

Information on obtaining a position as a chemist with the Federal Government is available from the Office of Personnel Management (OPM) through a telephone-based system. Consult your telephone directory under U.S. Government for a local number or call (912) 757-3000; Federal Relay Service: (800) 877-8339. The first number is not tollfree, and charges may result. Information also is available from the OPM Internet site: <http://www.usajobs.opm.gov>.

For general information on materials science, contact:

► Materials Research Society (MRS), 506 Keystone Dr., Warrendale, PA 15086-7573. Internet: <http://www.mrs.org>

Environmental Scientists and Geoscientists

(O*NET 19-2041.00, 19-2042.01, 19-2043.00)

Significant Points

- Work at remote field sites is common.
- A bachelor's degree in geology or geophysics is adequate for entry-level jobs; better jobs with good advancement potential usually require at least a master's degree.
- A Ph.D. degree is required for most research positions in colleges and universities and in government.

Nature of the Work

Environmental scientists and geoscientists use their knowledge of the physical makeup and history of the Earth to locate water, mineral, and energy resources; protect the environment; predict future geologic hazards; and offer advice on construction and land use projects.

Environmental scientists conduct research to identify and abate or eliminate sources of pollutants that affect people, wildlife, and their environments. They analyze and report measurements and observations of air, water, soil, and other sources to make recommendations on how best to clean and preserve the environment. They often use their skills and knowledge to design and monitor waste disposal sites, preserve water supplies, and reclaim contaminated land and water to comply with Federal environmental regulations.

Geoscientists study the composition, structure, and other physical aspects of the Earth. By using sophisticated instruments and analyses of the earth and water, geoscientists study the Earth's geologic past and present in order to make predictions about its future. For example, they may study the Earth's movements to try to predict when and where the next earthquake or volcano will occur and the probable impact on surrounding areas to minimize the damage. Many geoscientists are involved in the search for oil and gas, while others work closely with environmental scientists in preserving and cleaning up the environment.

Geoscientists usually study, and are subsequently classified in, one of several closely related fields of geoscience, including geology, geophysics, and oceanography. *Geologists* study the composition, processes, and history of the Earth. They try to find out how rocks were formed and what has happened to them since formation. They also study the evolution of life by analyzing plant and animal fossils. *Geophysicists* use the principles of physics, mathematics, and chemistry to study not only the Earth's surface, but also its internal composition; ground and surface waters; atmosphere; oceans; and its magnetic, electrical, and gravitational forces. *Oceanographers* use their knowledge of geology and geo-

physics, in addition to biology and chemistry, to study the world's oceans and coastal waters. They study the motion and circulation of the ocean waters and their physical and chemical properties, and how these properties affect coastal areas, climate, and weather.

Geoscientists can spend a large part of their time in the field identifying and examining rocks, studying information collected by remote sensing instruments in satellites, conducting geological surveys, constructing field maps, and using instruments to measure the Earth's gravity and magnetic field. For example, they often perform seismic studies, which involve bouncing energy waves off buried rock layers, to search for oil and gas or understand the structure of subsurface rock layers. Seismic signals generated by earthquakes are used to determine the earthquake's location and intensity.

In laboratories, geologists and geophysicists examine the chemical and physical properties of specimens. They study fossil remains of animal and plant life or experiment with the flow of water and oil through rocks. Some geoscientists use two- or three-dimensional computer modeling to portray water layers and the flow of water or other fluids through rock cracks and porous materials. They use a variety of sophisticated laboratory instruments, including x ray diffractometers, which determine the crystal structure of minerals, and petrographic microscopes, for the study of rock and sediment samples.

Geoscientists working in mining or the oil and gas industry sometimes process and interpret data produced by remote sensing satellites to help identify potential new mineral, oil, or gas deposits. Seismic technology also is an important exploration tool. Seismic waves are used to develop a three-dimensional picture of underground or underwater rock formations. Seismic reflection technology may also reveal unusual underground features that sometimes indicate accumulations of natural gas or petroleum, facilitating exploration and reducing the risks associated with drilling in previously unexplored areas.

Numerous subdisciplines or specialties fall under the two major disciplines of geology and geophysics that further differentiate the type of work geoscientists do. For example, *petroleum geologists* explore for oil and gas deposits by studying and mapping the subsurface of the ocean or land. They use sophisticated geophysical instrumentation, well log data, and computers to interpret geological information. *Engineering geologists* apply geologic principles to the fields of civil and environmental engineering, offering advice on major construction projects and assisting in environmental remediation and natural hazard reduction projects. *Mineralogists* analyze and classify minerals and precious stones according to composition and structure and study their environment in order to find new mineral resources. *Paleontologists* study fossils found in geological formations to trace the evolution of plant and animal life and the geologic history of the Earth. *Stratigraphers* study the formation and layering of rocks to understand the environment in which they were formed. *Volcanologists* investigate volcanoes and volcanic phenomena to try to predict the potential for future eruptions and possible hazards to human health and welfare.

Geophysicists may specialize in areas such as geodesy, seismology, or magnetic geophysics. *Geodesists* study the size and shape of the Earth, its gravitational field, tides, polar motion, and rotation. *Seismologists* interpret data from seismographs and other geophysical instruments to detect earthquakes and locate earthquake-related faults. *Geochemists* study the nature and distribution of chemical elements in ground water and Earth materials. *Geomagnetists* measure the Earth's magnetic field and use measurements taken over the past few centuries to devise theoretical models to explain the Earth's origin. *Paleomagnetists* interpret fossil magnetization in rocks and sediments from the continents and oceans, to record the

spreading of the sea floor, the wandering of the continents, and the many reversals of polarity that the Earth's magnetic field has undergone through time. Other geophysicists study atmospheric sciences and space physics. (See atmospheric scientists and physicists and astronomers elsewhere in the *Handbook*.)

Hydrology is closely related to the disciplines of geology and geophysics. *Hydrologists* study the quantity, distribution, circulation, and physical properties of underground and surface waters. They study the form and intensity of precipitation, its rate of infiltration into the soil, its movement through the Earth, and its return to the ocean and atmosphere. The work they do is particularly important in environmental preservation, remediation, and flood control.

Oceanography also has several subdisciplines. *Physical oceanographers* study the ocean tides, waves, currents, temperatures, density, and salinity. They study the interaction of various forms of energy, such as light, radar, sound, heat, and wind with the sea, in addition to investigating the relationship between the sea, weather, and climate. Their studies provide the Maritime Fleet with up-to-date oceanic conditions. *Chemical oceanographers* study the distribution of chemical compounds and chemical interactions that occur in the ocean and sea floor. They may investigate how pollution affects the chemistry of the ocean. *Geological and geophysical oceanographers* study the topographic features and the physical makeup of the ocean floor. Their knowledge can help oil and gas producers find these minerals on the bottom of the ocean. *Biological oceanographers*, often called marine biologists, study the



Environmental scientists and geoscientists use a variety of sophisticated equipment.

distribution and migration patterns of the many diverse forms of sea life in the ocean. (See biological scientists elsewhere in the *Handbook*.)

Working Conditions

Some geoscientists spend the majority of their time in an office, but many others divide their time between fieldwork and office or laboratory work. Geologists often travel to remote field sites by helicopter or four-wheel drive vehicles and cover large areas on foot. An increasing number of exploration geologists and geophysicists work in foreign countries, sometimes in remote areas and under difficult conditions. Oceanographers may spend considerable time at sea on academic research ships. Fieldwork often requires working long hours, but workers are usually rewarded by longer than normal vacations. Environmental scientists and geoscientists in research positions with the Federal Government or in colleges and universities often are required to design programs and write grant proposals in order to continue their data collection and research. Environmental scientists and geoscientists in consulting jobs face similar pressures to market their skills and write proposals to maintain steady work. Travel often is required to meet with prospective clients or investors.

Employment

Environmental scientists and geoscientists held about 97,000 jobs in 2000. Environmental scientists accounted for 64,000 of the total; geoscientists, 25,000; and hydrologists, 8,000. Many more individuals held environmental science and geoscience faculty positions in colleges and universities, but they are considered college and university faculty. (See postsecondary teachers elsewhere in the *Handbook*.)

Among salaried geoscientists, nearly 1 in 3 were employed in engineering and management services, and slightly more than 1 in 5 worked for oil and gas extraction companies or metal mining companies. The Federal Government employed about 3,100 geoscientists, including geologists, geophysicists, and oceanographers in 2000, mostly within the U.S. Department of the Interior for the U.S. Geological Survey (USGS), and the U.S. Department of Defense. More than 2,600 worked for State agencies, such as State geological surveys and State departments of conservation. About 1 geoscientist in 25 was self-employed; most were consultants to industry or government.

For environmental scientists, about 2 in 5 were employed in State and local governments, about 1 in 8 in management and public relations, 1 in 10 in engineering and architectural services, and 1 in 10 in the Federal Government. A small number were self-employed.

Nearly 1 in 3 hydrologist worked in the Federal Government in 2000. Another 1 in 5 worked in management and public relations, 1 in 6 in engineering and architectural services, and 1 in 6 for State governments.

Training, Other Qualifications, and Advancement

A bachelor's degree in geology or geophysics is adequate for some entry-level geoscientist jobs, but more job opportunities and better jobs with good advancement potential usually require at least a master's degree in geology or geophysics. Environmental scientists require at least a bachelor's degree in hydrogeology; environmental, civil, or geological engineering; or geochemistry or geology, but employers usually prefer candidates with master's degrees. A master's degree is required for most entry-level research positions in colleges and universities, Federal agencies, and State geological surveys. A Ph.D. is necessary for most high-level research positions.

Hundreds of colleges and universities offer a bachelor's degree in geology; fewer schools offer programs in geophysics, hydrogeology, or other geosciences. Other programs offering related training for beginning geological scientists include geophysical technology, geophysical engineering, geophysical prospecting, engineering geology, petroleum geology, geohydrology, and geochemistry. In addition, several hundred universities award advanced degrees in geology or geophysics.

Traditional geoscience courses emphasizing classical geologic methods and topics (such as mineralogy, petrology, paleontology, stratigraphy, and structural geology) are important for all geoscientists and make up the majority of college training. Persons studying physics, chemistry, biology, mathematics, engineering, or computer science may also qualify for some environmental science and geoscience positions if their coursework includes study in geology. Those students interested in working in the environmental or regulatory fields, either in environmental consulting firms or for Federal or State governments, should take courses in hydrology, hazardous waste management, environmental legislation, chemistry, fluid mechanics, and geologic logging. An understanding of environmental regulations and government permit issues is also valuable for those planning to work in mining and oil and gas extraction. Hydrologists and environmental scientists should have some knowledge of the potential liabilities associated with some environmental work. Computer skills are essential for prospective environmental scientists and geoscientists; students who have some experience with computer modeling, data analysis and integration, digital mapping, remote sensing, and geographic information systems (GIS) will be the most prepared entering the job market. A knowledge of the Global Positioning System (GPS)—a locator system that uses satellites—also is very helpful. Some employers seek applicants with field experience, so a summer internship may be beneficial to prospective geoscientists.

Environmental scientists and geoscientists must have excellent interpersonal skills, because they usually work as part of a team with other scientists, engineers, and technicians. Strong oral and written communication skills also are important, because writing technical reports and research proposals, as well as communicating research results to others, are important aspects of the work. Because many jobs require foreign travel, knowledge of a second language is becoming an important attribute to employers. Geoscientists must be inquisitive and able to think logically and have an open mind. Those involved in fieldwork must have physical stamina.

Environmental scientists and geoscientists often begin their careers in field exploration or as research assistants or technicians in laboratories or offices. They are given more difficult assignments as they gain experience. Eventually, they may be promoted to project leader, program manager, or another management and research position.

Job Outlook

Employment of environmental scientists and hydrologists is expected to grow faster than the average for all occupations through 2010, while employment of geoscientists is expected to grow about as fast as the average. The need to replace environmental scientists and geoscientists who retire will result in many job openings over the next decade. Driving the growth of environmental scientists and geoscientists will be the continuing need for companies and organizations to comply with environmental laws and regulations, particularly those regarding groundwater contamination and flood control. However, oil company mergers and stagnant or declining government funding for research may affect the hiring of petroleum

geologists and geoscientists involved in research. Instead, increased construction and exploration for oil and natural gas abroad may require geoscientists to work overseas unless additional sites in the United States are opened for exploration.

In the past, employment of geologists and some other geoscientists has been cyclical and largely affected by the price of oil and gas. When prices were low, oil and gas producers curtailed exploration activities and laid off geologists. When prices were up, companies had the funds and incentive to renew exploration efforts and hire geoscientists in large numbers. In recent years, a growing worldwide demand for oil and gas and new exploration and recovery techniques—particularly in deep water and previously inaccessible sites—have returned some stability to the petroleum industry, with a few companies increasing their hiring of geoscientists. Growth in this area, though, will be limited due to increasing efficiencies in finding oil and gas. Geoscientists who speak a foreign language and who are willing to work abroad should enjoy the best opportunities.

The need for companies to comply with environmental laws and regulations is expected to contribute to the demand for environmental scientists and some geoscientists, especially hydrologists and engineering geologists. Issues of water conservation, deteriorating coastal environments, and rising sea levels also will stimulate employment growth of these workers. As the population increases and moves to more environmentally sensitive locations, environmental scientists and hydrologists will be needed to assess building sites for potential geologic hazards and to address issues of pollution control and waste disposal. Hydrologists and environmental scientists also will be needed to conduct research on hazardous wastesites to determine the impact of hazardous pollutants on soil and groundwater so engineers can design remediation systems. The need for environmental scientists and geoscientists who understand both the science and engineering aspects of waste remediation is growing. An expected increase in highway building and other infrastructure projects will be an additional source of jobs for engineering geologists.

Employment of environmental scientists and geoscientists is more sensitive to changes in governmental energy or environmental policy than employment of other scientists. If environmental regulations are rescinded or loosened, job opportunities will shrink. On the other hand, increased exploration for energy sources will result in improved job opportunities for geoscientists.

Jobs with the Federal and State governments and with organizations dependent on Federal funds for support will experience little growth over the next decade, unless budgets increase significantly. The Federal Government is expected to increasingly outsource environmental services to private consulting firms. This lack of funding will affect mostly geoscientists performing basic research.

Earnings

Median annual earnings of environmental scientists were \$44,180 in 2000. The middle 50 percent earned between \$34,570 and \$58,490. The lowest 10 percent earned less than \$28,520, and the highest 10 percent earned more than \$73,790.

Median annual earnings of geoscientists were \$56,230 in 2000. The middle 50 percent earned between \$43,320 and \$77,180. The lowest 10 percent earned less than \$33,910, and the highest 10 percent earned more than \$106,040.

Median annual earnings of hydrologists were \$55,410 in 2000. The middle 50 percent earned between \$43,740 and \$68,500. The lowest 10 percent earned less than \$35,910, and the highest 10 percent earned more than \$85,260.

Median annual earnings in the industries employing the largest number of environmental scientists in 2000 were as follows:

Federal Government	\$59,590
Engineering and architectural services	43,920
Management and public relations	43,900
Local government	42,880
State government	39,330

According to the National Association of Colleges and Employers, beginning salary offers in 2001 for graduates with bachelor's degrees in geology and the geological sciences averaged about \$35,568 a year; graduates with a master's degree averaged \$41,100; graduates with a doctoral degree averaged \$57,500.

In 2001, the Federal Government's average salary for geologists in managerial, supervisory, and nonsupervisory positions was \$70,763; for geophysicists, \$79,660; for hydrologists, \$64,810; and for oceanographers, \$71,881.

The petroleum, mineral, and mining industries offer higher salaries, but less job security, than other industries. These industries are vulnerable to recessions and changes in oil and gas prices, among other factors, and usually release workers when exploration and drilling slow down.

Related Occupations

Many geoscientists work in the petroleum and natural gas industry. This industry also employs many other workers in the scientific and technical aspects of petroleum and natural gas exploration and extraction, including engineering technicians, science technicians, petroleum engineers, and surveyors, cartographers and photogrammetrists. Also, some physicists, chemists, and atmospheric scientists—as well as mathematicians and systems analysts, computer scientists, and database administrators—perform related work in both petroleum and natural gas exploration and extraction and in environment-related activities.

Sources of Additional Information

Information on training and career opportunities for geologists is available from:

- ▶ American Geological Institute, 4220 King St., Alexandria, VA 22302-1502. Internet: <http://www.agiweb.org> Geological Society of America, P.O. Box 9140, Boulder, CO 80301-9140. Telephone: (717) 447-2020. Internet: <http://www.geosociety.org>.
- ▶ American Association of Petroleum Geologists, P.O. Box 979, Tulsa, OK 74101. Internet: <http://www.aapg.org>

Information on training and career opportunities for geophysicists is available from:

- ▶ American Geophysical Union, 2000 Florida Ave. NW., Washington, DC 20009. Telephone: (202) 777-7512. Internet: <http://www.agu.org>
- ▶ Society of Exploration Geophysicists, 8801 South Yale, Tulsa, OK 74137. Telephone: (918) 497-5500. Internet: <http://www.seg.org>

A packet of free career information, and a list of education and training programs in oceanography and related fields priced at \$6.00, is available from:

- ▶ Marine Technology Society, 1828 L St. NW., Suite 906, Washington, DC 20036. Internet: <http://www.mtsociety.org>

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Physicists and Astronomers

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Significant Points

- A doctoral degree is the usual educational requirement because most jobs are in basic research and development; a bachelor's or master's degree is sufficient for some jobs in applied research and development.
- Because funding for research grows slowly, new Ph.D. graduates will face competition for basic research jobs.

Nature of the Work

Physicists explore and identify basic principles governing the structure and behavior of matter, the generation and transfer of energy, and the interaction of matter and energy. Some physicists use these principles in theoretical areas, such as the nature of time and the origin of the universe; others apply their physics knowledge to practical areas, such as the development of advanced materials, electronic and optical devices, and medical equipment.

Physicists design and perform experiments with lasers, cyclotrons, telescopes, mass spectrometers, and other equipment. Based on observations and analysis, they attempt to discover and explain laws describing the forces of nature, such as gravity, electromagnetism, and nuclear interactions. Physicists also find ways to apply physical laws and theories to problems in nuclear energy, electronics, optics, materials, communications, aerospace technology, navigation equipment, and medical instrumentation.

Astronomy is sometimes considered a subfield of physics. *Astronomers* use the principles of physics and mathematics to learn about the fundamental nature of the universe, including the sun, moon, planets, stars, and galaxies. They also apply their knowledge to solve problems in navigation, space flight, and satellite communications, and to develop the instrumentation and techniques used to observe and collect astronomical data.

Most physicists work in research and development. Some do basic research to increase scientific knowledge. Physicists who conduct applied research build upon the discoveries made through basic research and work to develop new devices, products, and processes. For example, basic research in solid-state physics led to the development of transistors and, then, of integrated circuits used in computers.

Physicists also design research equipment. This equipment often has additional unanticipated uses. For example, lasers are used in surgery, microwave devices are used in ovens, and measuring instruments can analyze blood or the chemical content of foods. A small number of physicists work in inspection, testing, quality control, and other production-related jobs in industry.

Much physics research is done in small or medium-size laboratories. However, experiments in plasma, nuclear, and high energy and in some other areas of physics require extremely large, expensive equipment, such as particle accelerators. Physicists in these subfields often work in large teams. Although physics research may require extensive experimentation in laboratories, research physicists still spend time in offices planning, recording, analyzing, and reporting on research.

Almost all astronomers do research. Some are theoreticians, working on the laws governing the structure and evolution of astronomical objects. Others analyze large quantities of data gathered by observatories and satellites, and write scientific papers or reports on their findings. Some astronomers actually operate, usually as