UNITED STATES
NUCLEAR REGULATORY COMMISSION
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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. 66
"A STUDY OF THE REGIONAL TECTONICS AND SEISMICITY OF EASTERN KANSAS--SUMMARY OF PROJECT ACTIVITIES AND RESULTS TO THE END OF THE SECOND YEAR OR SEPTEMBER 30, 1978"

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. Memorandum N. B. Steuer to R. J. Mattson dated July 15, 1975. Subject: U.S. Tectonic Province Map.

INTRODUCTION

This memorandum transmits NUREG/CR-0666 entitled, "A Study of the Regional Tectonics and Seismicity of Eastern Kansas--Summary of Project Activities and Results to the End of the Second Year or September 30, 1978." The research effort to produce this report was conducted by the Kansas Geological Survey. This research is a cooperative geologic, seismic and geophysical effort of the State Geological Surveys of Kansas, Oklahoma, Nebraska, Iowa and Minnesota to study the earth science parameters of the Nemaha Uplift and the Midcontinent Gravity Anomaly. Some scientists have associated earthquakes with the Nemaha Uplift and Midcontinent Gravity Anomaly geologic structures. Hence, a knowledge of the Nemaha Uplift and Midcontinent Gravity Anomaly are of vital importance in the siting and licensing of nuclear power plants.

SUMMARY

The Kansas Geological Survey, in cooperation with the state geological surveys of Oklahoma, Nebraska, and Iowa, is conducting a 5-year study of the regional tectonics and seismicity of the Nemaha Uplift and other regional geologic structures of the central midcontinent.

The purpose of this research is to gain a better understanding of the sources of earthquakes that have occurred in the region as an aid to developing a more rational evaluation of earthquake risk as it applies to the siting and design of nuclear facilities. This NUREG summarizes the activities and results of all work done to September 30, 1978.

The elements of the study are: (1) a reinventory of historic earthquakes in Kansas; (2) regional surface and subsurface geologic studies; (3) regional aeromagnetic and gravity studies; (4) regional studies of specific areas; (5) detailed surface and subsurface studies of specific areas; (6) acquisition, installation, and operation of a regional seismograph network for recording microearthquakes; (7) exploration of seismology for location of faults; (8) synthesis and analysis of data from above studies and integration with that from studies being done in adjacent states; (9) a synthesis, analysis, and interpretation of data; and (10) Bouguer gravity map of eastern Kansas.

Research on historic earthquakes in Kansas uncovered several hundred previously unpublished felt reports which resulted in relocation of three epicenters including those of the two largest moderate earthquakes to date, the "Manhattan" MM VII-VIII events of 1867 and 1906. Reports indicate these epicenters occurred east of Manhattan, near or on the subsurface trace of the Humboldt fault zone.

A new map of the top of the Precambrian surface from a study of approximately 2900 well logs was compiled. Data were replotted to a standard map projection. The map shows major features on the Precambrian basement surface which are important to understanding the tectonic history of the region. Basement faulting and reactivation of Precambrian fracture systems is thought to be the cause of past and possibly future seismic activity.

A map of Precambrian basement rock types, distribution, and ages was compiled. Rock samples from approximately 800 wells were studied. Much of northern Kansas is underlain by mesozonal granites and metamorphic rocks ranging in age from 1450 to 1670 million years (m.y.). Southern Kansas is underlain by shallowly emplaced granites and associated volcanic rocks consisting of porphyritic rhyolite and dacite. Age of this terrane is considered to be about 1400 m.y. The midcontinent rift system in north-central Kansas contains mafic rocks, mainly olvine-bearing gabbros of Keweenawan age, or about 1100 m.y. They are surrounded by arkosic rocks and siltstones of the Rice formation. Age of these sediments is presumed to be Late Precambrian, but they may be younger.

The best marker beds that are more or less continuous over much of the Nemaha ridge, except for its highest point, are those of the Kansas City group (Upper Pennsylvanian). A structural contour map of the base of Kansas City (BKC) was compiled. Faulting of the BKC is inferred along the trace of the Humboldt zone in the northern part of the state and draping of sediments over deeper faults is inferred toward the south. Sharp changes in the structural attitude of contours in the basinal areas east of the Nemaha Uplift were also thought to reflect faulting.

An aeromagnetic map of eastern Kansas shows many of the features of the Precambrian anomalies of unknown origin. Less intense linear and curvilinear magnetic anomalies reflect faults bordering the midcontinent rift system and extensions into Kansas of NW trending Precambrian fracture systems which are known or inferred in Missouri.

A map of lineaments and circular features in eastern Kansas, mainly reflecting straight segments of streams and circular drainage patterns, was compiled from LANDSAT imagery. Many of the major stream lineaments coincide with Precambrian fracture systems mentioned previously. The minor trends may reflect subsurface faulting or joints. The circular features may represent doming or circular fractures in the crust, perhaps caused by meteorite impact during early stages of crustal formation.

Studies in Pottawatomie County, found no evidence of faulting at the surface. Monoclinal flectures occurred in surface beds of Upper Pennsylvanian and Lower Permian age over the trace of the fault zone. Subsurface faulting was detected in beds older than basal Kansas City (Upper Pennsylvanian), and suggested that the stream drainage pattern might indicate strike-slip or wrench fault movement on basement faults.

Studies demonstated that faulting occurred at and near the surface immediately south of the Nebraska border and that glacial till of Kansan age was affected. The studies showed a strong correlation between stream drainage patterns, surface geomorphic features, and the Precambrian basement structure.

Only a slight correlation of positive gravity anomalies with a moderately strong magnetic anomaly in the Wolf Creek area was found. The magnetic anomaly suggests that it was caused by low density, along a basement fault zone.

A microearthquake monitoring network near the Nemaha Uplift was installed and is being operated. Equipment for three stations (Lawrence, LAK; Emporia, EMK; and Hiawatha, HWK) was purchased and installed under NRC funding during the spring of 1977. Concurrently, three additional stations (Belvue, BEK; Tuttle Creek, TCK; and Milford, MLD) were installed under funding of the Kansas City District, U.S. Corps of Engineers. These stations became operational between July 15 and October 1, 1977. During the spring of 1978, three more stations (Concordia, CNK; Salina, SND; and El Dorado, EDK) were purchased and installed under NRC funding. These stations became operational about April 15, 1978. The work involved locating sites, arranging for telephone service, drilling and casing of boreholes, and installation and testing of equipment. The seismometers are installed in 190-foot deep boreholes to reduce surface noise. The signal is telemetered to Lawrence via commercial telephone lines and recorded on a rock of paper-drum recorders at the Kansas Geological Survey. During the first full year of monitoring, 12 microearthquakes were recorded within or near the borders of Kansas. Several of these occurred along the trace of the Humboldt fault and, together with others recorded in central Oklahoma and southeastern Nebraska, indicate that the Humboldt system is at least slightly active.

An eight-channel exploration seismograph system was purchased in 1977 with partial NRC funding. Refraction lines run near the Humboldt fault zone in northern Kansas in 1977 were inconclusive because the complexity of the fault zone was not recognized at that time and the lines were too short. Acquisition of new multichannel cables and geophone strings in early 1978 permitted shifting to reflection spreads with geophone groups 12 m apart, six geophones per group aligned 1.5 m apart along a radial line from the shot point. Shots were 1.5 to 3 lbs of high explosive detonated by seismic cap and primer. Early results were favorable, and faulting was detected on what is believed to be the main zone of the Humboldt fault as well as subsidiary or related zones. During the 1979 field season, several profiles, two to three miles long, will be run along the trace of the fault.

Preliminary conclusions of the Kansas Geological Survey study results to date suggest that: (1) the Humboldt fault zone along the eastern flank of the Nemaha Uplift may be at least slightly active as indicated by several microearthquakes recorded along its length by the Kansas Geological Survey network during the first full year of monitoring. The reinventorying of past historic earthquakes also suggests that two of the largest events may be related to the Humboldt zone; (2) indirect evidence which appears to center about stream lineaments detailed geologic, geomorphic, and exploration seismological studies, suggests that the Humboldt and related faults in extreme northern Kansas have offset bedrock at or near the surface and affected glacial till deposits of Kansan age; (3) geophysical studies and surface and subsurface geological studies indicate that the Humboldt fault zone is more complex than previously recognized. Seismic profiles near the Kansas-Nebraska border indicate that the steeply dipping to vertical zone of sheared and broken rock in the main fault is at least 150 feet (48 m) wide. Branching and paralleling subsidiary faults are evident along the trace across Kansas. The zone displays characteristics of strike-slip or wrench faulting but no major displacement of Precambrian structures is indicated on the aeromagnetic map of eastern Kansas. The aeromagnetic data also indicate that the Nemaha ridge is complexly faulted along its entire length; (4) a major fault zone between the west flank of the Nemaha Uplift and the east side of the Keweenawan Mafic Belt rocks is inferred from geophysical and geological evidence in northern Kansas. Post-Middle Cretaceous movement may be suggested by the emplacement of a linear trend of kimberlite bodies at the surface in Kansas and a carbonatite in the subsurface in Nebraska along the trace of this fault zone; (5) the Nemaha granite ridge and associated structural features comprising the Nemaha Uplift may be related to the presence of the adjacent Keweenawan Mafic Belt rocks of the midcontinent rift system; (6) the midcontinent rift is not known to be tectonically active, but the presence of a wedge of dense mafic rocks in the crust may cause concentration of stresses around its margins; (7) larger moderate historic earthquakes along the inferred or known trace of the midcontinent rift system seem to be located at the offsets in the rift, and may be related to preexisting and cross-cutting Precambrian fracture systems; and (8) regional

studies of stream patterns and drainage divides which are in progress show a strong correlation with known or inferred Precambrian basement fracture systems. These studies show promise in helping to unravel the tectonic history of the region. It is emphasized that these are preliminary conclusions which may be changed or modified as additional data are obtained.

BACKGROUND

Support for Licensing Decisions

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 to the study, previous NRC effort and organization of the current programs.

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 during the period 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 viable 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 rigorous guidelines 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 Midcontinent region because of the lack of instrumentation and/or the sensitivity of the instruments deployed to monitor earthquake 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 to delineate the Nemaha Uplift and its associated structures, to investigate the relationships between the Nemaha Uplift and the Keweenawan Mafic Belt, and 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 already in existence, 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 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

A 5-year multidisciplinary study in cooperation with the Nebraska, Oklahoma, Iowa and Minnesota Geological Surveys is planned. The study will outline the geology, structure, tectonics and seismicity of the Nemaha Uplift and Midcontinent Gravity Anomaly region.

Project work is planned in three separate but interrelated phases, which are:

1) existing data synthesis;

2) acquisition of new data, seismic network installation and operation;

3) final synthesis of new and old data, interpretation, map and report preparation.

This interim report presents results of work completed in Phases I and II.

RECOMMENDATIONS

It is recommended that the information contained in NUREG/CR-0666 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.

The programs in Kansas have been very fruitful; therefore, 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, so that we may better understand the geology and seismicity of the eastern U.S.

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

Technical questions concerning NUREG/CR-0666 results may be directed to Neil B. Steuer at 427-4370.

Saul Levine

Saul Levine, Director
Office of Nuclear Regulatory Research

Enclosure: NUREG/CR-0666

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