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

DEC 28 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. 77
THE ORIGIN OF SURFACE LINEAMENTS IN NEMAHA COUNTY, KANSAS

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-0321, entitled "The Origin of Surface Lineaments in Nemaha County, Kansas." 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 (NU) and the Midcontinent Gravity Anomaly (MGA). The NU and MGA are buried geologic structures along which some scientists have associated a history of earthquake activity. Hence, a knowledge of the NU and MGA is 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 NU 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.

The studies are funded jointly by the Division of Reactor Safety Research, U.S. Nuclear Regulatory Commission; the Kansas City District, U.S. Corps of Engineers; and the Kansas Geological Survey, University of Kansas. This NUREG discusses linear and curvilinear features detected on remote sensing imagery in Nemaha County, Kansas.

The elements of the overall study, as proposed, 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 seismology for location of faults; and (8) synthesis and analysis of data from above studies and integration with that from studies being done in adjacent states. Of the ten major maps or studies to be produced or completed, all but two have been submitted to NRC. The remaining two are: (1) a synthesis, analysis, and interpretation of data; and (2) Bouguer gravity map of eastern Kansas.

Linear and curvilinear features detected on remote sensing imagery were correlated to drainage pattern in Nemaha County.

The influence of the Nemaha Ridge on present drainage networks appears significant. The Humboldt Fault was shown to breach the surface in the Fourmile Creek drainage basin near Bern, Kansas, offsetting Permian and Pennsylvanian beds by 54 to 74 m. Steep aeromagnetic and gravity gradients are superimposed over the trace of the Humboldt Fault zone and are likely related to it. The geophysical data suggest a complexly-fractured basement surface. Several of the linear trends, apparent on the aeromagnetic map, coincide with present drainage.

Available subsurface well information was used to generate a modified interpretation of the Precambrian surface configuration compatible with geophysical and surface observations. Underlying structure, especially on the west side of the Humboldt Fault zone where basement rocks are relatively shallow, is believed to exert considerable control over present drainage patterns. A lineament formed by two streams near Baileyville, Kansas, suggests recent movement in glacial deposits.

As part of the 5-year study, McCauley and others, (1978) conducted a search for surface lineaments using LANDSAT-MSS and side-looking airborne radar imagery as well as conventional and satellite photography.

Many recent studies using LANDSAT imagery elsewhere have emphasized the relationships between lineaments and areas of high seismicity (O'Leary and Offield, 1977). However, as O'Leary and Offield (1977) stated:

> "... work is only beginning to establish the geological meaning and causes of lineaments. Far too often work stops with photoanalysis, statistics, and assumptions; detailed field examinations and comparisons with geophysical data are too rarely pursued."

The purpose of this study was to define and to determine the origin of the surface lineaments observed in Nemaha County and portions of the surrounding counties in Kansas and Nebraska. The study necessitated a surface investigation of the area, gathering of geophysical data, and a synthesis of existing information from water, oil and gas well records.

Significance and Geologic Background

Kansas has long been identified with the Central Stable Region of the North American Continent (Snyder, 1968; Merriam, 1963). However, 25 earthquake epicenters in the state have been recorded since the mid-1800's (Fig. 1). The two most severe events, in 1867 and 1906, reached intensities VII-VIII on the Modified Mercalli (MM) Scale; their epicenters, according to the Kansas Geological Survey, are located in northeast Kansas near Manhattan (Merriam, 1956; Docekal, 1970; DuBois and Wilson, 1978). Pinpointing the epicenters, however, may be beyond the resolving power of the present data set. Determination of the cause and mechanisms for these events is as yet an unsolved problem.

Merriam (1963), Lee (1954), and other early investigators attributed much of the earthquake activity to movement along the Nemaha Ridge or the Humboldt Fault (Fig. 1) because of the proximity of several epicenters (MM VII-VIII) to these features in Kansas, Oklahoma, and Nebraska. The ridge is composed of Precambrian granitic rocks. It forms the core of the Nemaha anticline which consists of younger sedimentary rocks which have been folded and possibly faulted as a result of uplifts in the basement. The Humboldt Fault zone forms the eastern boundary of the ridge.

More recently, the significance of the Keweenawan mafic belt as a major structural feature has been recognized. The Midcontinent Geophysical Anomaly or Midcontinent Gravity Anomaly (Fig. 2) represents this belt of mafic lavas and gabbroic rocks intruded along a late Precambrian rift zone (King and Zeitz, 1970; Coons and others, 1967). The structure is bounded by faults where it is

exposed at the surface in the Lake Superior region, and geophysical data suggest that similar faults exist to the south where the feature is deeply buried beneath Paleozoic and younger strata (King and Zeitz, 1970). Surface structures associated with the MGA in northern Kansas include the Abilene anticline and Irving syncline (Jewett, 1941), both of which parallel its southeast flank, and the Riley County kimberlites (Brookins, 1970) which follow the same structural trend. These intrusives have been associated with right lateral strike-slip movement along a buried fault on the east flank of the Abilene anticline (Chelikowsky, 1972).

Docekal (1970) studied the isoseismal patterns of intensity VII-VIII historical earthquakes in the midcontinent and showed a relationship to basement structure and lithology. He concluded that the stronger seismic events in the region were genetically related to the Arbuckle, Nemaha, or Keweenawan mafic structures or combinations of them.

Other possible causes for some of the minor earthquakes and lineaments include movement along previously undetected faults, and perhaps stress release associated with isostatic rebound after glaciation (Nansen, 1921; Daly, 1934; Wilson, personal communication). Neither of these mechanisms has been fully investigated in Kansas.

There is a need for a better understanding of seismic activity and structural history in Kansas from a practical standpoint as well. Proposed siting of nuclear power plants in eastern Kansas, southeastern Nebraska, and northeastern Oklahoma, along with locations of existing and proposed reservoirs near the trace of the Humboldt Fault zone or within areas affected by past earthquakes, illustrates the necessity for a scientific rationale in setting design and safety standards for engineered structures in this region.

Description of Study Area

The area (Fig. 3) centers in Nemaha County, in a glaciated region underlain by bedrock of Late Pennsylvanian and Early Permian age. The general northwestward dip of the sedimentary strata in northeast Kansas is interrupted in Nemaha, Pottawatomie, and Jackson counties as a result of Late Permian and possibly post-Permian movements (Ward, 1974) along the Nemaha anticline, which lies near the center of the study area. Localized deformation of Permian beds occurs near Bern in Nemaha County where an eastward dip of up to 20° is recorded on the eastern flank of the anticline.

Movement along the Nemaha Ridge has greatly affected the thickness of the sedimentary rocks. Those on the west flank range in thickness from 175 m (600 ft) near Seneca to 300 m (1000 ft) at the western border of Nemaha County. On the steeper eastern flank, the sedimentary sequence attains a thickness of 1200 m (4000 ft) within a few kilometers of the axis (Ward, 1974).

The Precambrian Surface Map of Kansas (Cole, 1976) shows the Humboldt Fault at the eastern flank of the Nemaha Ridge extending through Nemaha County into Pottawatomie County. Another shorter fault is plotted on the same map a few miles east of the Humboldt with a trend approximately 10° E.

The nature of the surface expression of these subsurface displacements is debatable. Conclusive evidence concerning the presence and age of surface faulting was one of the main objectives of this study.

Bedrock exposures (Fig. 4) are scarce throughout eastern Kansas because of the cover of Pleistocene glacial debris. Outcrops in Nemaha County are found only along stream valley walls, except in the northeastern corner of the county where erosion has removed some of the glacial deposits from the uplands (Ward, 1974). Both the Nebraskan and Kansan glaciers advanced into the study area (Fig. 3). The glacial deposits that remain vary in thickness from 1 to 155 m (Ward, 1974; Frye and Walters, 1950; Mudge and others, 1959). Alluvial deposits beneath the terraces and along present stream valleys are of Illinoisan to Recent age (Ward, 1974). Scattered loess deposits can be found throughout the area.

Many of the present streams display prominent angular or rectangular drainage patterns (Plate 3 of the NUREG). Alignment of streams, such as Manley Creek, Negro Creek, and the North Fork of Vermillion River, along with apparent parallelism of many tributaries, suggests the influence of underlying structure upon the drainage network. Several circular drainage patterns have developed; Turkey Creek, Wolf Pen and Deer Creeks, Harris Creek, Fourmile Creek, and Rock Creek exemplify this phenomenon in Nemaha County. Aeromagnetic and gravity surveys conducted by Yarger and others (open file, 1978) indicate that many of the geophysical anomalies in northeast Kansas are outlined by circular drainage features and lineaments found on the remote sensing imagery (McCauley and others, 1978).

BACKGROUND

In 1973 (Ref. 1) the ACRS recommended that investigations be initiated to determine the reasons for, and source of, earthquakes in areas of the eastern U.S. where large shocks have occurred.

This recommendation also was, in part, brought about by Appendix A, 10 CFR Part 100 (Ref. 2) which establishes requirements for seismic and geologic site investigations for nuclear power plants and associated nuclear facilities necessary for evaluation of the site and for providing information needed for engineering designs. Paragraph (6), Section IV

of Appendix A requires that, where possible, epicenters of historically reported earthquakes be correlated with tectonic structures, any part of which are within 200 miles of the site, and that epicenters or locations of highest intensity which cannot reasonably be correlated with tectonic structures should be identified with tectonic provinces, any part of which are within 200 miles of the site.

This part of the Regulation was developed to take into account the fact that tectonic settings of the eastern U.S. are significantly different from those of the western U.S. The Regulation does not provide guidance in the form of a map to establish seismotectonic provinces in the East. This has resulted in lengthy licensing delays because of the time needed to resolve controversies among applicants, the public and NRC regarding tectonic province boundary locations.

In 1974 the Office of Standards Development undertook an effort to develop an eastern U.S. Seismotectonic Province Map; however, when the map was completed, there was a consensus opinion that it was not adequate to clarify Appendix A to 10 CFR which requires the tectonic province approach. There remained specific information needs to be satisfied in order to develop a map which will be a useful regulatory tool. That is, more geologic data and seismologic input are needed to more accurately delineate eastern U.S. seismotectonic provinces. Consequently, the cooperative geologic and seismic programs were undertaken with state geological surveys and universities to gather regional data to (1) help delineate tectonic provinces; (2) identify earthquake source mechanisms; (3) improve knowledge of regional geologic conditions; (4) provide data to confirm past licensing decisions; (5) expand the existing geologic and seismic data base; and (6) to provide a consistent data base.

Approximately 23 state geological surveys and universities are cooperating under NRC funding to provide data needed to develop a data base for an eastern U.S. seismotectonic province map. The studies are being conducted in three phases: Phase I -- existing data compilation (complete), Phase II -- new data acquisition, and Phase III -- problem areas of the eastern U.S. and a seismotectonic provinces map. Many of these cooperative programs were funded initially by the Office of Standards Development (Ref. 3). Later, the program responsibility was transferred to the Office of Nuclear Regulatory Research because of their long-term nature.

CRITERIA FOR STUDY AREA SELECTION AND OBJECTIVES OF STUDY

Please refer to NUREG/CR-0666 and/or the RIL 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 criteria for study area selection and the objectives of the study are the same for that study and this one.

RESULTS

Refer to the Summary section for results and significance of the study. The project title is partially misleading as the origin of the lineaments is not proved. A more important purpose is to identify the lineaments and, if possible, correlate them with surface geology and ultimately determine whether or not they are related to the area's seismicity. An in-depth lineament study is not planned. The present study was conducted so that no possible geological elements that could contribute to a more comprehensive understanding of the relationships between geology and seismicity would be overlooked.

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 NU and MGA region.

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

1) Existing data synthesis;

2) Acquisition of new data, seismic installation and operation; and

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-0321 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.

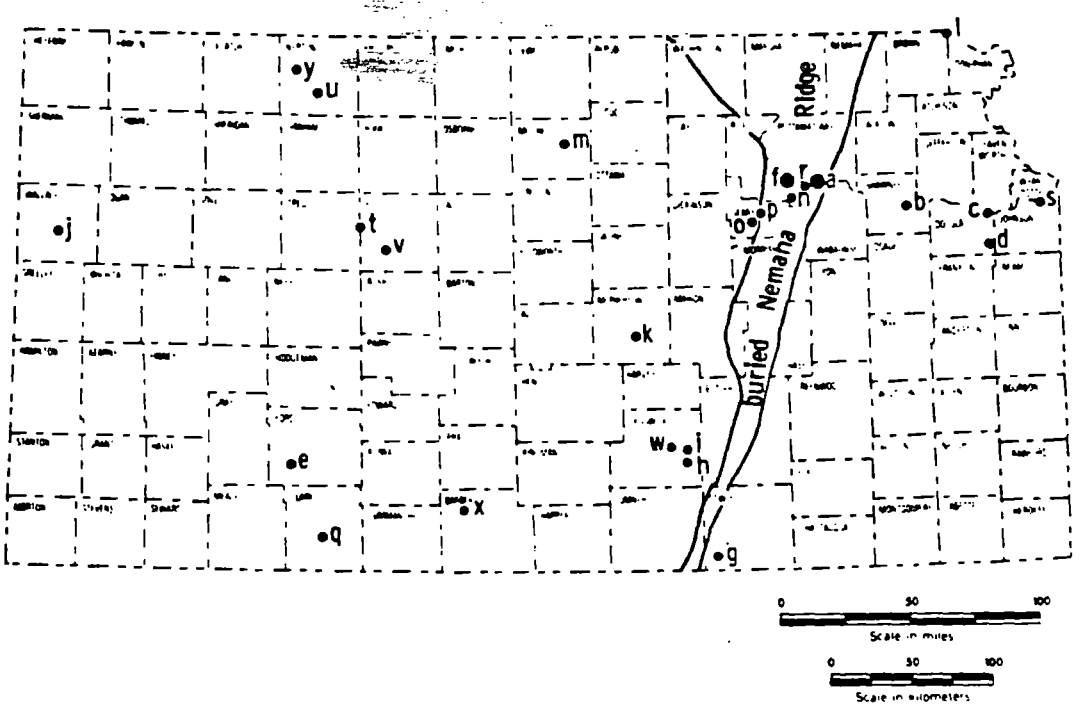
Additionally, RES recommends that studies be continued in this area to attain the objectives previously stated, with redirection and modification of projects as deemed necessary by ongoing work.

Technical questions concerning NUREG/CR-0321 may be directed to Neil B. Steuer at 427-4370.

Saul Levine, Director
Office of Nuclear Regulatory Research

Enclosures:
1. NUREG/CR-0321
2. Figure 1
3. Figure 2
4. Figure 4
5. Figure 4

EARTHQUAKES IN KANSAS



Explanation

a	1867	VIII	f	1906	VII	k	1927	V	p	1929	V	u	1933	V
b	1875	V	g	1907	IV	l	1927	VI	q	1929	V	v	1942	IV
c	1881	III	h	1919	IV	m	1928	IV	r	1929	V	w	1948	IV
d	1903	II	i	1919	IV	n	1929	V	s	1931	VI	x	1956	VI
e	1904	IV	j	1926	?	o	1929	V	t	1932	VI	y	1961	V

Location and dates of earthquakes in Kansas during the past 110 years. The number following the date is the earthquake intensity on the Modified Mercalli Scale.

Figure one

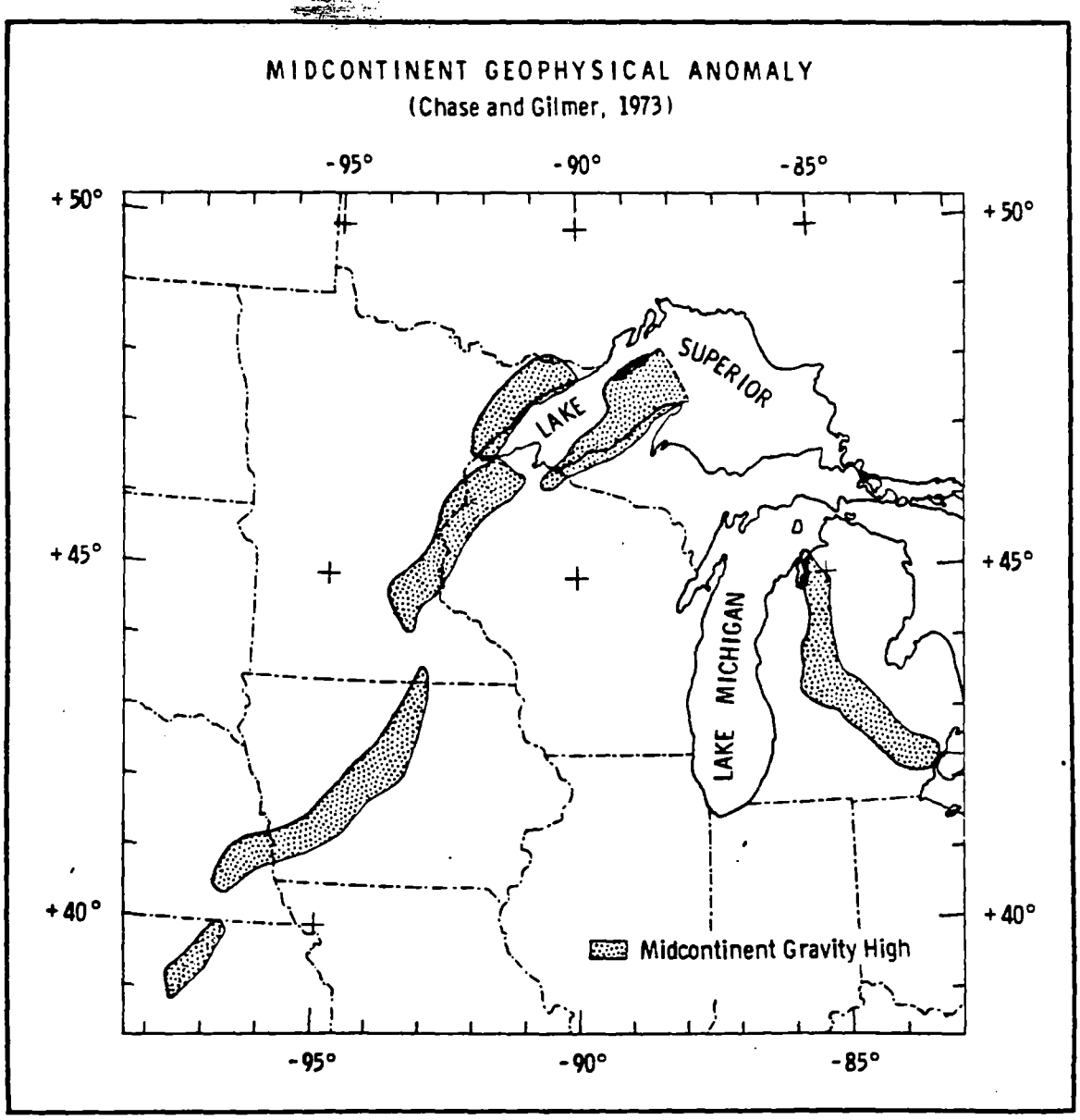

MIDCONTINENT GEOPHYSICAL ANOMALY
(Chase and Gilmer, 1973)
-95°
-90°
-85°
+50°
+45°
+40°
LAKE
SUPERIOR
LAKE MICHIGAN
Midcontinent Gravity High

Figure two

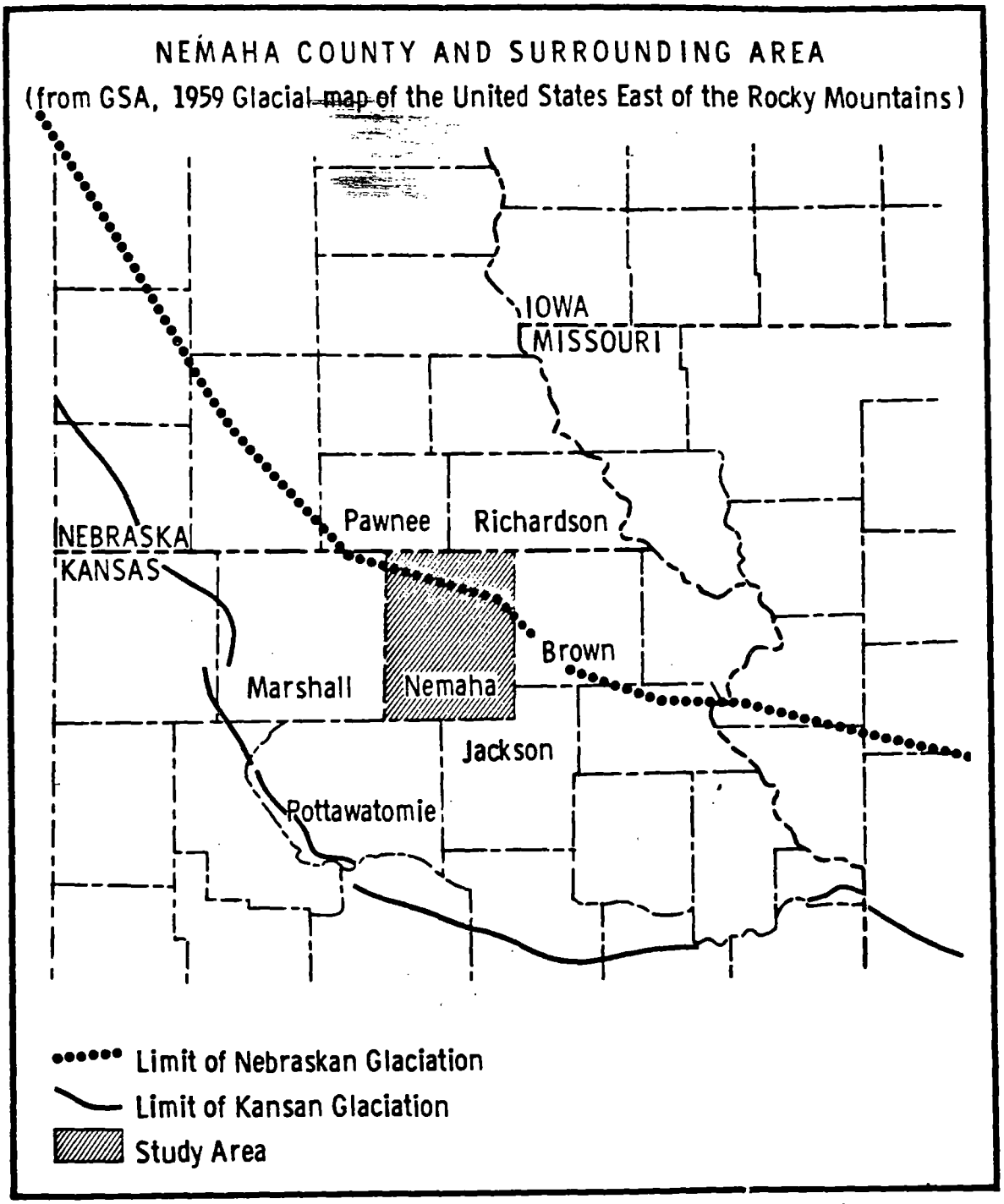


Figure three

STRATIGRAPHIC SECTION EXPOSED IN NEMAHA COUNTY

(Kansas Geological Survey Bulletin 189, Doris Zeller, ed., 1968)

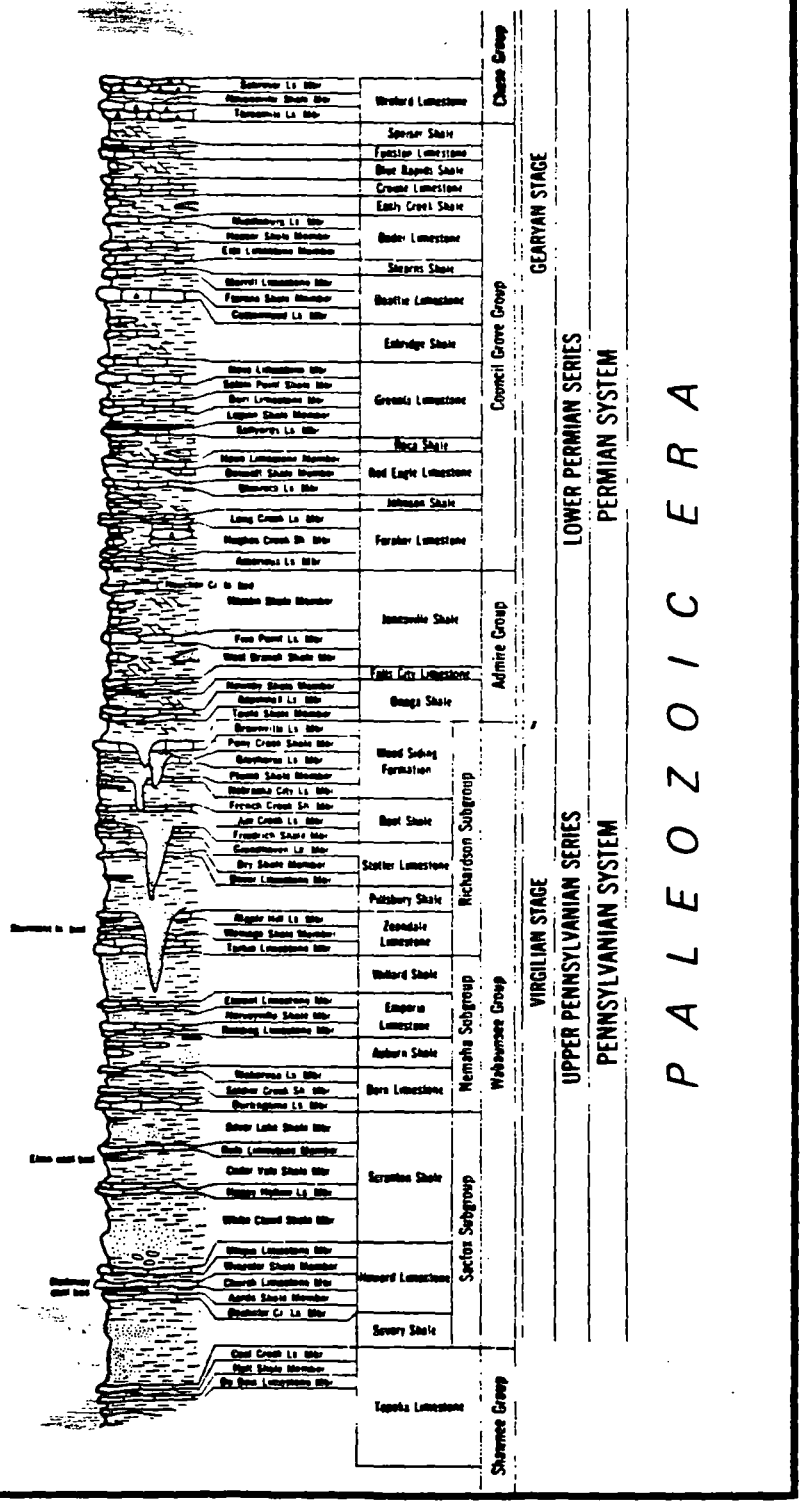


Figure four

Technical questions concerning NUREG/CR-0321 may be directed to Neil B. Steuer at 427-4370.

Original Signed By
Saul Levine

Saul Levine, Director
Office of Nuclear Regulatory Research

Enclosures:
1. NUREG/CR-0321
2. Figure 1
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