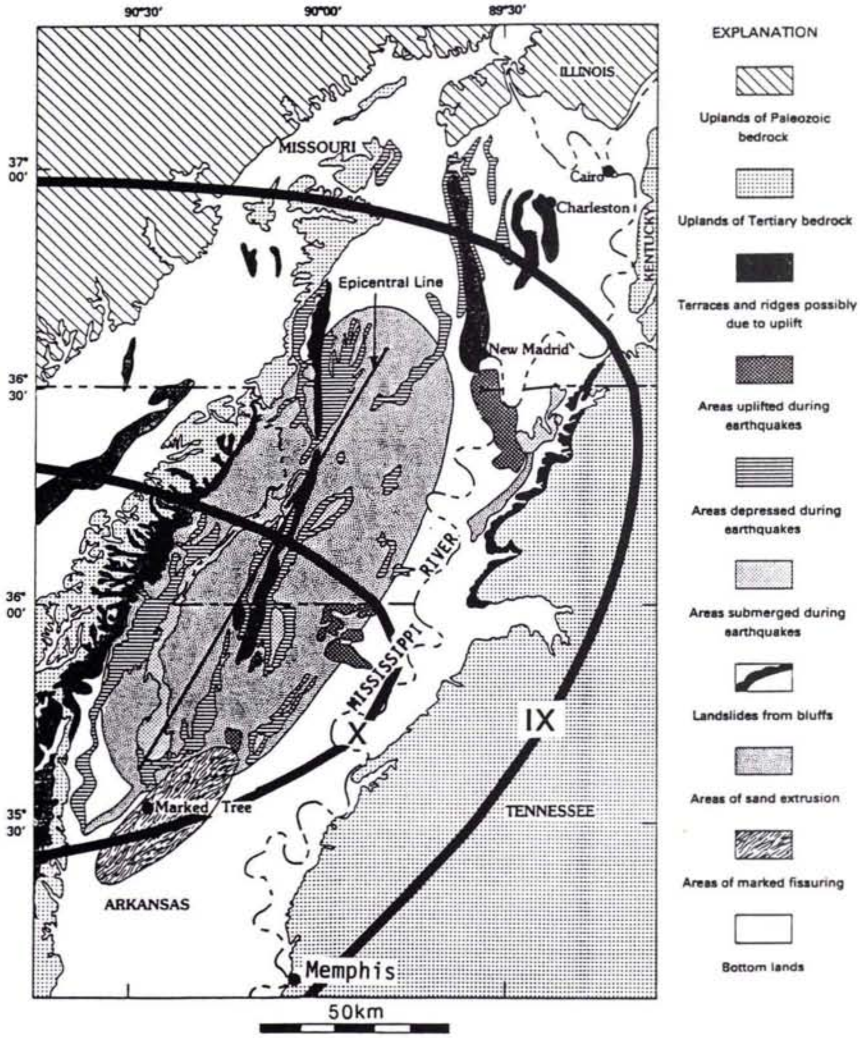


FIG. 2. Map showing generalized geology, ground failures, and other disruptions of the gound surface in the epicentral region of the 1811-1812 New Madrid earthquakes (modified by Jibson (1988) from Fuller (1912)). Also shown are isoseismals (modified Mercalli scale) from Nuttli (1973).

One subdivision is the Holocene alluvial valley of the Mississippi River and its tributary streams (Figure 4). A second subdivision consists of Pleistocene alluvial landforms, including valley trains, loess deposits, and blanket graveliferous deposits.

PREVIOUS STUDIES

One of the earliest investigations of the New Madrid seismic zone using remote sensing was by Fisk (1944). He used aerial photographs for the identification of lineaments in the lower Mississippi Valley. Krinitzsky (1950) summarized the surface expressions of fault systems in the same area, and outlined additional features used for recognizing faulting in alluvial deposits. These features included vegetation in back swamps, deltaic marsh drainage patterns, truncated floodplain sediments, sharp river bends, rectilinear drainage patterns in recent sediments, and topographic profiles. He also observed that, in spite of the meander loops, the course of the Mississippi River north of the mouth of the Arkansas River was an almost straight line paralleling the plotted trend of earthquake epicenters. O'Leary and Simpson (1977) used Landsat (MSS) images, sidelooking airborne radar (SLAR) image strips, and Skylab photos to search

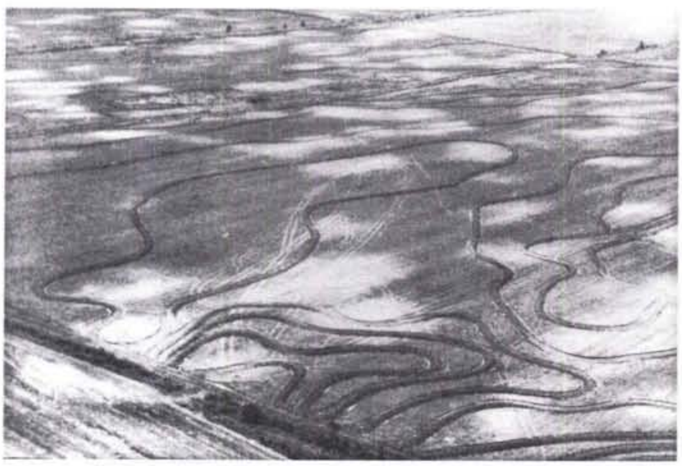


FIG. 3. Low aerial view of present day "sand blows" (light patches) in a rice field in southeastern Missouri. Most of the sand blows are about 5 m across. The contours are rice levees.

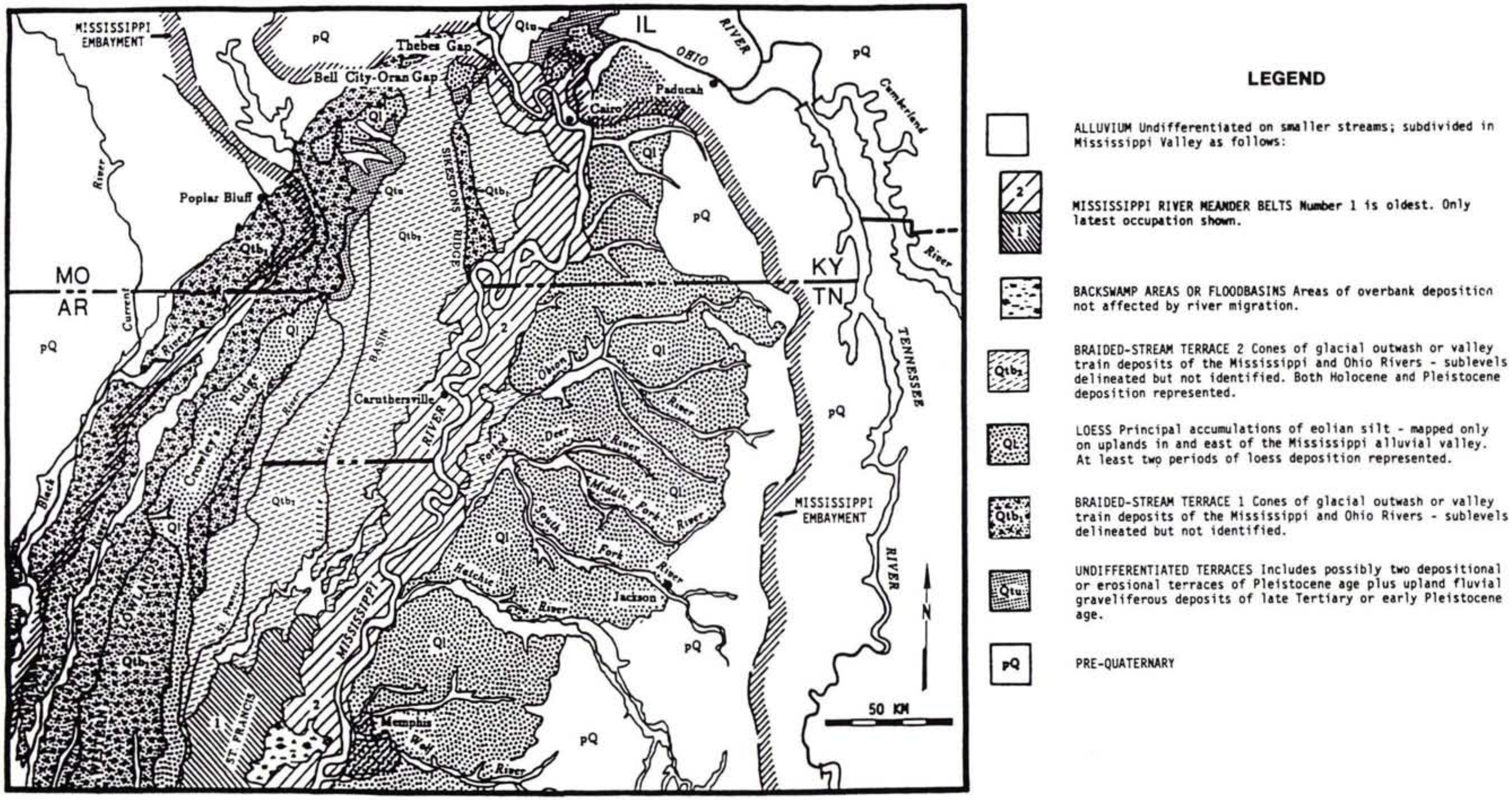


FIG. 4. Quaternary deposits of the Mississippi embayment (Saucier, 1974).

for subtle fault patterns and to develop a regional tectonic model for the northern part of the Mississippi embayment. They found that the azimuth frequency of Landsat lineaments yielded a good correlation with the magnetic anomaly trends in the northeast region of the embayment. Heyl and McKeown (1978) and Obermeier (1984, 1988) used aerial photography to map liquefaction deposits. O'Leary and Hildenbrand (1981) compared SLAR image data and aeromagnetic map data with mapped geology to produce an interpretation of the structural control of the Mississippi embayment. They noted that the most prominent directional trend of the lineaments is N40°-45°E.

O'Leary *et al.* (1983) used airborne microwave radiometry for fracture detection in parts of the Mississippi embayment near Blytheville, Arkansas and Ridgely, Tennessee. They concluded that, in the Blytheville area, the orientation and positions of lineaments corresponded well with previously reported fracture patterns and that, in the Ridgely area, they interpreted a major anomaly as corresponding to the subsurface Ridgely and Cottonwood Grove faults.

Argialas (1979) and Argialas *et al.* (1988) used Landsat MSS imagery to study the New Madrid seismic zone in western Tennessee. They were evaluating the use of Landsat image data for the identification of lineaments, to evaluate seasonal effects in the identification of lineaments, to compare these lineaments with gravity anomalies, and to consider the results in relation to the local structure. Their conclusions were that contrast- and edge-enhanced images were more effective than images generated using other techniques, that MSS bands 5 and 7 provided the most information about lineament patterns, and that lineaments were most easily detected on winter scenes, a conclusion confirmed in this study.

This study is somewhat more applied than the above studies in that we were looking for features to investigate further, either through trenching or shallow seismic reflection techniques. Also, all lineaments discussed in this paper were in some manner field checked.

DATA SOURCES

The types of data selected for this study are hard copies of Landsat MSS imagery, SPOT XS digital data, and vertical black-and-white aerial photographs that range in scale from about 1:10,000 to 1:80,000. The Landsat MSS imagery was chosen for its broad, relatively inexpensive coverage, although its spatial resolution (79 m by 79 m) is relatively poor. The SPOT XS digital data was chosen because of its relatively high spatial resolution (20 m by 20 m) and relatively low cost. The black-and-white aerial photographs were largely used for studying details of features noted on the satellite imagery. Winter scenes were chosen for all data because of the low level of vegetative cover during this time of the year.

LINEAMENT INVESTIGATION

In this study lineaments were defined by certain geologic phenomena including (1) boundaries between areas of contrasting density of surface liquefaction deposits; (2) relatively long and straight fissures exposed at the surface, often filled with liquefied sand; (3) abrupt changes along the profiles of streams; (4) linear zones of high soil moisture; and (5) abrupt discontinuities within fluvial patterns. Examples of many of these were located in this study, but only those that were determined to be of possible tectonic importance are discussed further.

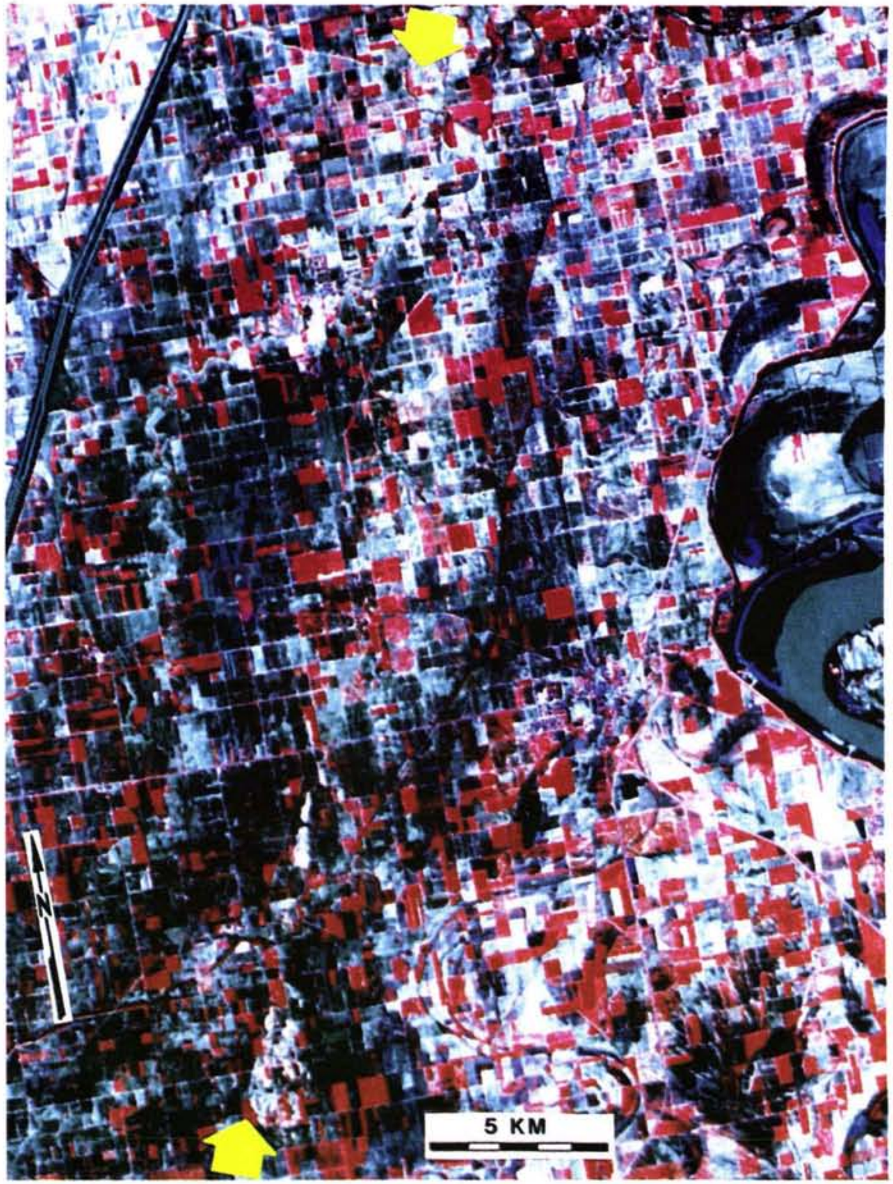
BOOTHEEL LINEAMENT

The most exciting result of this study was the discovery of a linear feature that we have named the Bootheel lineament, a linear feature which trends approximately N20°- 25°E for at least 80 km through northeastern Arkansas and the Bootheel region of southeastern Missouri (Figure 1). With the exception of the 11-km-long Reelfoot scarp in northwestern Tennessee, the Bootheel lineament is, to our knowledge, the first large-scale surface feature discovered in the New Madrid seismic zone that may reflect deep-seated faulting, rather than simply liquefaction-induced subsidence.

The Bootheel lineament was first noted while obliquely viewing a SPOT XS false color composite image of the three original bands (band 1: 0.50 to 0.59 μm, band 2: 0.61 to 0.68 μm, band 3: 0.79 to 0.89 μm) acquired 6 March 1987 (Plate 1). On the SPOT image the lineament appears as an alignment of short dark areas (presumably moisture related) and light areas of liquefied sand deposits. The lineament is more noticeable if viewed obliquely along its trend. Of the individual SPOT XS bands, the image created from band 3 (near-infrared) showed the lineament best, although the lineament is better shown by the false color composite image of all three bands. The lineament is also visible on a Landsat color composite image of MSS bands 4 (0.5 to 0.6 μm), 5(0.6 to 0.7 μm), and 7(0.8 to 1.1 μm) acquired 22 February 1973 (Plate 2). On this image the lineament appears as an alignment of the liquefied sand deposits.

Extensive study of the SPOT and Landsat imagery, as well as field investigations, reveals a number of characteristics of the Bootheel lineament. The nature of the trace varies along strike and is represented by some combination of (1) a contrast in sand blow density on opposite sides, generally denser to the southeast; (2) shallow linear depressions, commonly containing standing water during wetter times of the year (Figure 5); (3) apparent truncation of some fluvial features against the lineament on the southeast side; (4) continuous or discontinuous linear bodies of sand; and (5) a lack of noticeable topographic expression (Figure 5). Several of these characteristics are clearly discernible on Figure 6a, a black-and-white aerial photograph of the area denoted as B on Plate 2. In some areas southeast of the lineament the sand blow deposits are dense enough to form continuous "sheets" of sand (e.g., light area in the lower middle part of Figure 6a and location A in Plate 2). The apparent truncation of some meander scars on the southeast side of the trace in these photographs indicates that the lineament must be younger than about 9,500 years, the age of the earliest meandering streams in the upper Mississippi embayment at this latitude (Autin *et al.*, 1991). At location C in Plate 2, the trace lacks the linear

FIG. 5. Southwest view along the trace of the Bootheel lineament. Water occupies a shallow depression along part of the lineament's trace. This 25 March 1989 photograph corresponds to location B of Figure 6a.



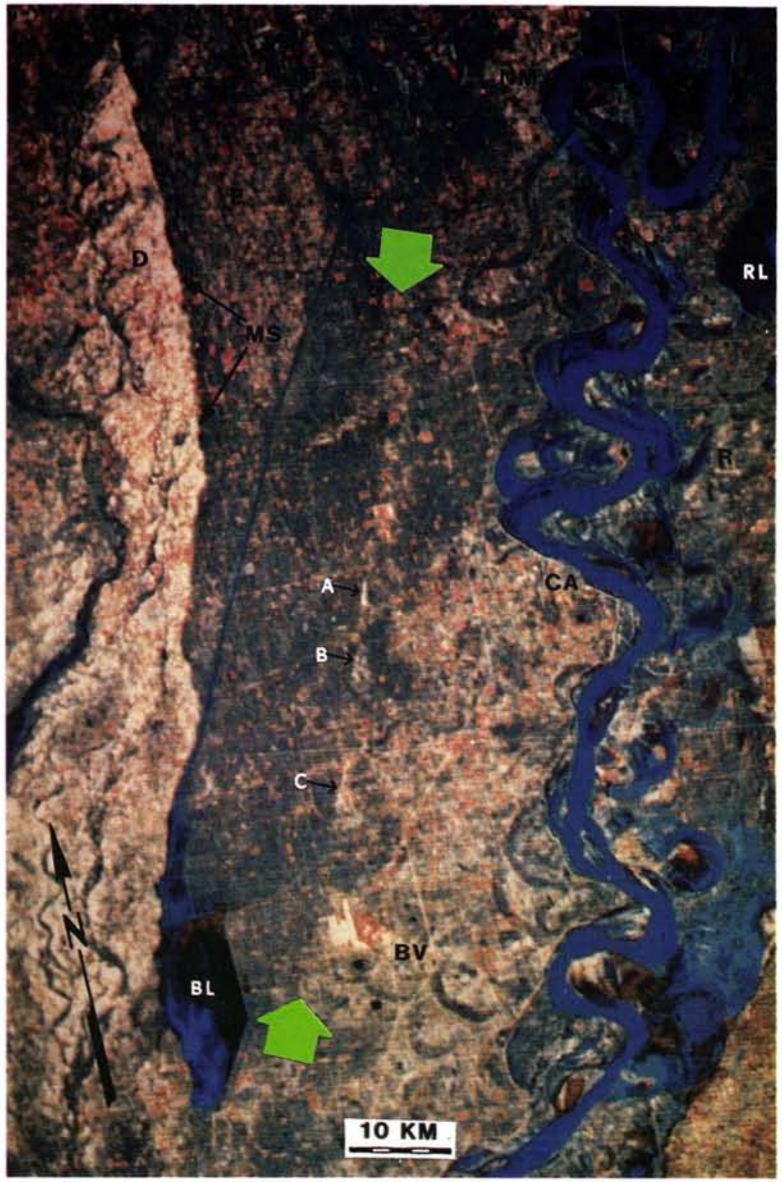


PLATE 1. SPOT XS color composite image of the Bootheel lineament. The lineament is more easily seen by obliquely viewing it along its trend. Image acquired 6 March 1987. © 1987 CNES, provided courtesy of SPOT Image Corporation, Reston, Virginia.

PLATE 2. Landsat color composite image of MSS bands 4, 5, and 7 acquired 22 February 1973. Arrows show the Bootheel lineament. D and E denote two different braided stream surfaces. Other features shown: BV, Blytheville; BL, Big Lake; CA, Caruthersville; MS, Malden-Bernie scarp; NM, New Madrid; R, Ridgely; RL, Reelfoot Lake. Reproduced by permission of EOSAT.

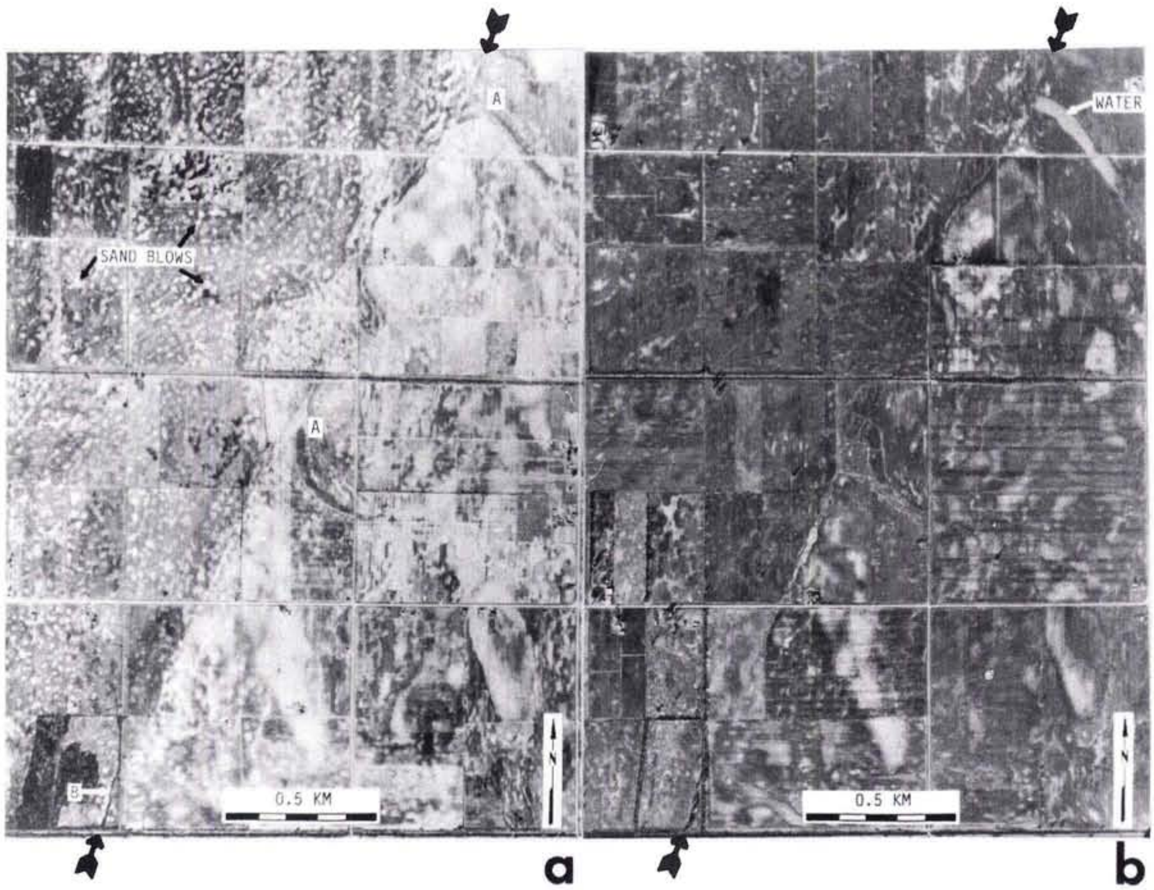


FIG. 6. Aerial photographs of the Bootheel lineament (arrows) southwest of Caruthersville, Missouri (see Plate 2 for location). a: Portion of a photograph acquired February 1953 by the U.S. Army Corps of Engineers. Note the strong contrast in sand blow density (light patches) on opposite sides of the lineament and the apparent truncation of the stream meander scars (A). Site B corresponds to Figure 5.b: Portion of an NHAP photograph acquired January 1975. The contrast between the sand blow deposits and the dark clayey soil is low. Note the damming of the water in the stream meander scar in the upper right against the trace of the lineament.

sand bodies and appears only as a relatively sharp boundary between the sandy area to the southeast and the darker, more clayey soils to the northwest (Figure 7).

The surface trace of the Bootheel lineament consists of a number of linear segments. Gaps between the segments are commonly due to small stream meander scars that obscure the lineament's trace. In other areas, the gaps separate segments with slightly different trends; these may represent original discontinuities in the lineament.

Southwest of Blytheville and just northeast of Marked Tree in northeastern Arkansas is a curvilinear feature that is about 30 km long and trends approximately N30°-35°E (Figure 1). It may be a southward continuation of the Bootheel lineament.

SLAR radar (X band, HH polarized) image strips of both near and far range were obtained for the area along the Bootheel lineament. The sandy areas at sites A and B of Plate 2 were the only visible evidence of the lineament.

We are currently investigating the Bootheel lineament using surface mapping, trenching, and seismic reflection (Schweig and Marple, 1989, 1991; Schweig *et al.*, 1990). All evidence gathered thus far indicates that the liquefied sand deposits present along the lineament formed in the great 1811-1812 New Madrid earthquakes. No evidence of earlier activity yet has been found.

Shorter Lineaments Along Trends of the New Madrid Seismic Zone

Two northeast-trending subparallel lineaments were noted on black-and-white aerial photographs south of Reelfoot Lake and near Ridgely, Tennessee (Figure 8). The longer one is about 12 km long and extends N55°-60°E from the Mississippi River west of Ridgely to just south of Reelfoot Lake. The other lineament is located just east of Ridgely and trends N45°-50°E for about 8 km. Both lineaments are highlighted by the apparent truncation of point bar patterns along the southeastern edge of their traces. Both also have linear and discontinuous sand bodies along portions of their traces and are aligned along the trend of New Madrid seismicity that runs between Ridgely and Marked Tree, Arkansas. D.P. Russ (oral communication, 1989) suggests that these two lineaments are not the surface expressions of faults, but the linear edges of a series of migrating point bars.

Three other relatively short (< 5 km) lineaments were located on aerial photographs northwest of Reelfoot Lake near the Mississippi River (Figure 1). The lineaments are marked by linear sand bodies, bends in stream channels, and linear depressions. They all trend about N25°-30°W, parallel to the northwest-trending arm of seismicity. Herrmann and Canas (1978) used focal mechanisms to infer thrust faulting along this trend. Interestingly, two of the lineaments approximately overlie sub-

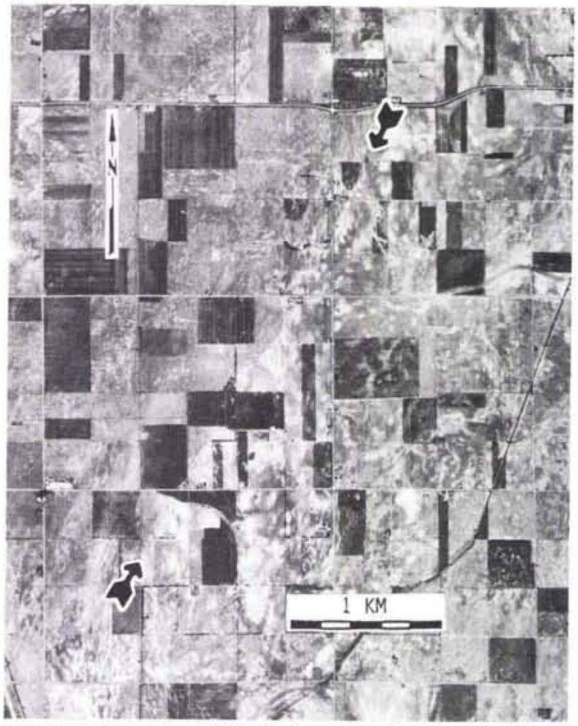


FIG. 7. Portion of an NHAP photograph of the Bootheel lineament along area C of Plate 2.

surface faults interpreted from a boat-based seismic reflection survey conducted on the river by Shedlock *et al.* (1988), who interpreted both faults as thrusts, northeast side down. None of the shorter lineaments were discernible on either the Landsat or SPOT imagery.

EFFECTS OF SEASON AND SOIL MOISTURE CONDITIONS ON LITHOLOGIC CONTRAST

Argialas (1979) and Argialis *et al.* (1988) noted that vegetative cover significantly influences the detection capability of Landsat images in western Tennessee. In this study, a comprehensive search was made of microform of 122 Landsat MSS and TM black-and-white (red band) images that best revealed the sand/clay contrast along the Bootheel lineament. It was noted that contrasts among the different soil types in the upper Mississippi embayment are, in general, best observed on winter (November through March) images and are generally poor for the rest of the year. For example, the February Landsat scene of Plate 2 shows a very strong contrast between the older, sandier braided stream surface (location D) and the younger, darker, clayey braided stream surface (location E), whereas a much weaker contrast between these braided surfaces is typical for images acquired April through October. This particular contrast boundary corresponds to a topographic escarpment known as the Malden-Bernie scarp (Plate 2). Both a tectonic (Fuller, 1912) and an alluvial (Saucier, 1970) origin have been proposed for the scarp.

It was noted in this study that only a few Landsat images acquired during the winter displayed high contrast between different soil types of the upper Mississippi embayment. For example, during an investigation of the association of the sand-clay contrast along the Bootheel lineament on Landsat imagery with rainfall and temperature records, it was inferred that soil moisture conditions strongly affect the contrast on winter images. Optimal contrast is best after a moderate rainfall (a half inch or greater) followed by several days of drying; the optimum period of drying depends on relative humidity, temperature, wind velocity, and solar illumination. It is apparent that immediately after heavy rains or during dry conditions the spectral reflectance characteristics of the quartz-rich sandy soils and the organic-rich clayey soils of the upper Mississippi embayment are too similar in the visible and near infrared portion of the spectrum to produce high contrast on Landsat imagery or conventional aerial photography. However, because the sandy soils dry faster after a significant rainfall than the clayey soils, there is a relatively short period of time (a few days) when the contrast in soil moisture content, and therefore the reflectance contrast, between the sandy and clayey soils is greatest. This is when the best contrast is observed on embayment imagery and aerial photography acquired in the visible and near infrared spectral region. Figure 6, two black-and-white aerial photographs of the same area along the Bootheel lineament at location B in Plate 2, demonstrates this phenomenon. The photograph on the right – taken in January 1975 immediately after a moderate rainfall – shows a weak contrast. The photograph on the left – acquired February 1953 after five days of drying following a moderate rainfall – shows a strong contrast. The blending of soil types by agricultural practices between 1953 and 1975 has not been great enough to account for this difference.

The variation in contrast was also observed on microform of Landsat imagery of the upper Mississippi embayment acquired during the winter. For example, the contrast along the southern part of the Bootheel lineament on the Landsat MSS band 2 (red) image (Figure 9) acquired 28 October 1983 appears very different from that shown on the February Landsat scene in Plate 2. The sandy areas at locations B and C in Plate 2 are not visible in the October scene. Instead, the lineament's trace is discernible as a diffuse boundary along the sandier soils to the southeast. However, the October scene shows the Bootheel lineament extending further southwest to a point south of Big Lake in northeastern Arkansas, yielding an overall length of at least 80 km for the lineament. The majority of the other Landsat winter scenes of the upper Mississippi embayment on microform did not reveal the Bootheel lineament because the contrast associated with the sandy and clayey soils along the lineament was very low or absent.

SCARP BENEATH REELFOOT LAKE

A west-facing scarp, trending approximately N0°-5°E, was identified on the SPOT XS image beneath the waters of Blue basin at the south end of Reelfoot Lake (Figure 1) in northwestern Tennessee. Much of Reelfoot Lake occupies a complex of former channels of the Mississippi River (Russ, 1982) (Figure 10). Drowned cypress trees lying just beneath the modern water surface and partially eroded Indian mounds are among the evidence that the lake was enlarged during the 1811-1812 earthquakes. Russ (1982) concluded from a study of bathymetry maps that the lake bottom had not been broken by dip-slip faulting. This study, however, suggests that Blue basin may have a tectonic origin.

In the SPOT XS band 3 image of Figure 11, the scarp is expressed as a relatively dark feature with a very straight edge on the west. This straight edge is an artifact of the "striping" effect commonly seen on SPOT images acquired over water bodies. The darkness of the scarp may be due to the acquisition of the image during mid-morning when the sun is low in the east. This feature has a similar appearance on images of the other two SPOT bands, as well as images derived from the first and second principal components and the intensity and saturation components. The striping effect seems to have been removed by computing the hue and third principal components from the original three SPOT bands. This is suggested by the somewhat different appearance of the scarp on images produced from these two transformations (Figure 11). On these images the dark area

FIG. 8. Black-and-white aerial photographs of the Ridgely, Tennessee area. a: Lineament north of Ridgely (between arrows). b: Lineament east-southeast of Ridgely (between arrows). Photographs acquired November 1959 by the USDA Soil Conservation Service.

of the scarp is curved (concave to the east-southeast) with a lighter zone around the dark area; the light zone may represent areas of higher turbidity flowing around a higher part of the scarp.

On a bathymetry map (Figure 12) the scarp in Reelfoot Lake corresponds to a gentle slope of about 0.5° to 1.0° that separates Blue basin from the much shallower area to the east. Although the slope on the scarp is very gentle, it is significant when compared with the rest of the lake bottom. The scarp may have been smoothed out by erosional and depositional processes. Aerial photographs and a color composite of the three principal components indicate a very high level of turbidity above and on the scarp, but not to the west. Also, a study of sedimentation of Reelfoot Lake (Denton, 1986) shows that little deposition has taken place in the area of the scarp in the last 100 years. However, the scarp may have been eroded by some combination of bioturbation and erosion by wave action during heavy storms.

Examination of aerial photography and the maps of Russ (1979, 1982) suggests that the scarp does not appear to be the bank of a former channel of the Mississippi River (Figure 10). If this west-facing scarp was produced by faulting, then it would form the east side of a graben bounded on the west by Reelfoot scarp (Figure 10). Blue basin may have been deepened by down-dropping of this graben during the 1811-1812 New Madrid earthquakes.

CONCLUSIONS

This study shows that remote sensing can be used effectively to study the tectonic geomorphology of humid, fluvially active settings. Trends of many of the lineaments examined in this study are parallel with trends of New Madrid seismicity. The fact that only short lineaments of about 12 km or less were found in areas with heavy seismicity could have several explanations. First, because of the proximity of the seismic trends to the Mississippi River, the surface expressions of any large faults may have been erased by deposition and erosion during flooding or channel migration. Second, with the possible exception of the Bootheel lineament, the major faults associated with the seismic trends may not have produced significant surface displacements during the 1811-1812 or earlier earthquakes.

The relationship between the Bootheel lineament and the New Madrid seismic zone is not yet understood, nor is it known if it is a seismogenic fault of the great New Madrid earthquakes of 1811 and 1812. However, the inconsistency in the sense of vertical offset of the surface, as well as the remarkably straight trace of its segments, strongly suggests that the Bootheel lineament is the trace of a strike-slip fault. Focal mechanisms in the New Madrid seismic zone indicate that strike-slip movement would be expected on a fault with this orientation (Herrmann and Canas, 1978; O'Connell *et al.*, 1982). The fact that the lineament does not lie along any of the major arms of New Madrid seismicity, although it is approximately aligned with a southwestward projection of the northern arm of seismicity, could indicate that current seismicity does not reflect the fault(s) that ruptured in 1811 and 1812, perhaps because the earthquakes resulted in release or major reorientation of stress on the fault system. An analogous situation may be the 1857 and 1906 segments of the San Andreas fault system that currently show very little seismicity relative to other segments. Also, ap-

FIG. 9. Landsat MSS band 2 image along southern trend of Bootheel lineament (between arrows). Image acquired 28 October 1983. Reproduced by permission of EOSAT.

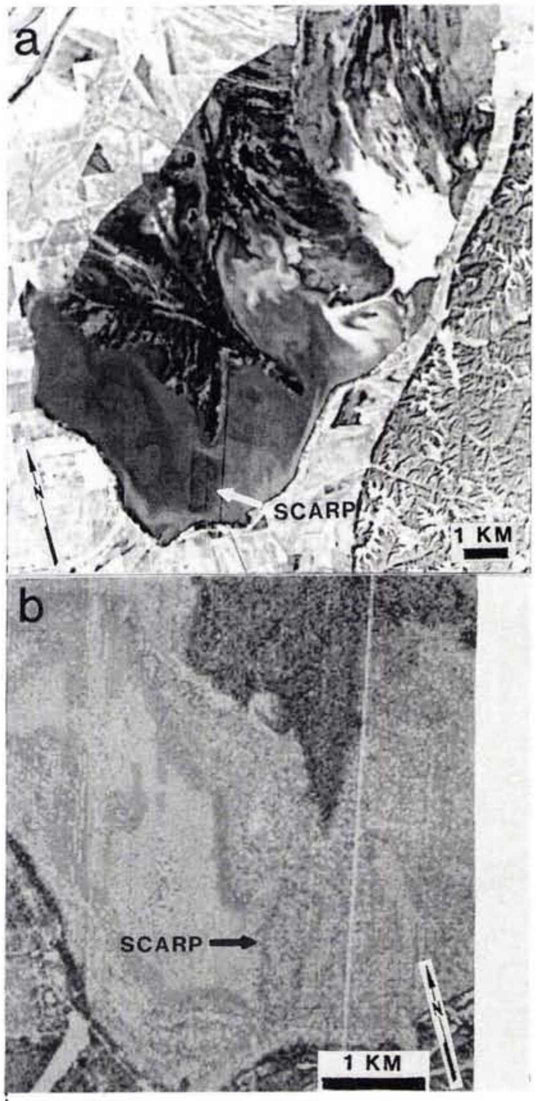


FIG. 11. SPOT images over Reelfoot Lake, Tennessee. Scarp shown by arrows. a: SPOT XS band 3 image. b: Third principal component image. © 1987 CNES, provided courtesy of SPOT Image Corporation, Reston, Virginia.

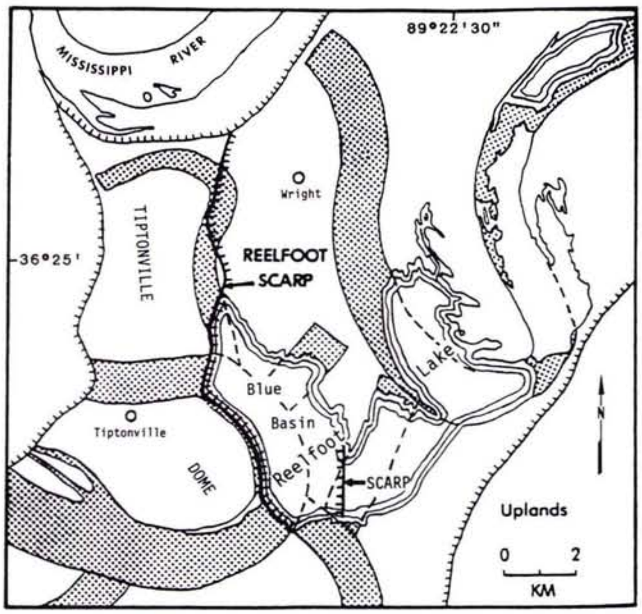


FIG. 10. Map showing relationship of Reelfoot Lake to former channels of the Mississippi River (after Russ, 1979). Note location of scarp on east side of Blue basin.

proximately where the lineament intersects the seismic zone to the south (just west of Blytheville), there is a change in seismic character; the seismicity is more diffuse southwest of this intersection than to the northeast. The reason for this change in seismic character is not yet understood.

If the Bootheel lineament and the one near Marked Tree represent one fault, its length would exceed 130 km; it would then be capable of producing a great earthquake (A.C. Johnston, written communication, 1990; D.L. Wells, written communication, 1990) and may have been responsible for at least one of the 1811-1812 earthquakes. Future studies of this structure may help to resolve some of the questions about the paleoseismic history of the New Madrid seismic zone, perhaps leading to a more accurate estimation for the recurrence interval of large earthquakes in the New Madrid area.

In spite of evidence for faulting, other possible mechanisms of formation of the Bootheel lineament must be considered. The most plausible is that the lineament represents the edge of a former braided stream channel or terrace. Although the linea-

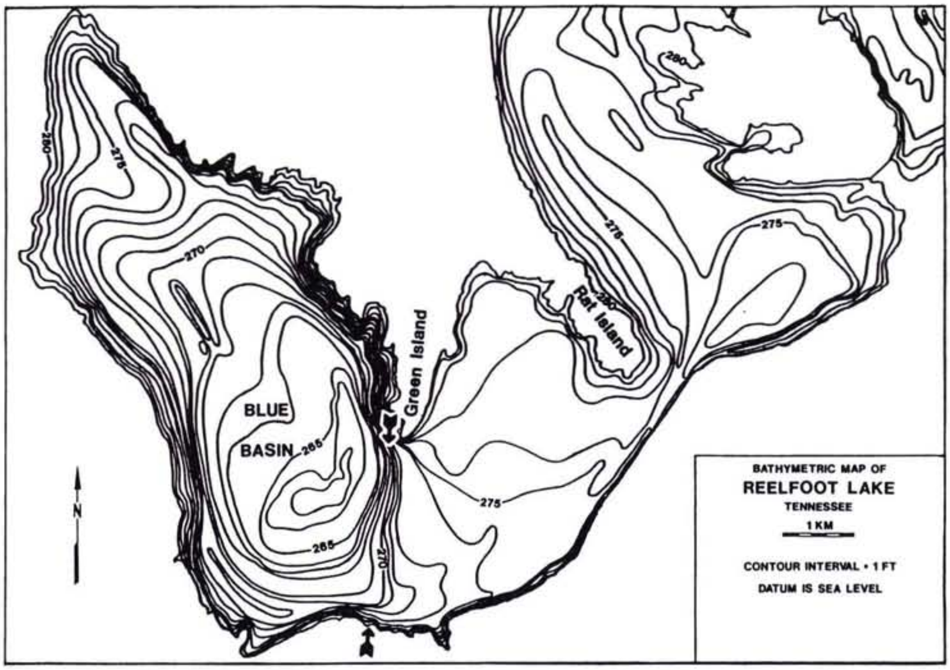


FIG. 12. Bathymetric map of the southern part of Reelfoot Lake, Tennessee. Scarp referred to in Figure 9 is shown by arrows. After an unpublished U.S. Army Corps of Engineers photomap (1956).

ment is located entirely within a braided stream terrace, mapping by Saucier (1964) suggests that in one area it does approximate the western edge of four topographically indistinct remnants of an older braided stream terrace, which he defined largely on the basis of its sandier soils. However, the lineament extends both north and south of these areas. Also, the sandier soils along the southeast side of the lineament are largely the result of more intense liquefaction, and could be interpreted as indicating some type of ground water barrier. This barrier may have been responsible for the water table being higher on the southeast side of the lineament than the northwest side during past large earthquakes. Thus, the southeast side of the lineament may have been more susceptible to soil liquefaction and sand blow activity. Of course, it may also be true that the older terrace deposits are simply more susceptible to liquefaction or that faulting has controlled the location of terrace remnants by isolating them slightly above the surrounding area.

This study also reveals that, for aerial photography and Landsat MSS and SPOT XS imagery, vegetative cover and possibly soil moisture conditions greatly affect the spectral contrast associated with differing soil types of the upper Mississippi embayment. Because of these strong influences, individual scenes of the embayment should be previewed, if possible, to determine if they have the contrast and quality desired for geologic studies of the embayment.

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Erratum

In the November 1991 issue of *PE&RS*, in GIS News (p. 1405) the photo used with the story, "ERDAS Introduces IMAGINE GIS" was incorrect. The correct photo appears with the exhibit description on page 1497.