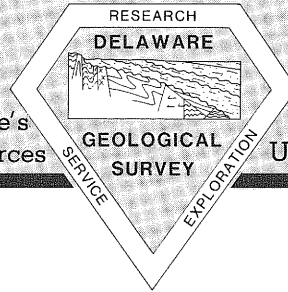


# First State Geology

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## 1983 Wilmington Earthquakes

At 2:55 on the afternoon of November 17, 1983, a moderate-sized earthquake startled residents of the Wilmington area. The strongest effects were reported from the north Wilmington area, but elsewhere in Delaware it was felt from as far west as the Newark area and as far south as Newport. Within minutes the DGS and police and public service offices began receiving numerous phone calls.

Two aftershocks occurred at approximately 4:28 p.m. and 4:41 p.m. Several persons felt the first of these. Kenneth D. Woodruff, DGS Associate Director, calculated the Richter magnitude (a measure of the size of earthquakes) of the main tremor at 2.9. The first aftershock probably had a magnitude of about 1.8.

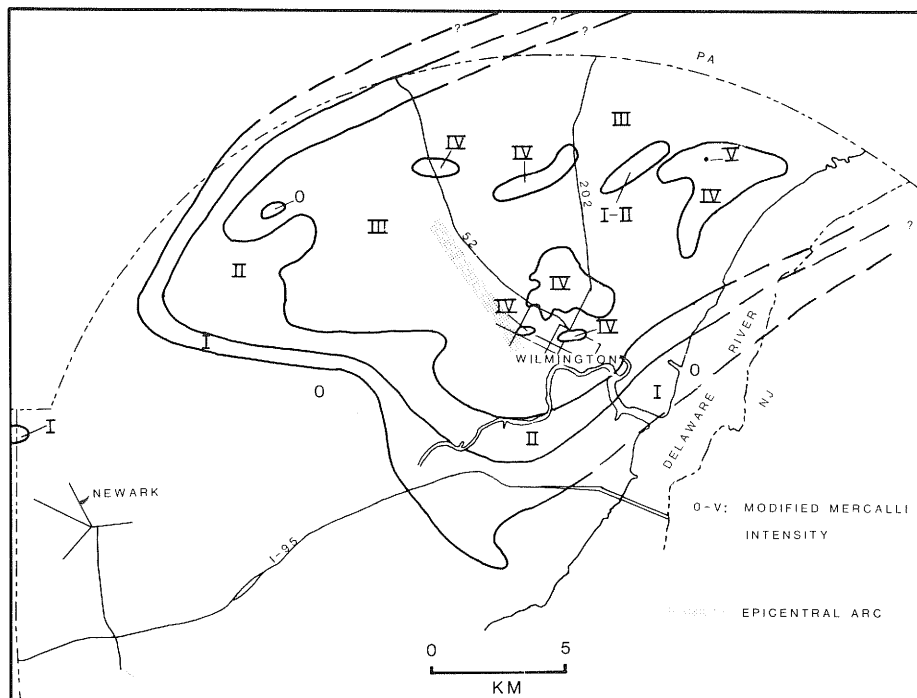
Again, at 12:15 a.m. on December 12, 1983, a small earthquake was felt in the same general area. Woodruff calculated the Richter magnitude at

2.4, considerably smaller than the earlier one. For both earthquakes, the majority of responses were that it felt and sounded like the furnace exploded.

Immediately following the earthquake of November 17 the DGS alerted fellow members of the Northeastern U. S. Seismic Network, a consortium of several public agencies and universities each with its own network of seismic recording stations operating in the northeastern United States. Four other stations in the Network recorded signals from the Wilmington event, but they were too weak to help in precisely locating the epicenter. In hopes of locating the epicenter and determining the mechanism of the earthquake by recording aftershocks, investigators from the Lamont-Doherty Geological Observatory, working with DGS staff, deployed three portable seismic recorders in Delaware and one in New Jersey on November 19. However, no identifiable aftershocks were recorded after about 24 hours of monitoring.

In the absence of sufficient instrumental data for determining the location of the epicenter, reliance must be placed on felt reports. The DGS greatly appreciates those persons who provided information on the effects of the earthquakes. On the basis of information from the phone calls, the several hundred returned "felt report" questionnaires distributed by DGS staff to public buildings in the Wilmington area, and instrumental data from New Castle County station NED of the DGS seismic network, Woodruff placed the epicenter of the November 17 tremor just west of Wilmington and northeast of Elsmere (see map). Data from the felt reports were classified according to the Modified Mercalli Intensity Scale, a measure of the physical effects of earthquakes. The highest consistent intensity at or near the epicenter is a IV, which means that most people felt the earthquake strongly and some small objects were moved. The Mercalli Scale ranges from I to X. Slight damage represents an intensity of VI.

**Previous Wilmington earthquakes.** In perspective, the Wilmington earthquake is not unusual and appears to be part of a pattern of seismicity that has been noted over at least the past 100 years. The largest known event in the area was a damaging earthquake that occurred on October 9, 1871, and, from newspaper accounts, probably had a Mercalli Intensity of VI to VII. Poorly documented events appear to have occurred in 1937 and 1944. In 1971 and 1972 a series of earthquakes occurred in the Wilmington area. Federal agencies and research groups from various universities became interested in the seismicity of the area. With the assistance of a private donor and the Delaware Division of Emergency Operations and Planning this interest culminated in the establishment of DGS' monitoring station NED located about 3 miles northeast of Newark. A short time later the Northeastern U. S. Seismic Network was formed with funding assistance from the U. S. Geological Survey and the U. S. Nuclear Regulatory



Commission. The Network brought together for the first time the various independent seismic networks operating in the northeastern United States and provided funds for badly needed instrumentation. Through the network, Delaware eventually acquired the initial equipment needed to install two other stations, one near Blackbird (BBD) and one near Georgetown (GTD).

On February 28, 1973, a magnitude 3.8 earthquake centered near Wilmington shook much of the northeast Atlantic seaboard. This was the largest recorded event in Delaware since the 1871 earthquake. The newly installed monitor near Newark (NED) was only a few miles from the epicenter. Technical data on this event are in an Open File Report by the DGS and a 1975 article by Sbar and others in the Seismological Society of America Bulletin.

**Eastern U. S. seismicity.** The study of eastern U. S. seismicity has a unique set of problems. Until a few years ago earthquakes in the western U. S. received most of the attention of seismologists in the U. S., and, consequently, the characteristics of western earthquakes are considerably better known. Researchers often struggle with the problem of applying to eastern U. S. earthquakes both magnitude formulas and intensity scales that have been developed from data in other parts of the country. In the east, monitoring sites free of background noise are difficult to find. The depths, mechanisms, and accelerations of eastern earthquakes are generally poorly known or understood. These factors become critical in constructing nuclear power plants, for example, and plant designers must often work with a minimum of instrumentally recorded data. What was probably one of the largest U. S. earthquakes occurred in Charleston, South Carolina, on August 31, 1886. This event had a probable maximum Mercalli intensity of about X and caused about 60 deaths.

In few places in the east can geologists relate known faults to recent seismic activity. The location of the Wilmington events, for instance, cannot be definitely correlated with mapped geologic structures. The seismic activity is probably related to stresses associated with continental drift involving the separation of the African and the North American plates and with sea floor spreading which began about 160-180 million years ago to form the modern Atlantic Ocean basin. These stresses are still operating today. Unfortunately, their manifestation usually has little regard for man's activities.

## Offshore Update

**Shell breaks water-depth drilling record.** On August 2, 1983, about 100 miles east of Delaware, Shell Offshore, Inc. began drilling its Wilmington Canyon Block 587 exploratory oil well in 6,448 feet of water, a new world record for deep-water drilling with a riser assembly. The well is permitted to a total depth of 14,500 feet, the target being the Jurassic shelf-edge carbonate build-up with, possibly, porous reef structures that may contain oil. Information from the well is tight, and if significant hydrocarbon shows are encountered, by regulation, they must be reported to the public. As of the middle of December the well was close to its proposed total depth.

The next well on Shell's schedule will be located immediately to the west in Block 586. The Application for Permit to Drill the 16,000 foot exploratory well in 5,840 feet of water was approved by the Minerals Management Service on November 28, 1983.

**Call for Information issued for June 1985 sale.** On October 29, 1983, the Minerals Management Service (MMS) issued a Call for Information for a June 1985 Mid-Atlantic lease offering. Potential bidders were requested to outline areas where they believe hydrocarbon potential is sufficient to warrant offering these areas for bids. Comments also were requested from all interested parties, including State and local governments, on possible environmental effects and use conflicts in the Call area. For the first time in the history of Mid-Atlantic lease offerings the MMS has identified the area of geologic potential to include the Outer Continental Shelf (OCS) up to the three-mile limit off the states of Delaware, Maryland, and Virginia.

**Consolidation of all Atlantic OCS functions.** All Atlantic OCS functions have been consolidated in the Atlantic OCS Regional Office in Vienna, Virginia. All leases and other information related to past and future lease offerings are maintained in the Regional Office. Until his untimely death in an automobile accident on October 18, 1983, the Regional Manager was Donald Truesdell. He was the principal contact for the DGS in matters dealing with OCS activities. He was widely respected for his technical and managerial abilities, especially in the complex issues confronting federal, State, and industry interests.

**OCS meetings.** Several significant meetings concerning offshore oil and gas exploration have been held in recent months.

The OCS Policy Committee of the Department of the Interior's OCS Advisory Board met at Anchorage, Alaska, in August 1983. Robert R. Jordan, State Geologist, represented the

State of Delaware. The Committee, which advises the Secretary of the Interior, studied the oil and gas activities offshore Alaska as they cope with hostile and delicate environments and impact sensitive social structures. The discussions of the Committee resulted in three principal resolutions: endorsement of OCS revenue sharing, requesting opportunities for review of 5-Year Leasing Programs, and recommending environmental studies for non-energy OCS leasing. The committee will meet next in Washington, D.C., January 12-13, 1984.

At its September 30, 1983, meeting at Ocean City, Maryland, the Mid-Atlantic Regional Technical Working Group, another committee of the OCS Advisory Board, considered the status of Mid-Atlantic activities and plans for the June 1985 lease offering. A paper on the DGS' geologic studies of the area by R. N. Benson, R. G. Doyle, and R. R. Jordan was presented. Jordan was elected State Co-Chairman of the Group.

The Mid-Atlantic Governors' Coastal Resources Council (MAGCRC) met at Albany, New York, on November 15, 1983, to share information about OCS activities and to compare the States' responses to federal and industry activities, in particular, the Call for Information for the June 1985 lease offering.

**Water Conditions** Hot, dry weather with below normal precipitation during July and August resulted in an agricultural drought in Delaware. However, during this relatively short period, there was little impact on surface- and ground-water sources used for water supply and irrigation. Heavy spring rains resulted in a surplus of water that sustained supplies during the dry summer months.

Although ground-water levels and streamflow declined seasonally during the summer months, they remained within or above the normal range. Water levels began to rise and streamflows increased during October and November in response to substantial precipitation and the seasonal decrease in evapotranspiration during this period. For the year 1983 through November total precipitation exceeded normal precipitation by 10 inches at New Castle, 12 inches at Dover, and over 14 inches at Georgetown.

The Water Conditions Index for New Castle County indicated wet conditions (index greater than 10.0) for the period February through July and normal conditions (index 5.0-10.0) for August, September, and October.

## DGS Funded to Study State's Nearshore Geologic Framework

The Delaware Geological Survey has received \$24,535 to study the geologic framework and oil and gas potential offshore Delaware Bay. Funds are provided by the U. S. Department of Interior's Minerals Management Service (MMS) in a cooperative agreement with the Association of American State Geologists. The University of Texas at Austin is administering the multi-discipline special studies program through the Texas Bureau of Economic Geology on behalf of 18 coastal State Geological Surveys. The Texas Bureau represents the Continental Margins Committee of the Association of American State Geologists, which negotiated the agreement with Interior. Total funding for the first year of the multi-year program is \$500,000, which has been divided equally among the coastal State Surveys.

The studies by the State Geological Surveys will focus on two areas: (1) identification of actual or potential offshore areas where commercial deposits of non-energy minerals may exist, and (2) geologic framework studies that will help to develop a better understanding of the basic geology of a State's onshore and/or offshore geology with the emphasis on potential petroleum resources.

Richard N. Benson, Senior Scientist, is the project's principal investigator for the DGS and will be joined by Robert R. Jordan, Director and State Geologist, and Kenneth D. Woodruff, Associate Director. The project is designed to integrate existing onshore and offshore geological and geophysical information and to acquire new geophysical data. Project funds have been used to conduct a marine seismic-reflection profile extending from near the mouth of Delaware Bay offshore to connect with existing seismic-reflection profiles on the Outer Continental Shelf. The support is especially welcome in Delaware as it will partially offset the loss of Coastal Energy Impact Program funds from the Department of Commerce which have helped to sustain responses to the impacts of offshore oil and gas leasing.

## Hydrocarbon Potential of Buried Rift Basins

A series of long, narrow, en echelon basins buried beneath the sedimentary fill of the Baltimore Canyon trough, as observed on offshore seismic reflection

profiles, are being studied for their hydrocarbon potential by Richard N. Benson, Senior Scientist, and Robert G. Doyle, Research Associate III. Onshore exposed "Triassic Basins" of Late Triassic-Early Jurassic age may be analogs of the offshore basins. Benson and Doyle have collected dark-colored, lacustrine, organic-rich shale samples from these basins from North Carolina to Massachusetts for geochemical analyses to determine organic richness, organic type, and thermal maturity. If the offshore basins had a similar geologic history as the onshore ones, and if the dark-colored shales from the onshore basins are promising as petroleum source rocks, the buried basins of the Baltimore Canyon trough may be a future exploration prospect for offshore oil and gas deposits. It is the nearshore area where the buried basins are best observed and where they are not buried at such great depths as to be unreachable by drilling.

As part of the project the researchers will locate and define the shape of the offshore buried basins, calculate the thickness of their sedimentary fill, and determine whether they encountered the "oil generation window" during their burial history. One product of this research will be a contour map showing depth to pre-Mesozoic (crystalline) basement.

## World-wide Occurrence of Glauconitic Sedimentary Rocks

For the past two and one-half years Nenad Spoljaric, Senior Scientist, has corresponded with and received data on the distribution and stratigraphy of glauconitic sedimentary rocks from geologists in more than 70 countries representing all continents. The result will be a book about the worldwide occurrence of these rocks and the origin of greensands. Greensands are rocks with high concentrations (ten percent or greater) of glauconite, a green-colored iron silicate mineral formed in sedimentary environments.

Spoljaric began the study in order to help understand the origin of Delaware's greensands, which are abundant but present mainly in the subsurface. Rare outcrops of Cretaceous-Paleocene age are located in the Middletown-Odesa area. Greensands were once economically important as a potassium fertilizer in the U. S. and may be useful as a filter of heavy metals from waste water (DGS Report of Investigations No. 32, N. Spoljaric and W. A. Crawford, 1979).

In 1982, while on professional leave, Spoljaric spent three months at the University of Canterbury in Christchurch, New Zealand, where he

investigated the relationship of glauconitic sediments to volcanic rocks. Glauconitic sediments are abundant, well exposed, and easily accessible in New Zealand.

## Woodruff Studies Perth Hydrogeology

While on professional leave from November 1, 1982, until June 15, 1983, Ken Woodruff, DGS Associate Director, worked for the Geological Survey of Western Australia on water-quality characteristics and the supply potential of a major water-bearing unit, the Leederville Formation, beneath the Perth area. The area is underlain by about 13,000 meters of coastal plain sedimentary rocks. Parts of this geologic section are similar in both age and lithology to the Potomac Formation underlying the Coastal Plain of Delaware.

Using geophysical logs, Woodruff subdivided the Leederville into major lithologic units and mapped zones of water salinities. This eventually permitted identification of major recharge and discharge areas of the formation. The amount of fresh water through-flow was then calculated from formation transmissivity maps also developed as part of the study. This quantity was then compared against present ground-water withdrawals to show those areas where water use was approaching, or in some cases exceeding, the available fresh water supply. The result of the work was a series of maps which will be used to guide the Perth Metropolitan Water Board in future drilling programs as the Board seeks additional sources of water. The techniques used in the Perth study are directly applicable to Delaware's situation provided that sufficient deep well data become available.

## Spoljaric Visits

### China

Nenad Spoljaric, Senior Scientist, was a member of the American Petroleum Technology Delegation that visited China August 28-September 18, 1983, at the invitation of the Ministry of Petroleum of the People's Republic of China. The Delegation visited oil fields in Renqiu south of Beijing and at Karamai in the northwestern part of the country. Karamai is the farthest west in China that any group of U. S. visitors has been in recent years.

The group also met with Chinese scientists and government officials in Beijing, Renqiu, Urumqi, Karamai, and Guangzhou. Discussion centered on specific problems of oil exploration and production in China and application of

U. S. petroleum technology by the Chinese. The Delegation had many opportunities to learn about present and future governmental programs to increase petroleum production in China.

The visit by Spoljaric served to establish ties between Chinese geologists and the DGS. The DGS will benefit from Chinese knowledge of petroleum exploration and production from nonmarine rocks. Some of the rift basins offshore Delaware, and perhaps buried beneath the Coastal Plain onshore, might become future targets of exploration for oil. These basins contain, for the most part, rocks that were deposited in nonmarine environments.

## Publications

### Recent DGS Publications

#### Reports of Investigations

- No. 37 Stratigraphic nomenclature of nonmarine Cretaceous rocks of inner margin of Coastal Plain in Delaware and adjacent States: R. R. Jordan, 1983, 46 p.

#### Geologic Map Series

- No. 6 Geology of the Dover Area, Delaware: T. E. Pickett and R. N. Benson, 1983. Scale 1:24,000.

#### Open File Reports

- No. 20 Configuration of the base and thickness of the unconfined aquifer in southeastern Sussex County, Delaware: J. M. Denver, 1983, 12 p.
- No. 21 A guide to fossil sharks, skates, and rays from the Chesapeake and Delaware Canal area, Delaware: E. M. Lauginiger and E. F. Hartstein, 1983, 64 p.
- No. 22 Geologic and hydrologic considerations in the disposal of low-level radioactive wastes: N. Spoljaric, 1983, 16 p.
- No. 23 Ground-water availability in southern New Castle County, Delaware: J. J. Groot, P. M. Demicco, and P. J. Cherry, 1983, 20 p.
- No. 24 Saturated thickness of the water-table aquifer in southern New Castle County, Delaware: J. J. Groot, P. M. Demicco, and P. J. Cherry, 1983. Map, scale 1:24,000, with discussion.

- No. 25 Saturated thickness of the Columbia Formation in southern New Castle County, Delaware: J. J. Groot, P. M. Demicco, and P. J. Cherry, 1983. Map, scale 1:24,000, with discussion.
- No. 26 Salinity distribution and ground-water circulation beneath the Coastal Plain of Delaware and the adjacent continental shelf: J. J. Groot, 1983, 24 p.
- No. 27 Availability of Earth Science Maps of Delaware: W. S. Schenck, 1983, 4 p.

### Forthcoming DGS Publications

- Biostratigraphy and lithostratigraphy of Dover Air Force Base test well Je32-4: Richard N. Benson, Robert R. Jordan, and Nenad Spoljaric.
- Hydrology of the Manokin, Ocean City, and Pocomoke aquifers of southeastern Delaware: Arthur L. Hodges.
- Instructions for preparation of Delaware Geological Survey data base schedules: John H. Talley and Dorothy C. Windish.
- Potential for ground-water recharge in the Coastal Plain of northern New Castle County, Delaware: Petty *et al.*; K. D. Woodruff, editor.
- Stratigraphy of Delaware: Robert R. Jordan and Thomas E. Pickett.

### Staff Notes

Robert G. Doyle has concluded his research association with the DGS. During his two-year contract period he made major contributions to the Outer Continental Shelf (OCS) Program Coordination and Review project. They include publication of a history of Delaware's involvement in the federal OCS oil and gas leasing program, preparing State responses to federal and industry activities on the OCS, and conducting geologic research on the history of the Baltimore Canyon trough. The OCS project was funded by the Coastal Energy Impact Program of the National Oceanic and Atmospheric Administration through a contract between the DGS and the Delaware Department of Natural Resources and Environmental Control. After retiring as State Geologist of Maine, a position he held for 20 years, Doyle first joined the DGS in 1980 under a contract to draft revisions to Delaware's mineral laws and regulations.

Robert R. Jordan, State Geologist, recently completed his service as Chairman of the North American Commission on Stratigraphic Nomenclature during its 1982-83 term. He continues to serve as a Commissioner, representing the Association of American State Geologists.

#### Papers presented:

Robert R. Jordan, "Quality aspects of ground-water management," at Mason-Dixon Task Force Seminar on Ground-Water Management in the 80's, Downingtown, Pa., October 6, 1983.

\_\_\_\_\_, Richard N. Benson, Robert G. Doyle, "DGS research on rift basins and their oil and gas potential," at the Mid-Atlantic Regional Technical Working Group of the Outer Continental Shelf Advisory Board, Ocean City, Md., September 30, 1983.

### DGS Adopts New Stratigraphic Code

The Delaware Geological Survey has adopted the 1983 Code of Stratigraphic Nomenclature for use in its investigations and publications. The DGS joins the U. S. Geological Survey and several other State Surveys in its early acceptance of the new standards. The major geological societies and other geological organizations are expected to approve usage of the Code.

The new Code, prepared under the auspices of the North American Commission on Stratigraphic Nomenclature and approved by the Commission in October 1982, was published in the May 1983 Bulletin of the American Association of Petroleum Geologists. It presents standardized procedures for the classification of bodies of rock. New classification systems are provided for igneous and metamorphic rocks and for rock masses differentiated by magnetic properties and various discontinuities.

### New Zip Code and Phone Number

The new zip code for the DGS is 19716. The new phone number is 451-2833. A new telephone system for the University of Delaware has been installed, and each DGS staff person now has his or her own extension.