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

SEP 19 1980

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

Robert B. Minogue, Director
Office of Standards Development

FROM: Thomas E. Murley, Acting Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER NO. 105
GEOPHYSICAL CORRELATIONS AND MODELING OF A SELECTED AREA ACROSS THE CLINTON-NEWBURY/BLOODY BLUFF FAULT ZONES IN NORTHEASTERN MASSACHUSETTS

INTRODUCTION AND SUMMARY

This memorandum transmits the results of a gravity survey of the Clinton-Newbury and Bloody Bluff fault zones in northeastern Massachusetts. It is a study correlating gravity anomalies, geomagnetic contours, and the surface bedrock. The work was done by the Massachusetts Institute of Technology under contract to the Office of Nuclear Regulatory Research (contract number NRC-04-76-209). The principal investigator was Dr. Steven R. Taylor.

Previous geophysical work in the survey area consists of a Bouguer gravity map of the Boston Basin region, Ginsburg (1959), and a simple Bouguer gravity map of Massachusetts, Bromery (1967). Total intensity aeromagnetic maps published by the U.S. Geological Survey (USGS) were available for the area of this survey. The data were collected along a nearly east-west traverse with a flight spacing of 0.8 km and elevation of 150 m above ground level.

A geological map was compiled from preliminary geologic maps of the Shirley (Russel and Allmendinger, 1975), Ayer (Gore, 1975), Westford (Albord, 1975), and Maynard (Hansen, 1956) quadrangles and was supplemented with information on the Boston 2° sheet (Barosh, 1977). The fault zone consists of a series of northeast striking middle to late Paleozoic imbricate thrusts which dip to the northwest. The stratigraphy is characterized by northwest dipping thick eugeosynclinal metasediments and metavolcanics ranging in age from late Precambrian to middle Paleozoic. Numerous Acadian intrusives are present in the stratified sequences.

The area surveyed crosses a highly deformed northeast-trending Paleozoic thrust belt extending from southern Connecticut through eastern Massachusetts. Magnetic anomalies associated with the formations in the thrust belt suggest that the faults continue offshore in an east-northeast direction into the Gulf of Maine (Weston Geophysical, 1976), and possibly into New Brunswick (Nelson, 1976).

The Clinton-Newbury fault is recognized to be a major structural feature in the region. It occupies a prominent strike valley along which a mylonite zone of variable thickness can be traced. The fault forms a conspicuous magnetic lineament between an area of strong magnetic relief to the southeast, and moderate relief to the northwest (Castle, 1976). No stratigraphic units can be positively correlated across the fault which suggests offsets on the order of tens of kilometers.

Southeast of the Clinton-Newbury fault zone exists a belt of northwest dipping imbricate thrust faults (Skehan, 1969). The stratigraphic units dip steeply to the northwest and are cut by numerous acidic to intermediate intrusions. Between the Clinton-Newbury and the Bloody Bluff fault zones, stratigraphic units include the Tadmuch Brook schist, the members of the Nashoba formation, and the Marlboro formation. Intrusive rocks include the Assabet quartz diorite, Andover granite, and Dedham granodiorite.

The Bloody Bluff fault zone marks the southeast border of the thrust belt. Southeast of the Bloody Bluff fault zone the metamorphic isograds decrease to chlorite grade and the structural trends shift from the northeast to the east. The Bloody Bluff fault zone is also associated with a magnetic lineament and can be traced on the gravity map of this survey.

Tectonic Implications

The northern Appalachians are the result of one semi-continuous orogenic episode extending from late Precambrian to Cretaceous time. Most of the protoliths of the metasediments and metavolcanics found in the area represent eugeosynclinal deposits laid down in early Paleozoic time. The predominant structural features, metamorphic zoning, and intrusions are the result of middle to late Paleozoic Acadian and Alleghanian orogenies. Nelson (1976) suggests that the Clinton-Newbury and Bloody Bluff fault zones represent the suture zone in an area of continental convergence.

METHODOLOGY

Measurements

A total of 232 stations were occupied in the area under study. The survey area was confined to a strip approximately 40 km in length and 5 km in width oriented in a northwest-southeast direction perpendicular to the strike of the Paleozoic thrust belt in eastern Massachusetts.

Gravity measurements were made at most of the available USGS benchmarks and at Department of Public Works survey markers. In areas without adequate elevation control, readings were taken at sites which could be located accurately on a topographic map, such as road intersections.

All of the readings were tied to a base station located in the courtyard at Draper Labs in Cambridge, Massachusetts, where the absolute value of gravity is known to be 980.3874 gal. The gravity value at this base station is from a gravity transfer from the Air Force Cambridge Research Laboratories absolute gravity site in the Haskell Seismic-Gravity Facility. A LaCoste and Romberg model G gravimeter was used in the transfer.

Crustal Models

The strip covered in this study is oriented perpendicular to the strike of the regional structural fabric and, therefore, is analyzed using the two-dimensional modeling technique of Talwani et al. (1959). The vertical component of the gravitational attraction, g_z, is computed using polygons to model two-dimensional bodies of arbitrary shape. At specified points above the structure being modeled, g_z is found by summing all of the contributions from each side of the polygons. The calculations of the anomalies require only the polygon shapes and the relative density contrasts. This fact emphasizes the nonuniqueness inherent in the gravity models. Without any geologic or density control, the infinite information regarding densities, structures, and mapped distributions of geologic formations will decrease the number of degrees of freedom involved in the modeling. Densities were measured for all of the formations included in the structural model.

Based on the constraints of structure and stratigraphy, the initial model had all of the units dipping at an angle of 60° to northwest, and extended to a depth of 2 km. The value of 2 km was selected by noting that the average wavelength of the residual gravity field is approximately 15 km. Comparison of this value with the wavelength of the gravitational field associated with a buried horizontal cylinder suggests that the contributions of the surrounding material to the observed anomalies become negligible at depths greater than 2 km.

The final model was derived by adjusting dips of various formations, varying the shape of intrusive bodies, and truncating units against known regional faults. Geological constraints were crucial in the construction of the model. For example, geological evidence indicates an unconformable contact between the Devens-Long Pond Gneiss and the overlying Eliot Formation (Gore, 1976). Adjustments made in constructing the final structural model suggest that this contact is an angular unconformity.

CONCLUSIONS

A gravity strip map crossing a major thrust belt in eastern Massachusetts has been prepared. Good correlation exists between the gravity field and the mapped geology. The two locations of highest gravity gradient occur over the Bloody Bluff and Clinton-Newbury faults which support previous geological and geophysical interpretations that these are the major faults in a broad thrust zone.

Using measured densities, a two-dimensional gravity profile has been computed which is consistent with a series of northwest dipping formations and thrusts.

Data from total intensity aeromagnetic maps were used to test the gravity model. The unreasonably high susceptibilities required to fit the observed magnetic anomalies suggest that a substantial component of natural remanent magnetism exists in many of the formations between the Clinton-Newbury and Bloody Bluff fault zones.

RECOMMENDATIONS

This is a significant study providing further corroborative detail to the previously mapped Clinton-Newbury and Bloody Bluff fault zones. It is recommended that these results be incorporated into the growing body of knowledge concerning the geomorphology, tectonics, and seismicity of the region, and they be taken into consideration in future estimates of the seismic hazard associated with these fault systems.

Note: This study is published in its entirety in NUREG/CR-1186.

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"Original signed by
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Record Note: This study resulted from the seismological monitoring program in the northeastern United States endorsed by the addressees in response to a request contained in a memorandum from Levine to R. B. Minogue and Harold Denton, dated Jan. 25, 1979. This RIL has been approved in its present form by Robert Jackson of NRR and Leon Beratan of SD.

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