

The Delaware Geological Survey: The Formative Years—1951–1969

by Johan J. Groot

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THE DELAWARE GEOLOGICAL SURVEY:
THE FORMATIVE YEARS, 1951-1969

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Johan J. Groot

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First Draft
of
A BILL TO CREATE A GEOLOGICAL SURVEY FOR THE STATE OF
DELAWARE

I, Introduction

More than a century ago the Legislature of the State of Delaware, by an act of 1837, created a Geological and Mineralogical Survey which was charged with investigating and mapping the various geological formations found within the boundaries of the State, and of discovering and examining all beds and deposits of ores, coals, clays, marls and such other mineral substances as were deemed useful or valuable. This survey was created to function only a limited number of years for the purpose of preparing a report which has by now been long out of date and inadequate.

The fact that the Legislature passed this bill in 1837 indicates that already a long time ago the importance of the application of the geological sciences to the development of earth resources was recognized. Since then, the importance of such resources has, with the rapid economic development of the State, increased considerably, with a subsequent demand for more detailed geological investigations.

Today there are several compelling reasons for a more advanced and detailed study of the geology and earth resources of the State. In the first place, minerals which had no economic value a hundred years ago, may be valuable now, or may be considered useful in the near future. For instance, in the Great Circle area there are a number of pegmatite dikes which may contain such important minerals as uranium. Furthermore, such useful materials as building stones, road materials, marl, lignite and clays are needed and should be sought. For example, even now a number of the State's contractors and operators of sand and gravel pits are eager to find new sources of sand and gravel within the State, because the paucity of existing knowledge on these materials compels their importation from beyond the State's boundaries at a transportation-cost that runs into many thousands of dollars annually.

Ground water is one of the most important, and probably the most abundant mineral in the State. However, the increasing population creates an increasing demand on the water resources, especially since the per capita use of water rises sharply with economic progress and expansion of industry. Already it has been reported that in some places the water table is falling, or artesian pressure declining, and salt water encroachment constitutes a real danger in the coastal area of the State. In order to avoid difficulties in the future, a ground water inventory is badly needed, but even a rough estimate of the available ground water resources requires a great deal of geologic research directed toward determining the location, dimensions and nature of aquifers or water bearing layers.

The geologic research needed for the development of the earth resources would be greatly helped by a more detailed topographic mapping of those areas of the State, the relief of which is inadequately expressed on maps now available.

The need for geological knowledge has been recognized by every State in the Union; all States, including Rhode Island, but excepting Delaware, employ one or more geologists in a Geological Survey, Department of Conservation, or other specified State agency or commission.

J. J. Groot

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FOREWORD

Although geological surveys have produced knowledge essential to all for more than a century and a half, they are not the most conspicuous of publicly funded agencies. It is appropriate that their activities be chronicled as an additional accounting to the people they serve. Moreover, scholars concerned with the history of geological science find the record of people and actions scanty because of our dedication to technical products. It is, therefore, gratifying that Johan J. Groot contributed his time and exclusive insight to provide this account of the Delaware Geological Survey.

Dr. Groot is most qualified to present the origins and development of the Second Delaware Geological Survey because he participated in its founding and thereafter served as State Geologist for 18 years. We are as fortunate to have inherited the benefits of his efforts in applied science as we are this accounting of the experience.

Emphasis is placed herein on the years of Dr. Groot's leadership of the Survey. The remarkable work of James C. Booth in the last century is acknowledged but has elsewhere been entered in history. Some continuing activities of the Survey after 1969 are noted together with comments of an experienced observer; this current period may someday receive the attention of a recorder having the enhanced perspective of time.

Geologists deal with the fragmental record of earth history. Here we seek to preserve the record of Delaware's attempts to understand and learn from the history of its land before that too is obscured by time. We hope readers will be served by greater familiarity with their State geological survey and its impacts on public affairs.

R. R. Jordan
State Geologist
and Director

THE DELAWARE GEOLOGICAL SURVEY:
THE FORMATIVE YEARS, 1951-1969

Johan J. Groot

INTRODUCTION

All states in the United States of America and virtually all nations of the world have, at present, organizations engaged in the investigation of the geology and natural resources of their territories. Whatever the titles of these organizations may be, and they vary considerably, they all were created in response to the need to furnish a scientific basis for the development and conservation of natural resources. This basis is provided by the earth sciences, particularly by geology. It is not surprising, therefore, that many of these organizations are called geological surveys.

Although the general goal of geological surveys is studying geology and natural resources, the functions of each differ greatly from state to state; they have also changed through time in response to changing economic conditions which, in turn, required the development of different natural resources. Thus, early geological surveys were concerned with providing bases for the improvement of agriculture and road and railroad building.

With the rapid industrialization in the United States after the Civil War, the scientific search for a wide variety of mineral resources, including fuels, became a priority. As agriculture, industry, and the growing cities required large quantities of water, the study of water resources, particularly ground water, became a major part of geological survey activities in many states. And in the last couple of decades, with continuing industrialization and increasing population, the growing awareness of various threats to the environment led to the investigation of water pollution problems and of geologic hazards such as earthquakes and landslides. Thus, the increasing complexity of society led to diversification of the activities of many geological surveys.

THE FIRST DELAWARE GEOLOGICAL SURVEY, 1837-1841

During most of the 19th century, Delaware, with the exception of Wilmington, had a farm economy; therefore, the State's first geological survey focused most of its attention on the relationship between geology and agriculture. In fact, the scientist who carried out this survey, James C. Booth, devoted nearly all of the "Economical Geology" part of his report to agriculture and soils. He also discussed the use of various types of crystalline rocks "in arts of construction," that is, the construction of buildings, roads, and breakwaters. Surprisingly, he already understood the environmental importance of Delaware's wetlands long before concern for the environment was common (Pickett, 1976).

Booth was engaged as Delaware's first State Geologist on June 1, 1837, a few months after the General Assembly appropriated funds for the survey. He presented his findings (Booth, 1841) in a report titled "Memoir of the Geological Survey of the State of Delaware: Including the Application of the Geological Observations to Agriculture." That volume, which became exceedingly rare with the passing years, was reproduced in facsimile by The Delaware Geological Survey as a United States Bicentennial project (Pickett, 1976).

Booth's work so substantially advanced geologic knowledge of Delaware at the time of its publication that no need was felt to continue his work. Indeed, it was to be a long time before the growth of industry and the introduction of irrigation required the development of considerable ground-water resources, which in turn demanded the systematic investigation of the hydrogeology of Delaware.

The discontinuation of many geological surveys in the late eighteen thirties and early eighteen forties was not unusual, in part, because it was felt that they had fulfilled their goals. But, also, a depression and its attendant financial difficulties resulted in suspensions of appropriations for many years (Rabbit, 1979).

In the mid 1880s, Frederick D. Chester, a young professor at Delaware College (now the University of Delaware), was investigating sand and gravel deposits and the crystalline rocks of the Piedmont in Delaware. He attempted to gain recognition from the Delaware General Assembly as State Geologist but without success (Pickett, 1988).

THE CREATION OF THE SECOND DELAWARE GEOLOGICAL SURVEY, 1951

In the nineteen forties, the need to develop considerable water supplies led to the realization that very little was known about ground-water resources and that something should be done to rectify this situation. In the early part of the first term of Governor Elbert N. Carvel (1948-1952), a small ground-water program was started by personnel of the U. S. Geological Survey's (USGS) Salisbury, Maryland, office. The State of Delaware was represented in this program by the State Highway Department and the School of Agriculture of the University of Delaware.

It was clear, however, that Delaware needed its own geological organization if future investigations were to be conducted with a view to achieving the greatest benefits for its citizens. Indeed, the chief of the USGS office in Salisbury, William C. Rasmussen, encouraged State officials to create a geological survey.

At the same time, Huber Denn of the Delaware Chamber of Commerce, George Simpson of the Farm Bureau, and George M. Worrilow of the School of Agriculture of the University of Delaware recognized the importance of a geological survey and supported its creation. Great credit is due to then Governor Elbert N. Carvel who acted decisively in promoting legislation with regard to water resources, in particular, Senate Bill 129 which created the Delaware Geological Survey (DGS). This bill was introduced by State Senator William O. Cabbage in the 116th General Assembly and signed into law by Governor Carvel on June 4, 1951.

In the same year, the Water Pollution Commission was created. The DGS and water pollution programs were the only two new activities funded by the State in 1951. Whereas the Water Pollution Commission and its successor organizations were regulatory agencies, the DGS was conceived as, and remains, a natural resources research unit.

During the early 1950s, the State had a commission type of government. It was therefore appropriate that the legislation provided for a Delaware Geological Commission which had general charge of the Survey in cooperation with the University of Delaware. The President of the University was an ex-officio member of this Commission; other members were Richard A. Haber, Chief Engineer, State Highway Department, Clayton M. Hoff, Executive Vice President of the Brandywine Valley Association, and Daniel F. Shields, Jr. The University was in administrative charge of the Survey and appointed its "superintendent," called the State Geologist.

He was to be a member of the staff of the University, which paid one-half of his salary, the other half being paid from the Survey's appropriation. This arrangement has continued to the present day.

In addition to the "...systematic investigation of the geology, water, and earth resources of the State," the Survey was charged with participating in the "...recommendation and preliminary drafting of such new State laws as are deemed advisable or necessary for regulating the optimum utilization and equitable administration of the State's geological resources." This activity proved to be an important one in the ensuing years.

The Survey started its investigations in July 1951 with Johan J. Groot as State Geologist and Lecturer, later Professor of Geology, and Louis P. Vlangas as Geological Field Assistant. The University provided office space, which was shared with the Department of Geography. The cooperative program with the USGS, begun prior to 1951, was continued. Studies of the geology of New Castle County and of the ground-water resources of the Newark area were initiated, the latter with financial support of that city.

The budget of the Delaware Geological Survey was very small in 1951 because of the rather stringent financial conditions then existing in the State. The tiny staff began its work with great enthusiasm and energy, soon to result in the publication of a number of reports.

RESEARCH AND SERVICE, 1951-1969

"The systematic investigation of the geology, water, and earth resources of the State" with which the Survey was charged required a thorough study of the geologic formations present at the surface and in the subsurface of Delaware. Such basic geologic knowledge is the essential foundation upon which to build a program of applied research with regard to ground-water and mineral resources. Thus, from the very beginning of Survey activities, basic geological problems were given much attention, in some cases in the form of distinct projects and in other cases within the framework of ground-water projects. It was also clear from the start that the Quaternary age sediments, mostly sand and gravel, were important sources both of ground water and engineering materials for road building, and that they covered most of the Coastal Plain of the State, although varying greatly in thickness. Another obvious fact was that the Potomac Formation was a main source of ground water in the area

between the crystalline rocks of the Piedmont and the Chesapeake and Delaware Canal. Therefore, initial research was concerned both with the Potomac Formation and the Quaternary deposits (Columbia Formation) which mantle nearly everywhere the older formations.

The study of the Potomac Formation was hampered by a lack of exposures except those occurring in the banks of the Chesapeake and Delaware (C & D) Canal. Therefore, the combination of Survey priorities, i.e., study of the Potomac and Columbia formations, and geologic opportunity - exposures of Upper Cretaceous sediments - led immediately to a project concerning the stratigraphy and environments of deposition of the sediments of the Potomac Formation and the overlying Cretaceous sediments of the C & D Canal area. A beginning was made with the study of the Columbia Formation within the framework of the ground-water project for the City of Newark.

The difficulty of obtaining subsurface geologic information led the Survey to a systematic program of well data collection based on the voluntary cooperation of drilling contractors. In order to improve upon the detail of drillers' logs, the Survey needed electric and gamma-ray logging equipment. Because the DGS budget did not provide the funds needed for this purchase, the State Geologist requested the Tidewater Associated Oil Company (later Getty, now Texaco) to donate it. The company responded, and, in 1956, a simple electric and gamma-ray logging outfit mounted on a trailer was added to the Survey's as yet very limited equipment. This gift recognized the importance of the application of the scientific investigation of the Potomac Formation to the water supply needs of the refinery built at Delaware City, an immediate example of the use of basic geology in economic development.

In order to obtain subsurface data from areas where there were none available from drilling contractors, the Survey was anxious to obtain and operate a drilling rig for its own use. As no State funds were available for its acquisition, the then President of the University of Delaware, John A. Perkins, who was an ex-officio member of the Geological Commission, requested Henry B. du Pont to donate a small truck-mounted auger drilling rig to the University of Delaware for use by the Survey. This request was promptly granted, and the rig was put into operation in 1951.

Acquisition of both the logging and drilling equipment demonstrated an advantage of the Survey's traditional relationship to the University wherein modest State support could be augmented by benefactors recognizing the value of its basic mission.

The Survey's first rig had its limitations; the greatest depth that could be reached was usually 100 feet. In order not to compete with private drilling contractors who construct water wells, it was intended solely to obtain subsurface samples for geologic studies. In spite of the limitations of the equipment, basic tools for subsurface studies were now available.

The source of the sediments and the environment of deposition of the Potomac Formation were investigated first by means of heavy mineral and size frequency distribution analyses. This study resulted in a zonation of the formation based on the occurrence of heavy mineral assemblages, and the results were published in DGS Bulletin 5 in 1955. Another study, initiated in 1957, was aimed at determining the age of the Potomac sediments on the basis of plant microfossil assemblages. The first results of this investigation were published in 1960, but the study was continued for several years thereafter.

Several other investigations were made in the early 1950s. A thorough study of the ground-water resources of the Newark area was conducted in cooperation with the city and the Ground Water Branch of the USGS. It was concluded in 1954 with the publication of Bulletin 2 of the DGS. In the same year, the investigation of the marine Upper Cretaceous formations exposed in the Chesapeake and Delaware Canal resulted in the publication of DGS Bulletin 3. In cooperation with the USGS, a report was prepared on the ground-water and surface-water resources of northern Delaware, published in 1956, and a preliminary review of the water resources of Sussex County was completed in 1960.

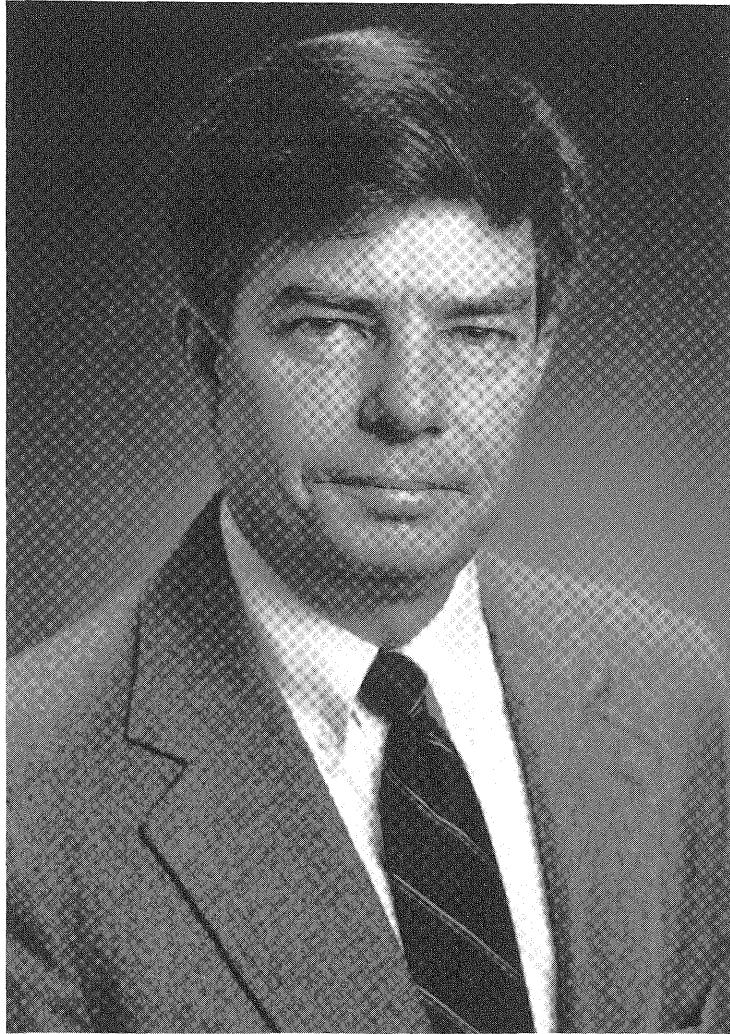
An important opportunity to learn more about the subsurface geology of the State came with the drilling and coring of a deep well (more than 1,400 ft) at the Dover Air Force Base in 1957. This exploratory well not only contributed significantly to the knowledge of the stratigraphy of central Delaware, but also found a 200-foot thick aquifer in the Piney Point Formation. This aquifer was later to become a major source of water for the air base, the City of Dover, and other communities.



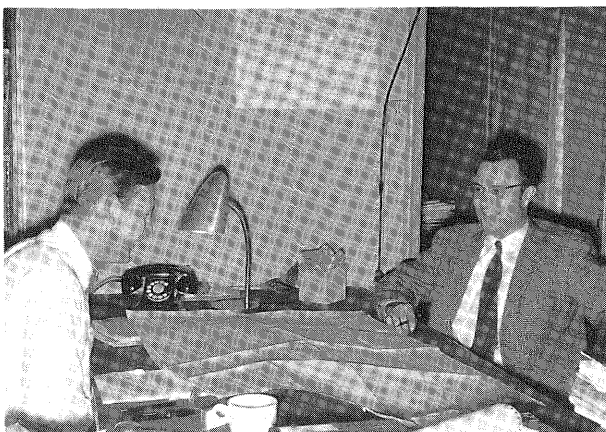
James C. Booth, ca. 1840, Delaware's first State Geologist, 1837-1841 (lithograph from James C. Booth Papers, University of Delaware Library, Newark, DE 19717-5267).



Johan J. Groot, State Geologist, 1951-1969.

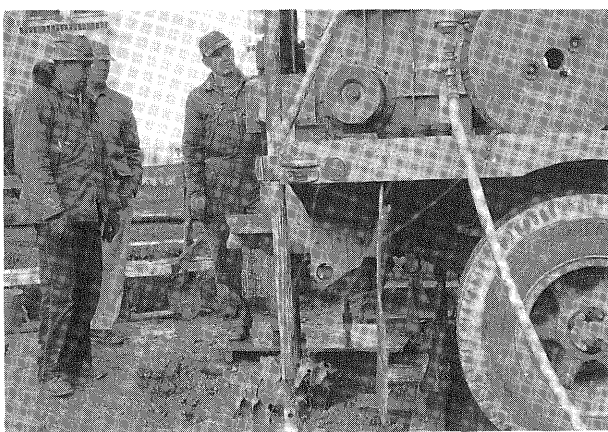


Robert R. Jordan, State Geologist, 1969-.

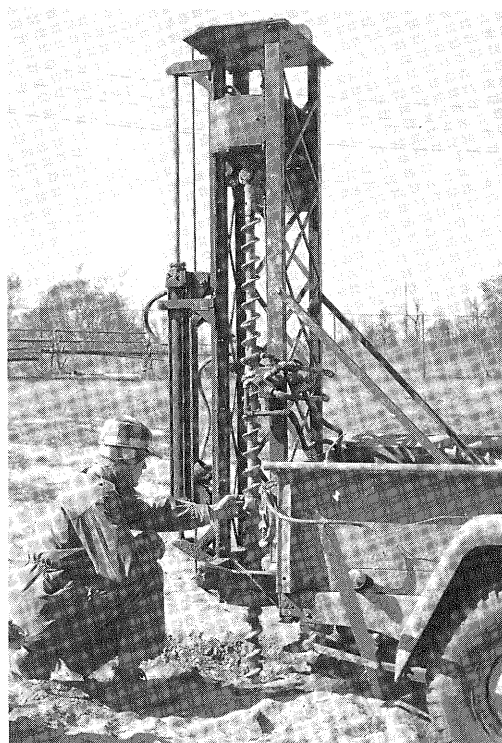


J. J. Groot (on left)
conferring with the
late William C.
Rasmussen of the U. S.
Geological Survey.

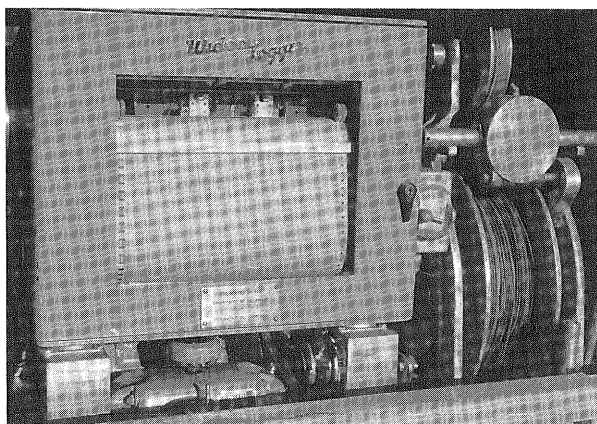
Columbia Formation
(dark colored)
overlying Upper
Cretaceous sediments in
outcrop along the
Chesapeake and Delaware
Canal. St. Georges
bridge in background.



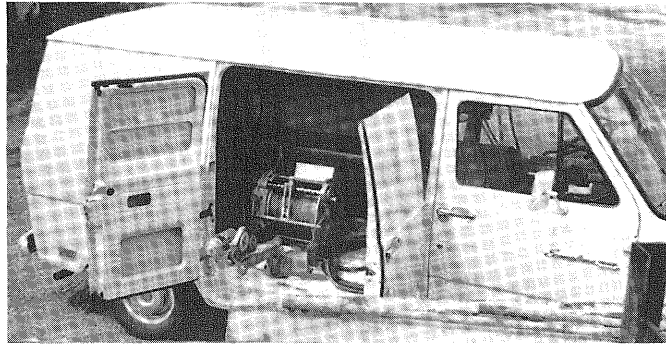
Subsurface geologic infor-
mation was first obtained
by DGS from data supplied
by water-well drilling
contractors. From left
to right, Fred
Kielkopf, John Ennis,
and Jerome Unruh, ca.
1956.



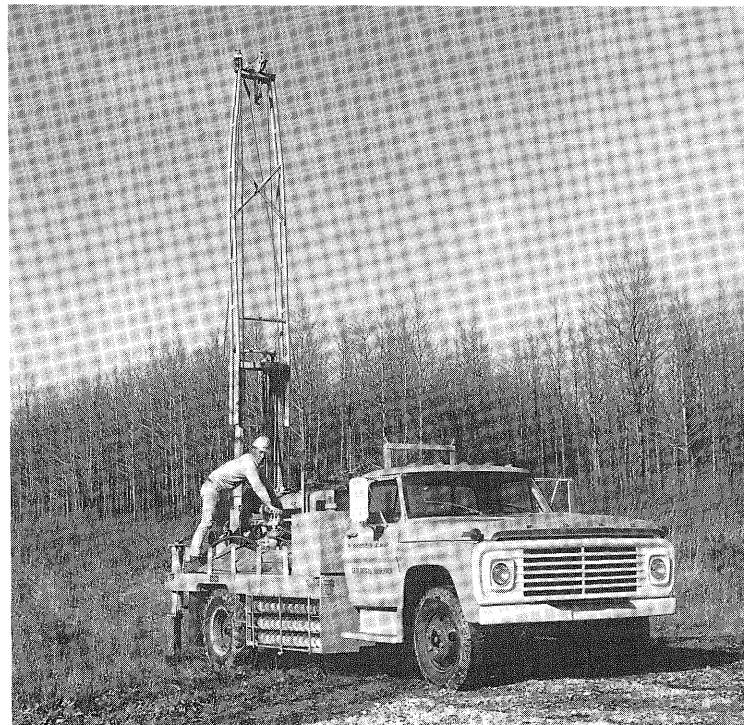
Louis P. Vlangas collecting a sample off the auger of the truck-mounted drilling rig donated by Henry B. du Pont.



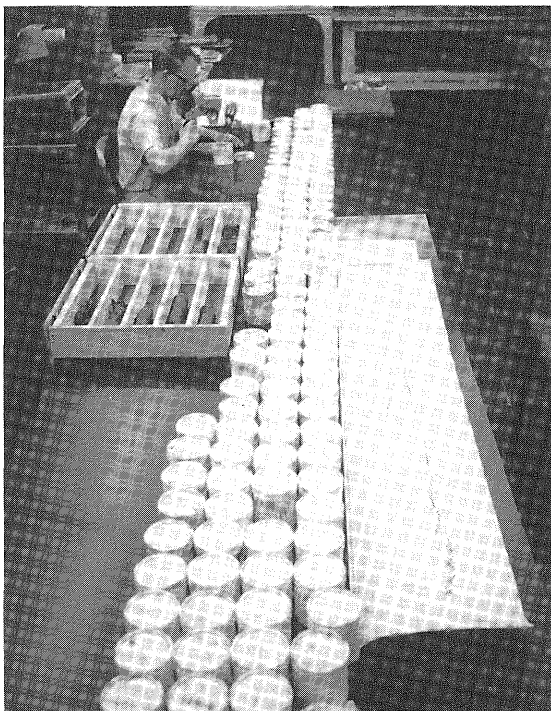
Trailer-mounted electric and gamma-ray logging equipment donated by the Tidewater Associated Oil Company.



New well-logging equipment acquired in 1969.



DGS field technician Arnold Fogelgren on drilling rig purchased in 1967 with funds donated by a private foundation and the Getty Oil Company. Rig is currently in operation but mounted on a newer truck body.



Studies in the first laboratory of the DGS, basement of Robinson Hall.



First office of the DGS at 231 South College Avenue was shared with the Department of Geography.



The basement of Robinson Hall housed the offices of the expanding Delaware Geological Survey and Department of Geology.



In 1969 the DGS and Department of Geology moved to renovated Penny Hall.

As Delaware is, in part, surrounded by bodies of saline water, the potential danger of salt water intrusion was recognized. Therefore, an investigation was made of the salinity of the Delaware Estuary, and of water levels and chlorides in aquifers that cross the Chesapeake and Delaware Canal (DGS Bulletin No. 10, 1963; Report of Investigations No. 3, 1958).

The Columbia sediments were the subject of a number of studies with regard to their composition, stratigraphy, and ground-water potential. R. R. Jordan studied the basic geologic features of the Columbia Formation, and all reports dealing with regional ground-water studies included sections on the water-table aquifer of this formation. In addition, some staff members investigated its potential use for engineering materials.

Space does not permit description in detail of all studies conducted by the staff of the DGS and its cooperating agencies. Suffice it to mention that investigations were conducted on subjects as diverse as the possibilities for the storage of natural gas (1961), the Cretaceous-Tertiary boundary in Delaware (1962), and the sediments of the Delaware River (1962).

Titles in the annually published list of DGS publications indicate the scope and diversity of work accomplished. Such publications are the tangible products of a state geological survey. Those of the DGS are a balanced mixture of basic and applied science. Publications fulfill the DGS's statutory charge to make available to the public the results of its studies as well as contribute to the scientific literature of geology.

In addition to the many projects the DGS was engaged in during the period 1951-1969, the staff assisted many organizations and individuals by providing information and advice, mainly, but not exclusively, with regard to water resource development. Thousands of "requests for information" were answered, some of which required considerable time and funding. Among those who wished the Survey's assistance were, in the early years, the City of Newark, the Tidewater Associated Oil Company, the U. S. Army Corps of Engineers, the U. S. Air Force, the City of Dover, and the State Planning Office. Finally, the State Geologist was called upon by the Governor to represent the State at various meetings and to participate in preparing legislation with regard to water resources development.

The rather large number and diversity of activities the DGS was engaged in was only made possible by a gradual expansion of the number of professional staff. In 1951, the staff consisted of the State Geologist (half time), one full-time geological field assistant, and a part-time secretary. From that time to 1969, several full- and part-time professionals made significant contributions to the Survey's programs (see Appendix). By 1969 the staff was composed of six geologists and a number of field and laboratory assistants. The cooperative programs with the USGS provided an important addition to the capabilities of the staff. Nevertheless, the available personnel were always stretched to the limit, and the many accomplishments of the Survey were only made possible by the enthusiasm, dedication, and competence of its small staff.

With the growth of the Survey and its activities, new and better research tools were needed. The original auger drilling rig had its limitations and was dismantled because it could not provide the subsurface rock samples required for the geologic and hydrologic studies of the late 1950s and 1960s. The trailer-mounted electric and gamma-ray logging system, however, was used continuously during this time and is still used, occasionally, today. It was replaced by newer and more sophisticated equipment in 1969. In 1967, a new drilling rig was purchased by the University of Delaware with gifts from a private foundation and the Getty Oil Company. It is still used extensively today and is capable of augering, coring, and hydraulic rotary drilling to depths of 250 feet. Although the DGS operates and maintains the rig, it is administratively assigned to the Water Resources Center of the University.

OTHER SURVEY ACTIVITIES AND RELATIONSHIPS WITH VARIOUS STATE AND FEDERAL AGENCIES, 1951-1969

According to the law creating the DGS, the Survey was under the general direction of the University of Delaware and the Delaware Geological Commission, and the State Geologist was a member of the instructional staff of the University. Survey offices were, and are, located on the Newark Campus of the University of Delaware. This close relationship offered several advantages, not only in financial terms (the Survey had no bills to pay for office space and utilities), but also in having a favorable environment in which to accomplish its research tasks, good library facilities, and, after the establishment of the Department of Geology, a share in the use of laboratory equipment.

In the period 1951-56, the State Geologist was a Lecturer in the Department of Geography and Geology; in 1956 he became Professor and Chairman of the Geology Department. The presence of geologists on the campus, the publication of geological reports, and the teaching of a physical geology course which satisfied a part of the science requirements for undergraduates aroused enough interest among students, faculty, and University administrators to warrant the establishment of a separate department. Thus, the Geology Department grew out of the Survey, and the appointment of the State Geologist to the Chairmanship of the Department was a logical step. This arrangement also prevented competition between Survey and Department for space and other facilities. On the other hand, with the growth of both departmental and Survey staffs, the task of the State Geologist-Chairman became gradually more demanding, particularly because, as State Geologist, he had to participate in advising State government on matters relating to legislation and the administration of water resources. At the same time, as a member of the faculty, University policy with regard to promotion and salary required him to attract funds from various foundations for research, publish in the scientific journals, and teach effectively. Consequently, the State Geologist-Chairman had numerous tasks, and decisions as to how much time and attention to allot to each were frequently difficult and sometimes controversial. The dichotomous (if not trichotomous) aspect of the position was at least in part eliminated in 1969 when the separate posts of State Geologist and Chairman of the Department were created, although the State Geologist remained a member of the faculty with part-time teaching duties.

In the early 1950s, interest in water resources was considerable, and many organizations and individuals thought that legislation concerning the wise utilization and conservation of water should be considered. This interest led Governor J. Caleb Boggs to appoint the Delaware Water Resources Study Committee, which had a large membership representing municipalities, industry, farm organizations, and conservation groups. Dr. G. M. Worrilow, then Dean of the School of Agriculture of the University of Delaware, was its Chairman, and the Committee elected the State Geologist to be its Secretary. At about the same time, the Chamber of Commerce in Wilmington was instrumental in establishing the New Castle County Water Resources Committee, of which the State Geologist was also a member. The two Committees worked closely together in order to determine whether or not legislation was needed for the orderly development of Delaware's water resources, and, if so, to recommend a water policy for the State and ways and means for implementing such a policy.

The Governor's Committee's first task was to pull together widely scattered data on water resources, the Survey staff being heavily involved in this matter. A study was also made of various doctrines and water-resource laws enacted in the past in other states, and, after many meetings of the committees and various subcommittees, a draft of a proposed act was presented to the Governor. It was introduced in the General Assembly as Senate Bill 98 in 1957. It failed to pass, but the State did have regulatory powers with respect to water quality since the Water Pollution Commission was established in 1951. Moreover, the considerable amount of work done by the Water Resources Committee was not entirely without effect; new legislation creating the Water and Air Resources Commission (WARC) in 1966 built on the foundation laid between 1954 and 1957. The State Geologist became an ex-officio member of the new Commission, which had wide regulatory powers with regard to air and water pollution, water allocation, and the development and exploration of subaqueous lands. The State Geologist was, therefore, in a position to give technical advice to WARC but, being a non-voting member, was not directly involved in regulatory activities. The Commission could, however, with his consent, ask the State Geologist to act in its behalf in the consideration of applications for mineral exploration and subaqueous land development. This created the potential for blurring the distinct separation of research activities by the Survey and regulatory activities of WARC.

The DGS staff worked closely with WARC in the late nineteen sixties. It aided that Commission in drafting water well regulations, a water resources plan, a water inventory, and four studies of ground-water resources which were published by the University's Water Resources Center (New Castle and Kent counties and eastern and western Sussex County, 1968-1971).

The DGS also became involved in interstate water management. The Delaware River is a prime source of water for New York City and is also of importance to the downstream states for water supplies. In Delaware, the River is used primarily as a source of cooling water and exerts a major influence on the ecology of the Bay. The downstream states' main interest is, therefore, in maintaining sufficient fresh-water flows in order to prevent the "salt front" from moving so far upriver as to make the water unsuitable for industrial purposes. In response to a law suit and in order to maintain a balance between the interests of New York City and the downstream states of Pennsylvania, New Jersey, and Delaware, the U. S. Supreme Court in 1954 issued a Decree which in effect constrained New York City's diversion from

the River according to a formula designed to maintain a certain minimum fresh-water flow. The Court appointed a river master to administer its Decree apportioning the waters of the Delaware among the parties to the suit. The River Master requested the governors of each Delaware River Basin state and the Mayor of New York City to appoint the members of an advisory committee. The Governor of Delaware appointed the State Geologist to this committee in 1955, an arrangement continued by subsequent governors. It brought with it DGS responsibility for payment of the annual assessment by the River Master.

The establishment of WARC and the involvement of the DGS in advisement on legislation with regard to natural resources were expressions of the growing interest, both on the State and national levels, in environmental protection and in natural resources development planning. It was thought that water resources planning needed to be done on a basin-wide scale. Consequently, the governors of New York, Pennsylvania, New Jersey, and Delaware appointed a committee to study the creation of an organization to do such planning for the Delaware River basin. Brigadier General Norman M. Lack was the main representative for Delaware in the deliberations, and the State Geologist provided technical advice in the discussions that led to the adoption of a State-Federal Compact and the establishment of the Delaware River Basin Commission (DRBC). The draft of the Compact was published in February 1961, and the DRBC was born with the approval of Congress in September 1961.

Throughout the period under discussion, the DGS and the USGS conducted cooperative ground-water, surface-water, and water quality programs. The latter two programs were concerned with rather routine measurements of streamflow and chemical quality of water, respectively, and were executed by USGS personnel and financed on a 50-50 basis by State and federal funds. The cooperative ground-water program, financed in the same manner, was, as were all such programs throughout the United States, under the direction of a staff member of the USGS, although DGS personnel frequently and actively participated in the investigations. Generally in investigations, federal funds are made available to states, to be disbursed by state organizations for specified purposes and in accordance with federal guidelines. However, the cooperative programs (now termed joint-funded) with the USGS were the opposite, state funds being contributed to the federal agency which disbursed them for purposes enumerated in a cooperative agreement under federal direction and following federal rules and regulations. This arrangement was not always satisfactory, and sometimes there were serious problems with regard to staffing, the content of the

programs, and delays in completing investigations and reports. These delays meant that considerably more money, state and federal, was expended than originally foreseen, and several times the question arose whether or not some of the ground-water programs benefited from federal participation. In fact, the cooperative ground-water program was suspended from 1964 to 1969.

RESEARCH AND SERVICE AFTER 1969

This account of the DGS concentrates on its founding and activities between 1951 and 1969, the period when the author served as State Geologist. During those 18 years the basic assignments of the Survey were defined, and geologic knowledge of the State recovered from a 110-year hiatus. As history approaches current events it lacks the perspective of time and involves active personalities; therefore, only the briefest summary of the post-1969 Survey will be noted, leaving its details to subsequent recorders.

The change in the directorship of the DGS with Robert R. Jordan becoming State Geologist in 1969 did not signal sharp changes in the Survey program. Rather, nationwide developments, such as increasing concern for the environment and for the availability of energy, led to adjustments in the existing program, the initiation of new activities, and some staff additions to deal with these developments. In addition, the use of computers made it possible for efficient storage and retrieval of well and other data, and for digital modeling of ground-water behavior. Greater awareness of geologic hazards led to studies of floods, droughts, and earthquakes. The need to present increasing information in succinct form induced the Survey to publish various types of brief reports and map series in addition to the bulletins and reports of investigations.

Many investigations served more than one purpose. Studies of the Quaternary geology of Delaware were related to problems of ground-water quality and rising sea level. Subsurface stratigraphic studies allowed the DGS to better understand the geologic conditions that provided targets for the offshore exploration for hydrocarbons. Studies of geologic hazards, e.g., earthquakes, not only defined certain potential dangers, but also served to better understand tectonic movements and crustal structure beneath the Piedmont, Coastal Plain, and adjacent continental shelf, also with implications about the occurrence of hydrocarbons. The areal and vertical distribution of ground-water salinity has significance for the possibility of underground storage of

liquid wastes, ground-water development, the movement of brines, and the migration of hydrocarbons. In all these studies, a thorough knowledge of the geology of Delaware was crucial, and the DGS continued to be the only agency responsible for and capable of providing and expanding this fundamental knowledge.

It is not possible here to detail the many projects of the DGS from 1969 to present. Such documents as annual reports, the annual List of Publications, and First State Geology may be consulted for that purpose. Selected examples include: systematic geologic mapping of the entire State (begun 1969); investigation of glauconite for removal of contaminants from waste waters (1970); economic clay resources (1970); sources of nitrate pollution (1972); hydrologic map series (begun 1973); resources of the Coastal Zone (1976); and the Cartographic Information Center (1984). The work was facilitated by major equipment additions including the establishment and expansion of the DGS seismic network to five stations (1972-1985); spectrophotometer and x-ray diffraction apparatus (1976 and 1985); and new and continually upgraded well-logging equipment (from 1969).

Energy investigations have been major efforts of recent years. The DGS acted as the State's technical reviewer for exhaustive site studies for the proposed nuclear power plant at Summit during 1971-1975. A search for geothermal resources was conducted with the U. S. Department of Energy in 1978. And the potential for oil and gas offshore Delaware has demanded much research in support of the development of public policy and representation of the State to the Federal Government and industry since 1972.

A measure of the success of the Survey in applying knowledge of earth resources to practical problems lies in the numerous assignments, appointments, and commissions of the State Geologist and other members of the Survey to boards, committees, and task forces. A list would be tedious; the DGS maintains relationships with about a hundred units in the government, private, and scientific communities. Such additions to the statutory responsibilities are necessary but demanding and not generally recognized or sponsored with funding. Additionally, specific requests for information have risen to an estimated 6,000 per year.

The Survey's programs of research, exploration, and service continue to respond to the far-sighted statutory charge of 1951.

OBSERVATIONS

Since the beginning of the Delaware Geological Survey, office, laboratory space, and library facilities have been provided by the University of Delaware. It is difficult to express this support in terms of money, but it certainly is of great significance to an organization that has geological research as one of its major tasks. It is important that the DGS operates in an environment where research and service to the community are basic ingredients of daily life. If the Survey had been otherwise structured, it would have required more funding and would have lost its flexibility in program development, if not the considerable scientific standing it enjoys today.

To some, the Survey's organization has seemed complex. In fact, it is a practical arrangement, traditional and retained in many states. The University retains administrative charge. Absent the Geological Commission, which was discontinued in 1966, the DGS reports in State government to the Governor. The DGS is a creation of the General Assembly and a statutory advisor to that body, on which it also depends for funding. All interests are represented in programmatic decisions so that the Survey is objectively responsible to all of its governing parties. Accountability is assured in all areas as is the ability to objectively serve all needs.

Nevertheless, for many years the State Geologist was overburdened by a great variety of duties. A partial solution to this problem was a reorganization, carried out in 1978, that spread administrative duties by the appointment of two associate directors, Kenneth D. Woodruff with special responsibility for geohydrology and geophysics and Thomas E. Pickett for geology.

Another difficulty has been adequate space. The DGS originally (1951) shared one office with the Department of Geography. Shortly thereafter, it acquired considerably better accommodations and a laboratory in the basement of Robinson Hall, where conditions became very crowded in the late 1950s and 1960s with the gradual growth of both the Department of Geology (created in 1956) and the Survey. By the late 1960s the University decided to ameliorate the situation with the renovation of the building now called Penny Hall. Although initially it seemed spacious, the steady growth of the instructional program of the Department of Geology, with more undergraduate and graduate students and faculty, and the modest increase of Survey personnel and equipment soon led to crowded conditions again. In fact, the DGS was forced to move professional staff into office

trailers and to place personnel, facilities, and equipment at five locations, some quite makeshift. Lack of proper facilities imposed significant additional impediments to the execution of demanding programs. Thus it is particularly gratifying that the General Assembly funded a building to replace the office trailers in Fiscal Year 1986 and appropriated planning monies in the following year for a building for the Survey that should finally provide a proper home, which, at this writing, is under construction.

The funding of the Survey operations has always been rather tight. In 1951, the State appropriated \$15,000, which paid for one-half of the State Geologist's salary, a geological field assistant, secretarial help, and not much more. In general, appropriations increased slowly and consistently, but the amount of money that was, and is, available for operations by the Survey staff remains a small percentage of total outlays. By far the greatest portion of the budget (over 66%) is needed for salaries and other personnel costs of the professional staff; another large part (about 22%) is reserved for various cooperative programs with the USGS and for assessment of the State for the Delaware River Master program. This leaves only a small part (about 12-13%) of the total appropriation for all other operations. If the DGS had not received occasional funding for special investigations conducted for various federal, state, or county governmental units, its operations would have been hampered considerably. However, such special funding cannot be depended upon and cannot be used for hiring permanent staff, either of the professional or support type. Indeed, some federally-supported programs, for instance those concerned with energy, are no longer being funded, and others are likely to be curtailed in the near future.

Joint water-resources programs with the USGS have presented both benefits and problems. These programs are carried out by USGS personnel with both federal and state funds, leaving control of their execution and the disbursement of funds in federal hands. In fact, many state geological surveys have experienced similar difficulties. It is therefore not surprising that the organization to which all state geologists belong, the Association of American State Geologists, is continuing efforts to improve the jointly-financed programs with the USGS. Careful selection of pertinent projects beyond the resources of the State itself and single-point contracting to minimize intra-state confusion have yielded beneficial results overall, and some very significant contributions have been made by personnel of the counterpart federal agency. Additional benefits have

resulted from diligent attention to relationships between the DGS and the U. S. Bureau of Mines and U. S. Minerals Management Service.

Beginning with the Delaware Water Pollution Commission which evolved through the Water and Air Resources Commission to the current Department of Natural Resources and Environmental Control (DNREC), the DGS has served the State's regulatory needs with factual information and advice. With the growth of DNREC in response to increasing environmental concern and federal programs came the possibility that regulation would overshadow the generation of information and the potential for duplication of effort. Experience in Delaware and other states indicates that continuing coordination efforts are necessary to retain the inherent advantages of the natural division of labor between regulation and research and thus the public confidence in the credibility of DGS products that has been earned over nearly 40 years.

The present activities of the DGS are as varied as they have always been. Information and advice continue to be given to numerous private and public organizations and individuals with regard to water and mineral resources, ground-water contamination, geologic hazards, and energy. Service and consultation activities require considerable resources but, fortunately, can occasionally contribute important geologic and hydrologic data as well. There is an increasing need to document activities to assist in the legal and regulatory obligations required of the University and by the State and Federal governments. Most staff time is, however, still dedicated to various research programs, leading to the publication of geologic and hydrologic maps, bulletins, reports of investigations, and other responses to the ever-growing requirements for resource and environmental information.

The overall program of the DGS indicates that the Survey has, in the thirty-seven years of its existence, consistently and actively tried to implement the fundamental charges described in the statute of 1951. It has responded to changing economic and environmental conditions with appropriate changes in and additions to its program. It is the State's oldest agency in matters concerned with natural resources, and its accumulation of data and expertise is and will continue to be a source of information and advice not otherwise available.

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APPENDIX

Personnel of the Delaware Geological Survey (In order of date of appointment; highest degrees and titles while with DGS)

Johan J. Groot, PhD	Professor and Chairman and State Geologist Palynologist	1951-1969 1987-
Bonnie G. Seppanen	Secretary	1951-1952
Louis P. Vlangas, BA	Geological Field Assistant	1951-1953
Benjamin G. Nead, BA	Research Associate	1953-1954
Donna M. Organist, BA	Research Associate	1953-1956
Violet Marchetti	Secretary	1953-1958
Richard F. Ward, PhD	Geologist	1954-1958
Robert M. Germeroth, MS	Geologist	1956-1958
Margaret Nelson	Secretary	1958
Robert R. Jordan, PhD	State Geologist and Director; Professor	1958-
Marlene A. Carucci	Executive Secretary	1958 -
John K. Adams, PhD	Geologist	1958-1963
Robert D. Varrin, MS	Hydrologist and Asst. Research Prof.	1962-1968
Lawrence A. Taylor, MA	Asst. Geologist	1963-1964
Peter B. Smoor, MS	Hydrologist	1963-1965
Roger J. M. deWiest, PhD	Hydrologist	1965
William E. Bonini, PhD	Geophysicist	1965
Marilyn D. Maisano, AB	Research Assistant	1965
Nenad Spoljaric, PhD	Senior Scientist	1965-
Karl H. Wolf, PhD	Geologist	1965-1966
Thomas C. Gray	Research Assistant	1965
Wayne Baker	Research Assistant	1965

Kenneth D. Woodruff, MS	Associate Director, Hydrology and Geophysics	1966-
Thomas E. Pickett, PhD	Associate Director, Geology	1966-
Arnold H. Fogelgren	Field Technician	1967-1969
John D. Scott, BS	Geologist	1969
Boris J. Bilas, BS	Field Technician	1969-1973
John C. Miller, MS	Hydrogeologist	1969-1973
John H. Talley, MS	Senior Scientist	1972-
Josh T. Williams	Field Technician	1974-1979
Allan M. Thompson, PhD	Geologist	1974-1977
Susan Petty, BS	Project Geologist	1975-1976
William D. Miller, BS	Project Geologist	1975-1976
Barbara A. Lanan, BS	Project Geologist	1975-1976
Richard N. Benson, PhD	Senior Scientist	1975 -
William F. Hahn, BS	Project Geologist	1975-1977
Dorothy C. Windish, AS	Senior Secretary	1976-
Jean H. Ballentine	Contract Writer	1978
Kathleen M. Kent, MS	Research Associate II	1978-1979
Michael J. Christopher, BS	Research Associate I	1979-1982
Richard V. Smith, MS	Research Associate II	1979-1982
Thomas Kull	Senior Field Technician	1980
Roland E. Bounds, BS	Senior Research Technician I	1980-
Robert G. Doyle, MS	Research Associate III	1980-1984
William S. Schenck, BS	Research Associate III	1980-
Randall L. McAlister, MS	Project Geologist	1984
Alan S. Andres, MS	Associate Scientist	1984-
Michael G. Kramer, BS	Senior Research Technician I	1985-1987
Charles T. Smith, BS	Senior Research Technician I	1987-
Kelvin W. Ramsey, PhD	Research Associate II	1988-

Also, dozens of student assistants have worked on part-time bases for the DGS, contributing essential support to the professional staff while gaining initial experience in their own careers.