Neogene Grabens in Southernmost Illinois

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Annual Project Summary

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Investigations Undertaken

In this the first year of a two-year project, we investigated several grabens of Quaternary age in southernmost Illinois using high-resolution seismic reflection and ground-penetrating radar surveys. The grabens were identified earlier by means of geologic mapping and shallow drilling, which work was partially supported by previous NEHRP grants. Objectives of this year's geophysical surveys were to:

1. To determine whether the grabens are bona fide tectonic structures, as opposed to products of solution-collapse, landsliding, valley incision, and other non-tectonic processes.

2. To determine the structural style of tectonic faults, and thereby gain insights on the stress field(s) that produced them.

3. To bracket the age of faulting as closely as possible, and lastly

4. To identify targets for core-drilling under Year 2 of the current NEHRP grant. The core drilling is to provide closer constraints on the

timing of deformation and possibly to define targets for trenching studies.

Seismic Reflection Surveys

A total of 7 high-resolution seismic-reflection surveys were conducted at 5 sites under this year's program (Table 1 and Figure 1). The seismic data were acquired and processed by two different contractors who used different methods.

Seismic surveys at the Choat and Maple Grove sites were carried out on May 27-30, 1998 by a crew from the U.S. Geological Survey (USGS), of Golden, Colorado. William Stephenson was the crew chief. Both surveys were Mini-Sosie, using three earth tampers as the energy source and collecting data on a 60-channel seismograph. The geophone spacing was 3 meters, and sets of three geophones were placed at each station. Seismic surveys at Massac Creek (two lines), Kelley (two lines), and Post Creek were conducted on May 9-13 by a crew from the University of Missouri at Rolla (UMR) under the direction of Neil Anderson. This crew used an elastic weight-drop as the energy source and recorded on a 24-channel seismograph. Shot-point and geophone spacing was 10 feet (3.0 meters).

All seismic data were processed by the same contractors who collected the data. Initial copies of all seismic profiles, including stacked and migrated sections, were delivered to us by mid-August. In late August we met with Neil Anderson, discussed processing and interpretation, and suggested some additional processing, which is being carried out. We have discussed processing and interpretation of USGS seismic data with Bill Stephenson over the telephone and have scheduled a meeting in Golden in October to arrive at final interpretations.

Ground-Penetrating Radar Surveys

Mark Howell of Xenon Geosciences from Dayton, Ohio performed ground-penetrating radar surveys at 5 sites on May 19-21, 1998 (Table 1, Figure 1). These surveys were conducted by towing a wheeled antenna or transceiver along the line of traverse. The antenna continuously transmits radar signals into the earth and receives the reflected signals, which are processed into a format that (ideally) resembles a seismic reflection profile. The antenna operates at a frequency of 80 megahertz (MHz). Radar is intended to provide detailed information on ground conditions at shallow depths, typically less than 30 meters; whereas seismic can achieve reflections from

depths of hundreds or thousands of meters (depending on energy source and processing parameters). Ideally, radar and seismic surveys complement one another, the former providing information on very shallow or young sediments and the latter, information on older and deeper layers.

Radar data were processed in Dayton by Ernie Hauser of Xenon, and processed data were supplied to us in August of this year. Following preliminary processing, Xenon conducted additional surveys at the New Columbia site using 300- and 500-MHz antennas. The extra surveys, carried out at no charge to NEHRP, were intended to provide additional information on possible faults imaged by the 80 MHz antenna.

Seismic Surveys

RESULTS

Results of seismic reflection surveys were variable. Four of the five seismic profiles produced by UMR show well-defined reflectors in Paleozoic bedrock and clearly indicate tectonic faults. The fifth UMR seismic line, from Post Creek, had barely discernible reflectors; but hopefully these can be enhanced via additional processing. None of the UMR seismic profiles imaged clear-cut reflectors or geologic structure within the Cretaceous and younger sedimentary cover.

The two seismic profiles generated by the USGS present fair to good reflection quality in both Paleozoic bedrock and younger sedimentary cover. Interpretations of tectonic faulting from these profiles, however, are ambiguous. We have not yet had an opportunity to discuss interpretation of these seismic lines with the team that acquired and processed the data.

Radar Surveys

Results of the ground-penetrating radar surveys were disappointing. Radar apparently is unable to penetrate loess (compact silt of wind-blown origin) that mantles all uplands in the study area, and also is unable to penetrate clay-rich sediments in bottomlands. At three of the five sites surveyed, Choat, Maple Grove, and Reineking Hill radar yielded no usable data on subsurface features. At Massac Creek and New Columbia, radar images of subsurface features were obtained from valley bottoms but not from hillsides. The images received in valley bottoms consist of broken, tilted reflectors, that possibly

represent tectonic disturbance of near-surface sediments. The reflectors occur in areas of sandy, moist alluvial deposits. Radar reflections are too discontinuous to permit any confident interpretation of geologic structure.

Site-By-Site Interpretation

Massac Creek Two seismic profiles were acquired at Massac Creek, where previous drilling indicated the presence of a narrow graben containing Pleistocene and Upper Tertiary sediments. One profile passes within 30 in south of the two drillholes that indicate the graben. The second, longer profile follows a county road about 0.8 km south of the first profile.

Both profiles give clear indications of a zone of faulting that affects both Paleozoic bedrock and younger, Cretaceous through Quaternary sediments. Faults are indicated by abrupt offsets of well-defined reflectors. All faults dip steeply; some have apparent normal offsets whereas others appear to be reverse faults. Specifically a deep, narrow graben, bounded by a pair of steeply dipping normal faults, is indicated on the northern seismic line. This structure is directly in line with the graben that was interpreted earlier from borehole data. A possible continuation of the deep graben is imaged on the southern seismic profile where Rosebud Road crosses Massac Creek. The graben appears to be much narrower on the southern seismic line, and may be merging southward to a single fault zone.

A ground-penetrating radar profile was obtained along the same line of traverse as the northern seismic profile. No coherent data were obtained from loess-covered hillsides. Short, broken, tilted reflectors were imaged along a valley bottom, a short distance east of the prominent graben interpreted from the seismic line. The seismic line indicates numerous faults in the valley bottom area also. The discontinuous radar reflectors cannot be confidently attributed to geologic structure.

Kelley. The Kelley site, discovered in 1997, consists of a railroad cut wherein trenching and soil probing revealed a graben or synclinal structure affecting sediments as young as the Sangamon Geosol (75,000 to 125,000 years old). Given the lack of subsurface data in the vicinity, the Kelley structure could not be interpreted unequivocally as a tectonic fault. The structure plausibly could be interpreted as a late Tertiary or early Pleistocene paleochannel that was abandoned

and infilled with younger sediments. We acquired two parallel seismic profiles to test the tectonic vs. paleochannel hypotheses.

The two seismic profiles from Kelley leave no doubt that the site is underlain by a tectonic fault zone in Paleozoic bedrock. The reflections are of excellent quality, and the presence of several abrupt, steeply-dipping to vertical faults is indisputable. The surprising feature is that the seismic profiles depict not a graben, but a complex horst or faulted anticline. The central part of the railroad cut, coinciding with the graben observed during trenching, is at the crest of the uplift. On seismic, the Kelley structure resembles a positive flower structure.

Based on the seismic data, Kelley cannot be interpreted as the product of a single episode of tectonism. We infer an early (possibly late Paleozoic) episode of strike-slip faulting with an element of compression, which produced a positive flower structure in Paleozoic rocks. A Pleistocene episode of extensional faulting created the graben at the crest of the structure, as observed in the railroad cut. Only the deeper, compressional feature was evident on the seismic profile.

Post Creek Previous researchers (Kolata et al., 198 1) identified a graben-like structure displacing Pliocene to Pleistocene gravel in a ravine near the Post Creek Cutoff in eastern Pulaski County (Figure 1). The structure has an apparent trend slightly north of east. After drilling several test holes at the site, Kolata et al. concluded that the structure was the product of collapse of Cretaceous and younger sediment into sinkholes in the underlying Mississippian limestone.

To test the sinkhole hypothesis, we acquired an east-west seismic profile along a county road less than 1 km north of the ravine exposing the graben. If the Post Creek is a tectonic fault, it should intersect and be evident on the seismic profile, whereas sinkholes would not be imaged (or would appear as shallow, random loss of reflector continuity near the bedrock surface.)

The seismic profile we received proved to be of poor quality, with reflectors barely discernible along most of the line. Nevertheless, reflectors in the west-central part of the profile, in line with the Post Creek structure, are tilted and appear to be broken and offset. The profile thus lends support to a tectonic fault hypothesis. In discussion with Neil Anderson, we suggested that reprocessing the data, with frequency-wave number filtering might yield sharper reflection quality and enhance interpretation. This reprocessing is now being carried out.

Maple Grove. A narrow graben, probably part of the Lusk Creek Fault Zone, is inferred to underlie the Maple Grove School north of Joppa (Figure 1). The sample log of a water well at the school indicates Quaternary sediments are downthrown at least 30 m into this structure.

We had hoped to run our seismic line along a county road south of the school, but pumps at a nearby gas-compressor plant emit steady ground-shaking vibrations that would impair ability to collect seismic records. Accordingly, we ran the profile approximately I km north of the school, in line with the faults interpreted from well records.

The seismic profile shows several strong, continuous reflectors in Paleozoic bedrock and in overlying Cretaceous and younger sediments. The reflectors are generally horizontal to gently undulating. No clear-cut faults are evident, although there are several minor offsets and discontinuities that could be interpreted as faults. We need to discuss the results with the USGS crew and possibly, reprocess the data to enhance areas of interest.

A ground-penetrating radar profile acquired in a farm field just south of Maple Grove School failed to achieve any usable penetration of the silt-rich soil.

Choat. As at Maple Grove, well records indicate a graben near Choat townsite about 7 km northwest of Metropolis. Tertiary and Quaternary sediments apparently are downthrown against Cretaceous and Paleozoic units. The USGS crew acquired a seismic profile along an east-west county road that passes just south of two wells indicating a graben.

Initial results of the seismic survey at Choat are less than conclusive. On the eastern 1/3 of the line, Paleozoic bedrock reflectors are horizontal and undisturbed. A synclinal depression, or possible graben, is seen near the middle of the seismic profile, east of the graben indicated by drilling. The synclinal feature lacks clear-cut faults. Farther west, in line with the graben detected by drilling, are several breaks in the reflectors that could be faults. Additional work is needed to interpret the Choat seismic data.

Two ground-penetrating radar surveys were run in a pasture just south of the road where the seismic line was conducted. No usable results were obtained because of lack of radar penetration.

New Columbia. A narrow graben displacing Cretaceous strata and Pliocene-Pleistocene gravel has been mapped from outcrops southwest of the village of New Columbia (Figure 1). A ground-penetrating radar survey was conducted across the graben in hopes of detecting deformation in Pleistocene valley-fill sediments. The survey was taken across a small valley underlain by sandy alluvium, and flanked by hillsides on which loess overlies Mississippian sandstone. The radar could not penetrate loess on the uplands, but showed a series of broken, tilted reflectors along the valley bottom, where the graben is inferred to run. Because the findings appeared promising, Xenon Geosciences conducted two additional short radar surveys in the valley bottom, using antennae of higher frequency. The 300 MHz antenna yielded the highest quality of data, yet the area of coherent reflectors is too small to allow confident interpretation of subsurface structure.

Reineking Hill. As at New Columbia, outcrop mapping at Reineking all delineates a narrow graben, into which Cretaceous (and younger?) sediments are downdropped against Mississippian sandstone. We ran a ground-penetrating radar survey across a level bottomland where Pleistocene valley-fill sediments overlie the mapped graben. Surficial soils are silty clay loam; character of subsoil is unknown. The radar was unable to penetrate topsoil to any significant degree and no usable results were obtained.

Reference

Kolata, D.R., Treworgy, J.D., and Masters, J.M., 198 1, Structural framework of the Mississippi Embayment in southern Illinois: Illinois State Geological Survey, Circular 516, 38 p.

Reports Published

No reports (other than required internal NEHRP documents) have been published in relation to this research.

Non-Technical Project Summary

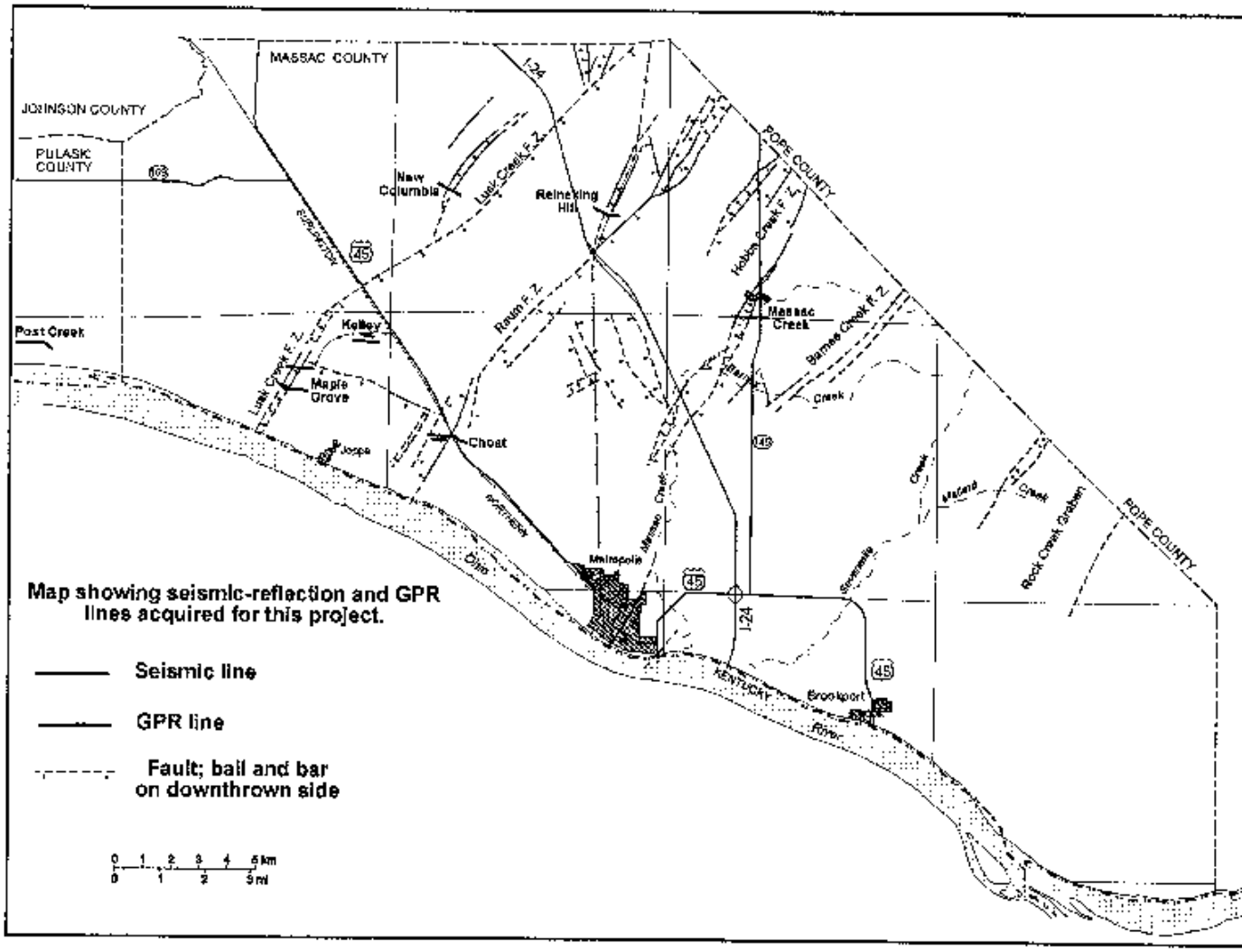
Seismic and ground-penetrating radar surveys were carried out at seven sites in southern Illinois where faults are believed to displace Quaternary sediments. Seismic surveys yielded generally good results, clearly indicating faults at two sites and possibly indicating faults at three other sites. Additional data processing may allow more confident interpretations at the latter three sites. Radar surveys yielded little or no usable data because radar cannot penetrate silty soils in the study

area. The faults detected by seismic work will be investigated further by drilling next year.

Table 1. Length (meters) of seismic and radar surveys conducted for this study.

Site	UMR Seismic	USGS Seismic	Radar
Massac Creek No. 1	875 m		790 m
Massac Creek No. 2	1070 m		
Choat		1507 m	2 lines, 440 m
Maple Grove		894 m	732 m
Reineking Hill			460 m
New Columbia			460 m
Kelley No. 1	342 m		
Kelley No. 2	730 m		
Post Creek	805 m		
Total	3822 m	2401 m	2882 m

Figure 1. Map showing seismic-reflection and GPR lines acquired for this project.



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