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

PDR

OCT 12 1979

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

Robert B. Minogue, Director
Office of Standards Development

FROM: Saul Levine, Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER NO. 60
SEISMICITY AND TECTONIC RELATIONSHIPS OF THE NEMAHA UPLIFT IN OKLAHOMA

REFERENCES:
1. Letter W. R. Stratton to Dixie Lee Ray dated May 16, 1973. Subject: Report on Seismic Research.
2. Title 10, Chapter 1, Part 100, CFR Appendix A - Seismic and Geologic Siting Criteria for Nuclear Power Plants.
3. Memo: N. B. Steuer to R. J. Mattson dated July 15, 1975. Subject: U.S. Tectonic Province Map.

INTRODUCTION

This memo transmits NUREG/CR-0050 entitled "Seismicity and Tectonic Relationships of the Nemaha Uplift in Oklahoma FY 77." The research effort to produce this report was conducted by the Oklahoma Geological Survey. This research is a cooperative geologic, seismic and geophysical effort of the State Geological Surveys of Oklahoma, Kansas, Nebraska, Iowa and Minnesota to study the earth science parameters of the Nemaha Uplift and the Midcontinent Gravity Anomaly. The Nemaha Uplift and Midcontinent Gravity Anomaly are buried geologic structures along which there has been a history of earthquake activity. Hence, a knowledge of the Nemaha Uplift and Midcontinent Gravity Anomaly is of vital importance in the siting and licensing of nuclear power plants.

SUMMARY

Geologic and seismologic investigations of the Nemaha Uplift began on October 1, 1976. The geological studies have focused, thus far, on the construction of a series of structure-contour maps on key stratigraphic horizons -- the top of the Ordovician Viola Formation, the base of the Pennsylvanian, and the top of the

Middle Pennsylvanian Oswego Formation. The contour-mapping phase of the program is approximately two-thirds completed. The initial mapping program reveals a complex fault pattern and geologic history of the Nemaha ridge. It appears that the uplift and associated faults began in Early Pennsylvanian time and that tectonic activity ceased in Middle Pennsylvanian time, at least in central Oklahoma.

A discussion of basement rocks in central Oklahoma is included within this report. The most systematic basement-rock study that includes the Nemaha ridge area was [illegible] Denison (1966), who classified the central Oklahoma basement rocks into [illegible]lowing four units: (1) Washington County Volcanic Group; (2) Spavinaw Granite Group; (3) Osage County Microgranite; and (4) Central Oklahoma Granite Group. The isotopic ages range from 1,150 to 1,270 million years, and these ages, when considered with analytical variations, indicate a main period of thermal activity within 1,200 million years ago.

The seismological studies have concentrated on the installation of eight seismometers in such a way as to include detailed coverage of the Nemaha ridge in Oklahoma as well as most of the remaining area of Oklahoma.

Geological Investigations

Oklahoma can be subdivided into several major geologic and tectonic provinces (Fig. 1). One of these structural features, the Nemaha ridge, is a long north-south uplift that extends northward from central Oklahoma through Kansas and into Nebraska. The Oklahoma portion of the ridge is 10 to 20 miles wide and nearly 150 miles long. A number of earthquakes have occurred along or west of the Nemaha ridge, with those at El Reno, Oklahoma, being most intense.

The Nemaha ridge consists of a number of small crustal blocks that were raised sharply along the axis of the uplift. These uplifted crustal blocks are typically 3 to 5 miles wide and 5 to 20 miles long and are bounded by faults on the east and/or west sides. These blocks were uplifted and eroded during Late Mississippian (350 million years ago ±) and Early Pennsylvanian (290 million years ago ±) time, and subsequently they were covered by later Pennsylvanian and Permian sediments. At least some of the deep-seated faults near the axis of the Nemaha ridge were reactivated during Middle Pennsylvanian time.

Structure-Contour Program

A comprehensive geological investigation began concurrently with the installation of a regional network of seismographs. To better understand the geologic and tectonic history of the Nemaha ridge, a series of structure-contour maps on key stratigraphic horizons is being constructed.

Three horizons were selected for structure-contour mapping -- the top of the Middle Pennsylvanian Oswego Formation, the base of the Pennsylvanian, and the top of the Ordovician Viola Formation. These units were selected because they have been penetrated by a large number of boreholes and because of their easy identification on electric logs.

Seismological Studies

An eight seismometer seismic net was installed in such a way as to include detailed coverage of the entire Nemaha ridge in Oklahoma, as well as most of the remaining area of Oklahoma (Fig. 2). This network of seismograph stations would allow the following capabilities: (a) marginal detection of all m_{3Hz} 1.7 earthquakes; (b) reliable detection of all m_{3Hz} 2.0 earthquakes; (c) marginal location of all m_{3Hz} 1.8 earthquakes, and (d) reliable detection of all m_{3Hz} 2.1 earthquakes.

It was anticipated that the maximum detection capability of the network would overlap into Kansas, and provide, with the Kansas and Nebraska networks, continuous coverage of the Nemaha ridge area.

CRITERIA FOR STUDY AREA SELECTION AND OBJECTIVES OF STUDY

The midcontinent area of the United States has a number of population centers that have undergone rapid growth since the second World War. This increased growth, in conjunction with the increase in fossil fuel costs, has stimulated electrical generation companies to consider nuclear power plants as a means to provide additional energy. There are, at the present time, two operating and four proposed nuclear power plants in Nebraska, Kansas, and Oklahoma. At least three more are being considered for this same area. All of the existing and proposed plants are located within or adjacent to an area which has been designated as seismic risk zone 2, an area having had earthquakes with resulting moderate damage and corresponding to seismicity up to MM VII.

NRC has rigorous guidelines which must be adhered to before a permit to construct a nuclear power plant is granted to an applicant. Local, as well as regional seismicity and structural relationships play an integral role in the final design criteria for nuclear power plants. This requires that a value for the maximum expectable seismic event be assigned at a proposed site. The existing historical record of seismicity is inadequate in a number of areas of the Mid-continent region because of the lack of instrumentation and/or the sensitivity of the instruments deployed to monitor earthquakes events. This inadequacy has made it necessary to rely on the delineation of major tectonic provinces that are based on broad regional geologic structures and associated seismicity. The delineation of tectonic provinces which accurately reflect the potential magnitude of seismic events is an important cost and risk factor in assigning appropriate design criteria for nuclear power plants.

Many earthquakes have occurred along the Nemaha Uplift, and they have, in the past, been ascribed to crustal adjustment associated with that structure. More recently, geologists have theorized that they are related to Precambrian basement configuration, structure and lithology, and are genetically related to the Arbuckle, Nemaha, and Keweenawan Mafic Belt structures stretching from Southern Oklahoma to the Northern Peninsula of Michigan. Little is known about the relationships of these structures, and this project will be a part of a larger study effort to investigate their possible interaction.

The objectives of the project are: (1) to delineate the Nemaha Uplift and its associated structures; (2) to investigate the relationships between the Nemaha Uplift and the Keweenawan Mafic Belt; and (3) to assign realistic values for maximum seismic magnitude in the region. In order to carry out the above objectives, the Geological Surveys of Oklahoma, Kansas, and Nebraska have established seismic networks in Oklahoma, central and eastern Kansas, and eastern Nebraska. Seismic data from the networks are collected and forwarded to the Oklahoma Geological Survey. Seismograms in existence prior to the NRC contract with the Oklahoma Survey, but unpublished, are being gathered and compiled. Gravity and aeromagnetic studies are being performed, and detailed field studies undertaken where necessary. Final results will be presented in the form of a series of maps and tables at a scale of (1:1,000,000) accompanied by explanatory text. These will outline the relative seismicity in the study area and attempt to correlate it with tectonic features known from surficial and subsurface geological and geophysical evidence.

This investigation will be closely related to an NRC-sponsored study conducted by the Geological Surveys of Michigan and Minnesota and the University of Minnesota and Michigan Technological University.

PLANNING

Initially, a five year program was planned. Project work is separated into the three phases listed below. This report presents results of work completed in Phase I.

Phase I
- Purchase and installation of equipment to establish the seismic network.
- Recruitment and training of volunteer operators.
- Compilation and synthesization of existing geologic and geophysical data.
- Analysis of the seismograms.
- Prepare an interim report for fiscal year ending October 1977.

Phase II - Installation of a microearthquake network.

- Operation and monitoring of the seismic network.
- Analysis of the seismograms.
- Prepare an interim report for fiscal year ending October 1979.

Phase III - Gravity profiles.

- Operation and monitoring of the seismic network.
- Analysis of the seismograms.
- Field studies of known or inferred fault areas.
- Final compilation and report after fiscal year ending October 1981.

NUREG/CR-0050 covers all of Phase I.

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, previous NRC effort and organization of the current programs.

RESULTS

NUREG/CR-0050 describes data that were gathered during the time period covered by the NUREG and presents some preliminary results.

The geologic and seismic data base available in this time period is insufficient to evaluate the area except on a preliminary basis. A seismotectonic model for the Nemaha Uplift in Oklahoma must be based on concepts developed from results of the studies and must consider vertical and lateral variations in composition and physical properties of this tectonic feature.

Study results are being used by Rondout Associates, Inc., in a project funded by the Office of Nuclear Reactor Regulation to produce a seismic zoning map for the eastern U.S. Additionally, data gathered by the Oklahoma Nemaha Seismotectonic Study are considered by the NRR staff in making licensing decisions.

RECOMMENDATIONS

It is recommended that the information contained in NUREG/CR-0050 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 studies be continued in this area to attain the objectives previously stated, with redirection and modification of projects as deemed necessary by ongoing work.

Technical questions concerning NUREG/CR-0050 results may be directed to Neil B. Steuer at 427-4370.

Saul Levine

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Office of Nuclear Regulatory Research

Enclosures:
1. NUREG/CR-0050
2. Figure 1
3. Figure 2

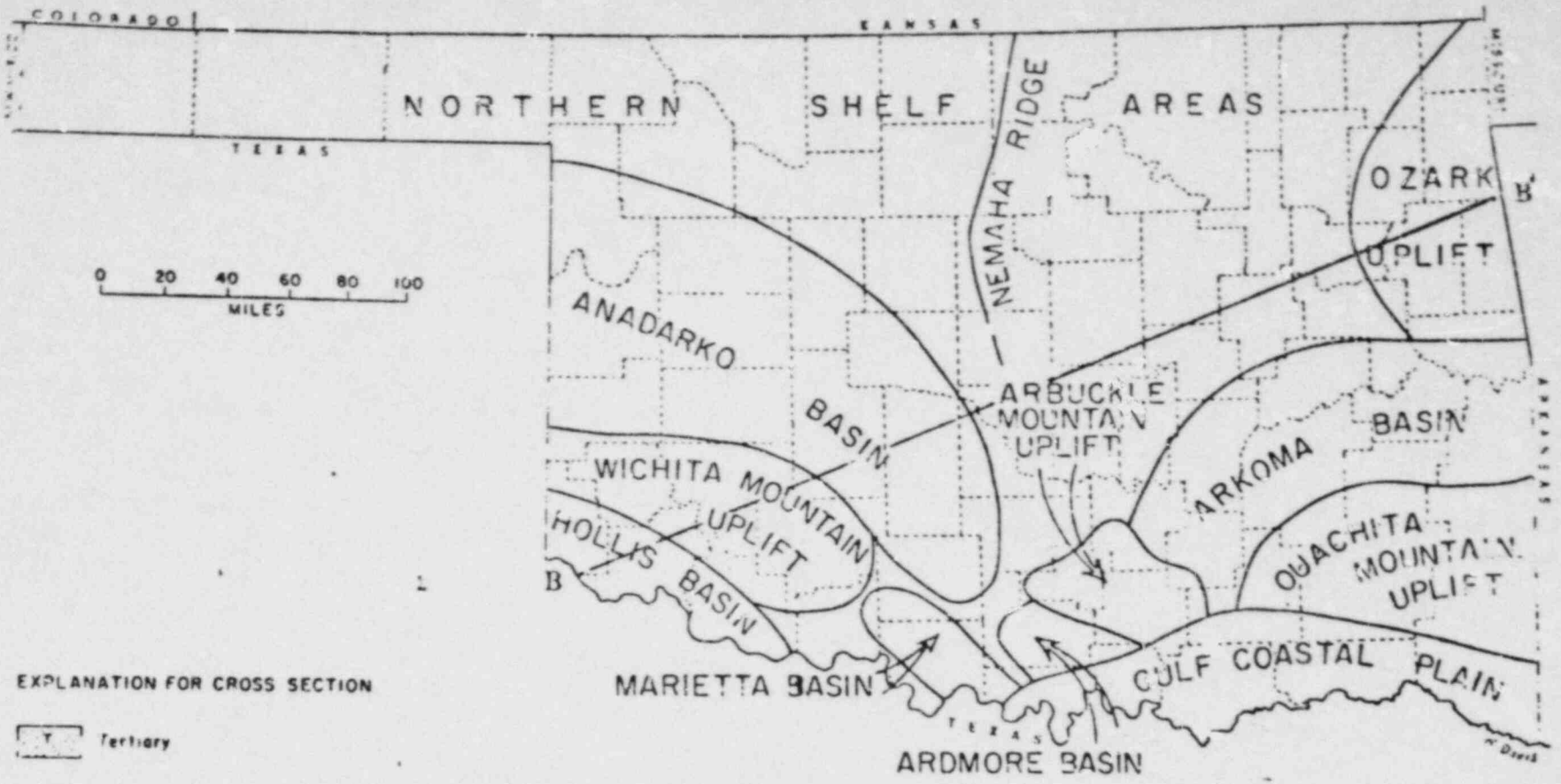

Fig. 1. Major geologic provinces of Oklahoma.

Fig. 2. TUL, symbol ✪, operates 25 seismographs (remotes excluded) and other geophysical instrumentation near Leonard, OK. Stations marked ☆ have high-frequency vertical seismometers whose signal is telemetered to TUL in the 216-220 MHz band. Stations marked ★ are field-recording, volunteer-operated, high-frequency vertical seismographs whose records are mailed to TUL.

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Original Signed By
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1. NUREG/CR-0050
2. Figure 1
3. Figure 2

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