



UNITED STATES  
NUCLEAR REGULATORY COMMISSION  
WASHINGTON, D. C. 20555

MAR 24 1980

MEMORANDUM FOR: Harold R. Denton, Director  
Office of Nuclear Reactor Regulation

Robert B. Minogue, Director  
Office of Standards Development

FROM: Robert J. Budnitz, Director  
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER NO. 85  
AN INTEGRATED GEOPHYSICAL AND GEOLOGICAL STUDY OF THE  
TECTONIC FRAMEWORK OF THE 38TH PARALLEL LINEAMENT IN  
THE VICINITY OF ITS INTERSECTION WITH THE EXTENSION OF  
THE NEW MADRID FAULT ZONE - ANNUAL PROGRESS REPORT -  
FISCAL YEAR 1979 - PURDUE UNIVERSITY

- References:
1. Title 10, Chapter 1, Part 100, CFR Appendix A -  
Seismic and Geologic Siting Criteria for Nuclear  
Power Plants
  2. Memo: N. B. Steuer to R. J. Mattson dated  
July 15, 1975, subject: U.S. Tectonic Province Map

This memo transmits NUREG/CR-1014 entitled, "An Integrated Geophysical and Geological Study of the Tectonic Framework of the 38th Parallel Lineament in the Vicinity of Its Intersection with the Extension of the New Madrid Fault Zone - Annual Progress Report - Fiscal Year 1979." The research effort to produce this report was conducted by Purdue University, Department of Geosciences, in cooperation with the University of Texas and the University of Pittsburgh Geoscience Departments. This effort was conducted under the direction of Prof. W. J. Hinze of Purdue University as a part of the New Madrid Cooperative Program. It is the third in a series of reports that summarizes information presented in previous reports and presents results of study data acquired since the previous interim reports were published.

SUMMARY OF THE PURDUE STUDY OF THE 38TH PARALLEL LINEAMENT

This study is a part of the "New Madrid Seismotectonic Study" which is a coordinated program of geological, geophysical, and seismological investigations of the area within a 200-mile radius of New Madrid, Missouri. The study is designed to define the structural setting and tectonic history of the area in order to realistically evaluate earthquake risks in the siting of nuclear facilities. An important goal of the research program is to produce useful seismotectonic and seismic zoning maps for the study area.

The principal progress in this integrated study program has been in acquiring and synthesizing critical magnetic, gravity, and geologic data; conducting crustal seismic investigations; and in interpretation of the available data.

Two of the most important tectonic features of the continental interior are the New Madrid Fault Zone and the 38th Parallel Lineament. The northeasterly-trending New Madrid Fault Zone has been the site of several intermediate and major earthquakes in historic time and is the most seismically active area in eastern North America. The trend of the New Madrid Seismic Zone extends into Southern Illinois and Indiana in the vicinity of the Wabash River Valley Fault System. This trend intersects the 38th Parallel Lineament in the vicinity of the confluence of the Wabash and Ohio Rivers. The 38th Parallel Lineament is a band of geologic features extending across the eastern U.S. along the 38th parallel of latitude. It is manifested in many ways, but primarily by a series of east-west trending fault zones (Figure 1) which were active at least through the Paleozoic Era. It may represent a Precambrian fracture zone or crustal boundary extending deeply into the crust and possibly the mantle.

A suite of geophysical data sets is being collected, processed, analyzed, and interpreted using observed geologic constraints from the basement and overlying sedimentary rocks to investigate the tectonic and geologic history of the 38th Parallel Lineament and the extension of the New Madrid Fault Zone and associated features, and to determine the variations in structure and properties of the crust and their relationship to the regional contemporary geodynamics. Gravity and magnetic anomaly data have been collected and reduced to complete coverage over the study area from 36.5° to 39°N latitude and from 85° to 90°W longitude. Preliminary compilations have been completed in the vicinity of the extension of the New Madrid Fault Zone and all data are being gridded in preparation for compiling the regional maps and the computation of interpretative maps. Several seismic refraction profiles have been recorded in the Wabash Valley by project personnel and a preliminary analysis in Indiana and Illinois to study the velocity structure of the crust. These profiles have centered on the Wabash Valley Fault Zone and the New Madrid Fault Zone extension. In addition, petrologic studies by the University of Pittsburgh and the mafic and ultramafic dikes and related intrusions have shown that the mantle was involved in the tectonic development of the region. Furthermore, various basement geologic maps including age, lithology, configuration, and geophysical provinces are being developed to assist and constrain the geophysical interpretation.

Although the principal effort has been directed toward collecting and processing data, several significant preliminary results have been obtained which bear strongly on the tectonic history or contemporary geodynamics of the region. Interpretation of the regional gravity and magnetic anomaly maps indicates parallel linear trends of isolated nearly circular, correlative positive gravity and magnetic anomalies which bound a central zone of low gravity and magnetic anomaly relief and are associated with the New Madrid Seismic Zone. These trends can be traced northeast across the 38th Parallel

Lineament and related prominent west-northwest striking geophysical anomalies into southern Indiana at least 39°N latitude. These trends of circular anomalies which are interpreted as having a source within the basement are associated with the trend of earthquake epicenters in the New Madrid area. This suggests that a linear basement structural feature is a primary control on the location of earthquake epicenters in the New Madrid region. The extension of the New Madrid structural feature to the northeast does not imply that it is or will be seismically active along its entire length. The frequency of occurrence of earthquakes northeast of the New Madrid area is clearly lower than in the New Madrid Seismic Zone. Thus, although the entire length of the feature (39°N latitude) is interpreted as a structural unit, it is unclear that it must be considered as a single unit for seismic regionalization.

Gravity and subsurface data indicate that the Rough Creek Fault Zone, a major element of the 38th Parallel Lineament near its intersection with the northern Mississippi Embayment, is the northern boundary of a complex graben. The scale and deep seated nature of the faulting suggest an origin by extensional tectonic forces related to intracratonic rifting. The graben was formed in late Precambrian-early Paleozoic time, has been reactivated and is now approximately 5 km deep.

Short to intermediate period (5-80 sec) Rayleigh waves recorded at St. Louis, Missouri and Oxford, Mississippi have been analyzed to determine group and phase-velocity dispersion curves. These data were used to determine crustal and upper mantle shear-velocity structure of the northern Mississippi Embayment. The derived models show the crustal thickness to be at least 47 km and probably in the range of 50-55 km. An anomalously high-velocity layer ( $V_s = 4.0$  km/sec) occurs in the lowermost crust. These results together with previous studies are highly suggestive of a failed rift zone (aulacogen).

The results of the investigation to date demonstrate the importance of regional, integrated geological and geophysical studies in investigations of contemporary tectonics and seismicity in the Midcontinent region. These data also provide striking evidence for basement structural control of contemporary stresses.

#### RESULTS AND EVALUATION

The major products completed in FY 79 include the following:

1. A gravity survey of Indiana, south of the 39th parallel, was completed;
2. Gravity data for the region around New Madrid were acquired and reduced;
3. Aeromagnetic data from southeastern Illinois (collected last year) were filtered and various interpretive maps were prepared;

4. Aeromagnetic and gravity data were integrated for the area bounded by 36.5°-39°N latitude and 85°-90°W longitude. With these data, a 2 km grid has been interpolated to facilitate computation of interpretive maps. Bouguer gravity anomaly and total magnetic intensity anomaly maps have been prepared for the area. These maps, along with the interpolated grid values, represent a most significant accomplishment toward making integrated geophysical information available to the researchers in the New Madrid region;
5. Crustal seismic refraction profiles were acquired, and preliminary interpretations of the data were made;
6. A new hypothesis was proposed suggesting that the rifting and associated igneous intrusions present in the New Madrid area may extend northeastward into central Indiana;
7. A bibliography, listing approximately 1200 studies on continental rifts, was prepared; and
8. Radiometric dating was completed for several samples of igneous rocks from the New Madrid region.

The potential extensions of the New Madrid seismic zone northeastward across the Rough Creek Fault Zone toward central Indiana has been postulated. This hypothesis is based on similarities of geophysical signatures from the New Madrid area to those to the northeast. This is a legitimate hypothesis that may be proved or disproved during current and future studies.

Geologic evidence that has been building up during the past few years suggests that the New Madrid area and its associated seismic activity is quite separate from the area north of the Rough Creek. This geologic picture is now counter-balanced by the geophysical picture. Seismology will be an important key to the puzzle. Currently the Wabash Valley array is recording few seismic events. Those that have been recorded appear to have hypocentral depths of 20 km or more. This is considerably deeper than earthquakes in the New Madrid area.

With another year of seismic records, a deep seismic reflection line across the postulated linear trend, and analyses by other workers in the region, we should be able to adequately test this hypothesis. The original licensing posture of NRC in extending the zone of potential New Madrid type earthquakes northeastward to Vincennes, Indiana, is conservative, and there is no reason to alter this posture until further studies are completed.

## BACKGROUND

Refer to RIL No. 48, "A Tectonic Overview of the Midcontinent." The background information in RIL 48 applies equally to this RIL. It covers ACRS recommendations, relevance of 10 CFR Part 100 Appendix A to the study, and previous NRC effort and organization of the current programs.

NUREG/CR-1014 presents results of gravity and aeromagnetic surveys conducted in critical areas around the intersection of the 38th Parallel Lineament and the extension of the New Madrid Fault Zone. Available aeromagnetic maps have been digitized and these data have been processed by a suite of computer programs developed for this purpose. Seismic equipment has been prepared for crustal seismic studies and a 150 km long seismic refraction line has been observed along the Wabash River Valley Fault System. Preliminary basement rock and configuration maps have been prepared based on studies of the samples derived from basement drill holes.

Interpretation of these data is only at a preliminary stage, but studies to this date indicate that the 38th Parallel Lineament features extend as far north as 39°N and a subtle northeasterly-striking magnetic and gravity anomaly cuts across Indiana from the southwest corner of the state, roughly on strike with the New Madrid Seismic Zone.

## RECOMMENDATIONS

While these interim results are not definitive, we recommend that the current practice of extending the New Madrid 1811-1812 earthquakes north of the Rough Creek Fault Zone (38th Parallel Lineament) be continued. It is also recommended that the information in NUREG/CR-1014 be considered by the Office of Standards Development and the Office of Nuclear Reactor Regulation as input to the development of a tectonic province or seismic zoning map of the eastern U.S. and to provide a basis and guide for ongoing studies in the area.

Additionally, RES recommends that these studies which are in the data gathering phase, especially the seismic monitoring in areas of low seismicity, be continued to attain the objectives previously stated so that we may better understand the geology and seismicity of the eastern U.S. Projects should be redirected and modified as deemed necessary by ongoing work.

It is also recommended that researchers make annual oral presentations to all NRC geologists and seismologists so that work progress can be discussed and studies redirected, if necessary.

Harold R. Denton  
Robert B. Minogue

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Technical questions concerning NUREG/CR-1014 may be directed to Neil Steuer  
at 427-4370.

A handwritten signature in black ink, appearing to read "Robert J. Budnitz". The signature is written in a cursive style with a prominent initial "R" and a long, sweeping underline.

Robert J. Budnitz, Director  
Office of Nuclear Regulatory Research

Enclosures:

1. NUREG/CR-1014
2. Figure 1

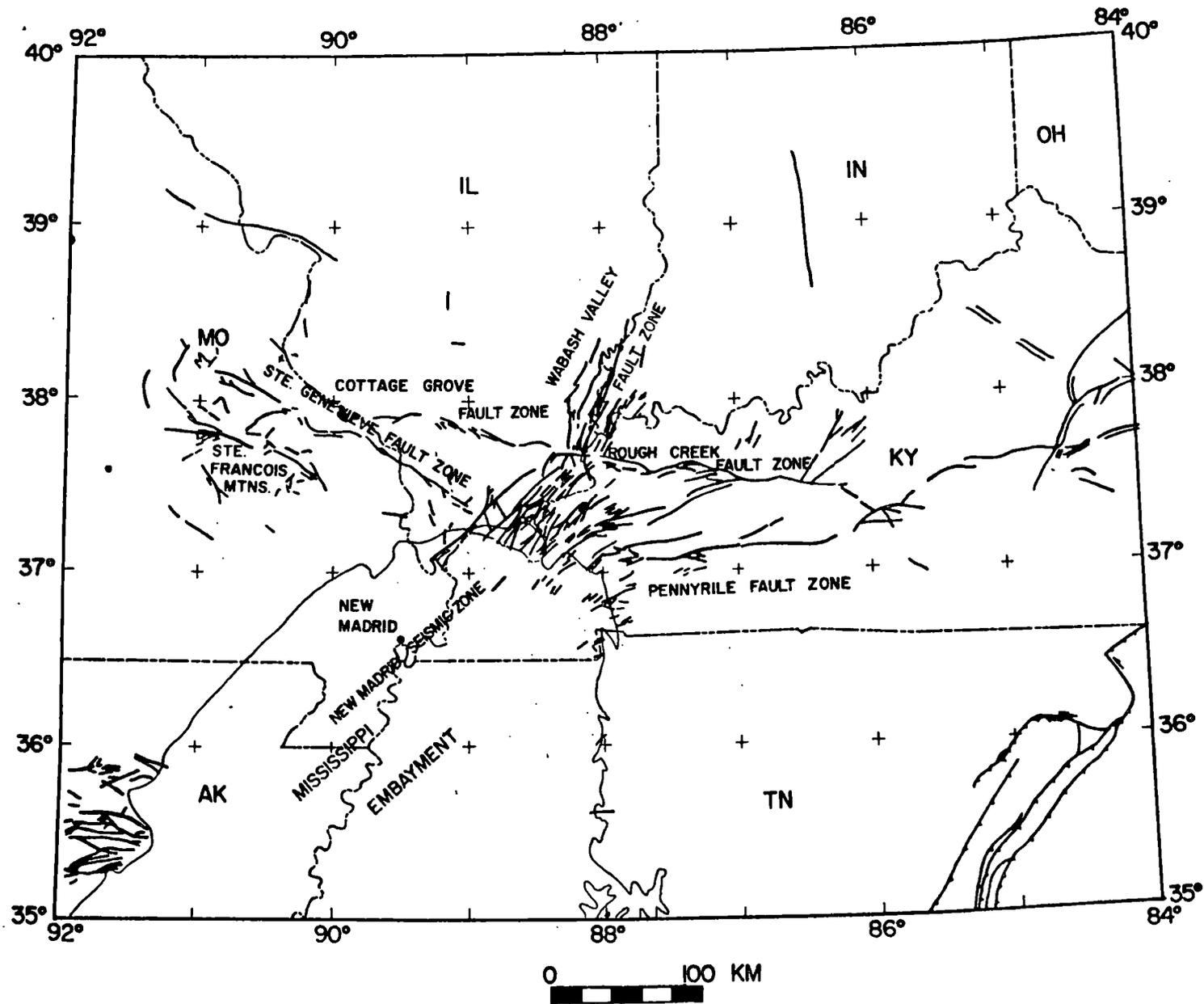


Figure 1 Tectonic features in the New Madrid Seismic Zone and surrounding area (generalized from Heyl and McKeown, 1978; Heyl, 1972; and other sources).

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Office of Nuclear Regulatory Research

- Enclosures:  
1. NUREG/CR-1014  
2. Figure 1

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