

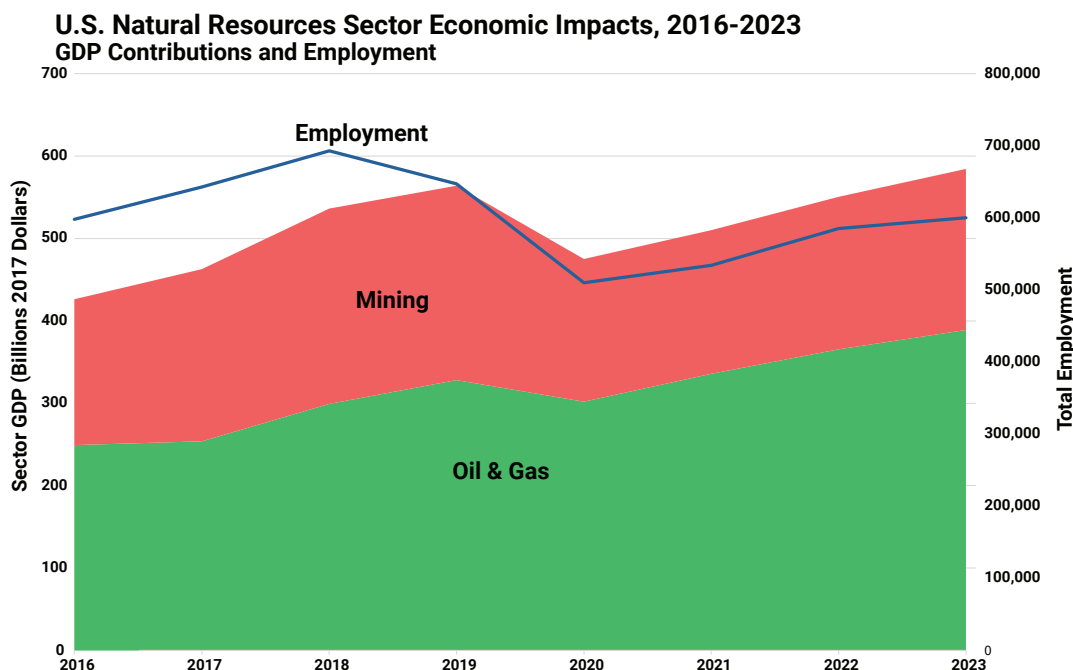
Geoscience Supporting a Vibrant Economy



GEOSCIENCES IMPACT ON THE ECONOMY

The geosciences are intricately linked to the growth and health of the economy, by serving a crucial role in sourcing materials, fostering innovations, and ensuring sustainable economic growth. Geological knowledge, and harnessing of natural systems underpins every industry, from the winds that drive wind turbines, water powering hydroelectric dams, to the extraction of minerals essential for technology and infrastructure development. Geoscientists' ability to learn from the earth's history of climate change aids in mitigation of its effects, minimizing impacts to transportation

networks and infrastructure. Additionally, the understanding and monitoring of Earth's systems allows for mitigating risk from natural hazards like earthquakes and floods which is vital for minimizing economic disruption and safeguarding lives. Moreover, geoscience knowledge and expertise are critical for addressing challenges such as water scarcity and the geological storage of CO₂, which is needed for sustainable development. Investing in geoscience research and its workforce is imperative for building a resilient economy capable of competing on a global scale.



The natural resource industries, which are driven by the knowledge and expertise of geoscientists, are growing engines of economic and employment development in the United States. Data from the U.S. Bureau of Economic Analysis and the U.S. Bureau of Labor Statistics.

Catalyzing Critical Mineral and Energy Security

As the world shifts towards cleaner and more sustainable energy sources, geoscience knowledge and technologies are central to sourcing critical minerals and siting locations for renewable energy.

Mitigating the Impact of Natural Hazards

Natural disasters, enhanced in severity and frequency by climate change, can have huge negative impacts on the economy. Through prediction and mitigation, geoscientists can reduce risk to life and property.

Leading Sustainable Agriculture

Agriculture is critical to the nation's food security, and vital to our economy. Geoscientists, specifically soil scientists, play a critical role in understanding the genesis, distribution, and productivity of soils while hydrogeologists are key to sourcing water for irrigation, and monitoring groundwater supplies.

Water Availability

Water availability is critical to all aspects of the economy, not just for drinking and agriculture. Without sufficient water, energy generation and manufacturing would not be possible. Geoscientists discover appropriate ground and surface water sources and advise on appropriate resource management.

Securing Supply Chains

International commerce is critical to U.S. economic vitality. International conflicts, the imposition of sanctions, and their reciprocal responses threaten U.S. national security and supply chains, driving demand for geoscientists to develop domestic sources of energy and minerals.

Supporting the Insurance Industry

Geoscientists have become increasingly more involved by the insurance and re-insurance industries to aid in risk assessment, hazard prediction, and assessments to mitigate expenses for covering claims related to natural disasters.

Catalyzing an Innovative Workforce

A robust innovative economy depends on a well-educated workforce, and in the digital and technological economy of today, STEM literacy is essential.

Environmental Compliance

Effective environmental stewardship yields direct economic returns, from improved community health, reduced liabilities, easier capital access, and improved efficiencies. Geoscientists are often the point person for companies in meeting regulatory compliance needs for NEPA.

EXEMPLARS OF IMPACTS OF GEOSCIENCE ON THE ECONOMY

Geoscientists play a vital role in finding and producing important minerals that are essential for the energy transition, national security, and consumer goods. Discovery of new deposits, in increasingly extreme environments, help build access to minerals, but also the opportunity to extract and process those resources with clean and efficient modern processes. This improves material access, reduces costs, and minimizes environmental impacts. A prime example is the extraction of lithium from brines in Nevada, yielding a major new source of an increasingly critical element.

The economy can suffer greatly from natural disasters, which are becoming more intense and common due to climate change. Geoscientists study the origin and consequences of natural disasters such as landslides, sinkholes, floods, earthquakes, and fires. More frequent and ferocious fires in the United States have led to more widespread destruction and deaths. By understanding the post-fire damage to soils and landcover, geoscientists can assist with the reclamation of fire-ravaged landscapes and help mitigate the future risks and impacts on society.

The insurance industry requires risk assessment, environmental protection, and land management, which has increased the

need for geoscientists. The employment of geoscientists in the insurance industry rose 21 percent from 2010 to 2020. Moreover, geoscience research helps to reduce risk from natural processes, leading to economic savings that can prevent insurance claims and lost productivity.

If farmers want to use groundwater for irrigation, they need hydrogeologists and hydrologists to map and describe the aquifers that provide it. Hydrogeologists also monitor groundwater levels to guide water management. Soils scientists help farmers find the best ways to improve their productivity, conserve soils, maximize irrigation efficiency, and determine the fate and transport of pesticides, herbicides, and fertilizers in soil and water.

Geosciences play a vital role in the creation of an innovation economy through training and investments in science, technology, engineering, and mathematics (STEM) fields. Many federal departments acknowledge this need and support STEM education and literacy programs. The Geoscience Directorate of the National Science Foundation requested \$1.24 billion for 2023 to fund the general progress of knowledge and stimulate innovation.



CASE STUDIES

Exploration and extraction of natural resources by geoscientists produce economic benefits such as generating wealth and creating employment. The mining industry provides 600,000 direct jobs and adds more than \$200 billion to U.S. GDP (U.S. Bureau of Labor Statistics and U.S. Bureau of Economic Analysis).

The Colorado Marshall Fire (2021–2022) caused more than 2 billion dollars of losses. The USDA 10-year wildfire plan and the Infrastructure Investment and Jobs Act are federal initiatives to boost funding for fire prevention. The USGS next generation Landsat satellites will be able to assist in identifying new wildfires in less than 30 minutes.

Space weather, such as solar flares, can pose serious risks to our electricity grids, computing and communication networks, navigation (GPS and GNSS) and other services that depend on satellites. A single severe space weather event could result in a daily economic loss of about \$41.5 billion for the U.S. (American Geophysical Union, 2017)

Geoscientists provide earthquake and risk modeling for the California Earthquake Authority (CEA) so they can provide insurance coverage for damage from seismic events for residential customers in California; These models provide insurance companies with projections and actuarial data that helps make homeowner insurance premiums more affordable. Together, the CEA and insurance company cooperative cover about 1 million residences and provide \$20 billion in coverage capacity.



EXAMPLES OF RELEVANT LEGISLATION AND POLICY

Executive Orders

- ▶ **14082:** Outlines implementation of energy and infrastructure provisions of the Inflation Reduction Act, including incentivizing clean energy usage on the corporate and individual levels.
- ▶ **13953:** Declared National Emergency over foreign reliance (particularly regarding China) on critical mineral resources. Ordering examination of mineral processing.
- ▶ **13744:** Establishes preparations for extreme space weather events, particularly those that may impact technology and energy infrastructure.

Congressional

- ▶ **H.R. 5770:** The Water Data Improvement Act, reauthorizes the SECURE Water Act that supports national stream and groundwater monitoring.
- ▶ **S.1871:** Implement intergovernmental coordination (federal, state, tribes, local) to address reliance on foreign sources for critical minerals, particularly with regard to China.
- ▶ **Public Law 117-58:** Infrastructure Investment and Jobs Act (2021) improves infrastructure to maintain supply chains; increases wildland firefighter pay.
- ▶ **Public Law 115-334:** Farm Bill

Relevant Federal Agencies

- ▶ U.S. Geological Survey (Interior)
- ▶ Department of Energy — National Nuclear Security Administration; Fossil Energy and Carbon Management; Office of Science; Energy Information Administration
- ▶ National Weather Service (Commerce)

Related National Academy Reports

- ▶ Community-Driven Relocation: Recommendations for the U.S. Gulf Coast Region and Beyond (2024)
- ▶ Critical Issues in Transportation for 2024 and Beyond (2024)
- ▶ Accelerating Decarbonization in the United States: Technology, Policy, and Societal Dimensions (2023)
- ▶ Carbon Dioxide Utilization Markets and Infrastructure: Status and Opportunities: A First Report (2023)
- ▶ Corrosion of Buried Steel at New and In-Service Infrastructure (2023)
- ▶ Developing a Highway Framework to Conduct an All-Hazards Risk and Resilience Analysis (2023)

Non-Partisan Non-Profit Expertise

- ▶ American Association of Petroleum Geologists
- ▶ American Institute of Professional Geologists
- ▶ Association of American State Geologists
- ▶ Association of Environmental and Engineering Geologists
- ▶ Association of State Boards of Geology
- ▶ National Association of State Boards of Geology
- ▶ Society of Economic Geologists
- ▶ Society of Exploration Geophysicists
- ▶ Society for Mining, Metallurgy, and Exploration
- ▶ Soil Science Society of America

Geoscience's Crucial Role in National Security Strategies

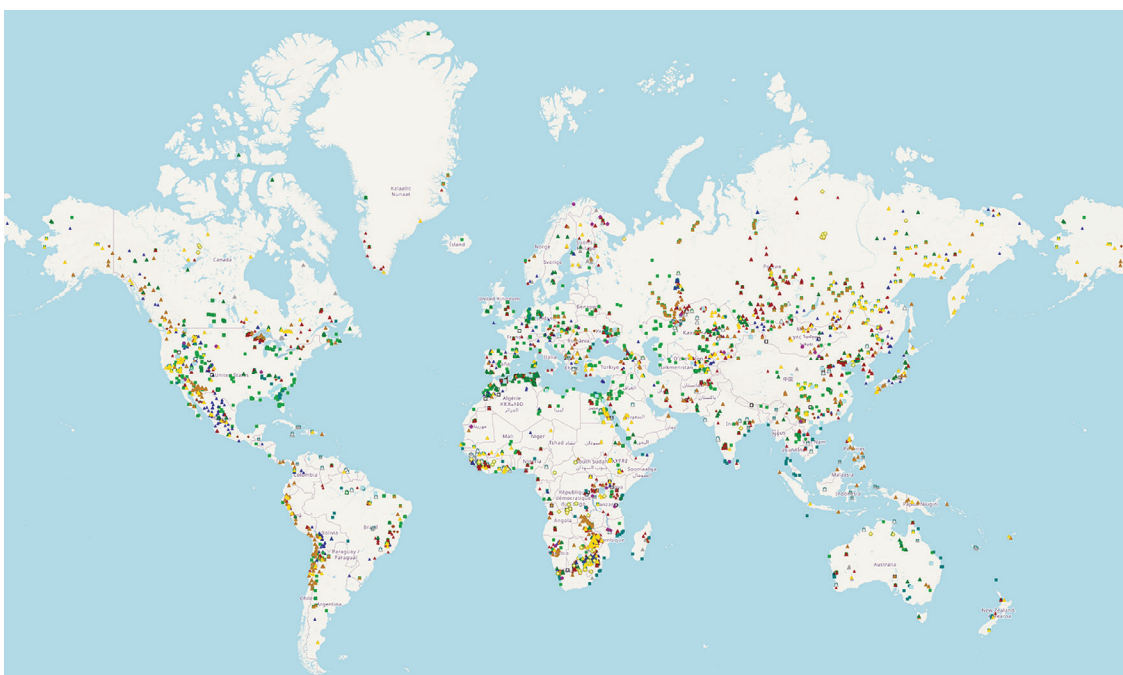


GEOSCIENCES IMPACT ON NATIONAL SECURITY

In the realm of national security, geoscientists play crucial roles in addressing a range of strategic imperatives. Ensuring global stability, for instance, demands an acute understanding of agricultural resilience, water security, and the potential destabilizing impacts of climate change. These insights guide policy and aid decisions, helping to preempt conflict and humanitarian crises before they escalate. Operational readiness across defense and security sectors also relies heavily on comprehending and anticipating natural conditions—from terrestrial and space weather to terrain stability to oceanographic conditions—which can significantly influence the effectiveness

of military and security operations. Moreover, the procurement and sustainable management of reliable energy and critical minerals are foundational for equipping and maintaining a mobile, technologically advanced military. Geoscientists locate and assess these essential resources, ensuring that the armed forces have timely access to the energy and material sources necessary for defense technologies. Together, these geoscience inputs are integral to shaping a responsive and informed national security strategy that addresses both immediate and long-term challenges on a global scale within which geoscientists operate intrinsically.

Mineral deposits are not uniformly distributed across the world. As seen from the U.S. Geological Survey's Mineral Resources Data System, ready access to needed minerals requires the expertise of geoscientists and diplomats to secure access to the resources to ensure National Security. (<https://mrdata.usgs.gov>)



Climate Adaptation

Geoscientists help us understand climate patterns and their impacts, aiding the national security apparatus in preparing for and mitigating the effects of climate change, such as increased frequency of extreme weather events, implications on global stability, and threats to force readiness.

Disaster Preparedness and Response

Geoscientists are crucial in predicting natural disaster risks like earthquakes, tsunamis, and volcanic eruptions, which enables better preparedness and response strategies to protect populations and critical infrastructure.

Environmental Monitoring

Monitoring environmental degradation and its security implications, such as soil erosion, deforestation, and water shortage or contamination, which can lead to food and water scarcity and drive mass migrations.

Oceanography for Naval Operations

Oceanographers develop the data that assists naval operations in navigation, submarine warfare, and the deployment of marine assets, enhancing maritime security.

Critical Minerals

Critical minerals are essential to national security due to their irreplaceable role in manufacturing defense technology, renewable energy systems, and advanced electronics. These minerals, including rare earth elements, lithium, and cobalt, are integral components in everything from jet engines and communication satellites to missile guidance systems and electric vehicle batteries. The availability and security of these mineral supplies are vital to maintain technological superiority, economic stability, and strategic autonomy.

Energy Security

Geoscientists are central to the exploration and development of energy resources, including fossil fuels and renewables such as geothermal, uranium for nuclear power, and helping to ensure a stable and independent energy supply.

Geopolitical Analysis

By mapping territorial waters and land boundaries, geoscientists aid in resolving territorial disputes and in strategic military planning, particularly in regions where borders are contested.

Space Weather Monitoring

Geoscientists involved in studying atmospheric sciences and solar-terrestrial interactions help predict space weather events that can disrupt satellite communications, navigation systems, and even power grids, all of which are critical to national security operations.

EXEMPLARS OF IMPACTS OF GEOSCIENCE ON NATIONAL SECURITY

Critical minerals are indispensable for both economic vitality and technological advancement, impacting national security directly. Direct investments by the U.S. Defense Department in securing future cobalt supplies from a developing mine in Idaho to advances in brine-based lithium production are ways geoscientists are securing future supplies of minerals crucial for manufacturing advanced military hardware, from stealth technology to communication systems, and critical civilian technologies like smartphones and electric vehicles. A secure and sustainable supply of these resources ensures that a nation does not become overly dependent on potentially unstable foreign sources, thereby maintaining its strategic autonomy and technological edge.

Geoscientists significantly enhance national security by providing accurate weather, space weather, and other geological hazard forecasts. These capabilities are essential for planning and

conducting military operations safely and effectively. Weather forecasting helps in strategic deployment of troops, while space weather alerts are critical for protecting satellites and communication systems from solar flares. Additionally, early warnings of geological hazards like volcanic eruptions or earthquakes can safeguard both military and civilian infrastructure, ensuring operational continuity.

Geoscience plays a pivotal role in promoting global stability by providing crucial data on climate change and environmental degradation, which can lead to food and water scarcity, impacting millions. By predicting these changes, geoscientists enable proactive international aid and intervention strategies, mitigating the risk of conflicts and unrest. Additionally, their work helps anticipate mass migrations caused by natural disasters or resource shortages, allowing for better preparedness and response, thereby preventing potential security crises before they arise.



CASE STUDIES

The Department of Defense's Climate Risk Analysis is a comprehensive document that assesses the various risks posed by climate change to U.S. military operations and infrastructure. The analysis highlights how rising sea levels, increased flooding, and extreme weather events threaten military bases and other infrastructure. Both Naval Station Norfolk and Cape Canaveral Space Force Station are facing risks of ongoing flooding, and projected annual major floods by 2050. Total expected climate-related risk to bases is estimated at \$387 billion. New initiatives emphasize the need for resilient designs and retrofitting existing facilities to withstand these changes. Additionally, climate change impacts are expected to complicate operational readiness and execution as altered weather patterns could affect training, logistics, and the ability to project force.

Geoscientific input is crucial in geopolitical analysis, where the management of transboundary natural resources can influence regional relations and stability. For example, the dispute over water rights in the Nile Basin involves several countries and requires detailed geological and hydrological data to negotiate equitable water sharing arrangements that can prevent conflicts and foster cooperation among the nations involved.

Space weather forecasting is critical for protecting satellite communications and navigation systems which are integral to national security. A notable example is the U.S. Air Force's use of space weather data to anticipate and mitigate the effects of solar flares on satellite functionality and communication systems, crucial for both military and civilian technologies.

U.S. military bases, National Laboratories, and munition test sites have long and continuing legacies of subsurface contamination of soils and groundwater. Geoscientists play a critical role in the characterization of the geologic framework beneath these sites, designing monitoring systems, and designing plans for the environmental cleanup and reclamation of these sites.



EXAMPLES OF RELEVANT LEGISLATION AND POLICY

Executive Orders

- ▶ **E.O. 13817:** Focuses on America's critical minerals. It mandates the identification of critical minerals and formulates a strategy to decrease the nation's dependency on foreign sources. This EO underscores the importance of geoscience in assessing and developing domestic sources of these essential minerals to enhance national security (USGS).

Congressional Legislation

- ▶ **118th — S. 2031:** This bill requires the Department of Defense (DOD) to develop supply chains that are not dependent on mining or processing of critical minerals in or by specified countries (e.g., China) to achieve critical mineral supply chain independence by 2035.
- ▶ **117th — H.R. 4559:** Requires the DoD to consider climate implications on its contracting, both from the standpoint of reduction of carbon emissions and on making strategic decisions for basing based on climate resilience.

Relevant Federal Agencies

- ▶ U.S. Department of Defense
- ▶ U.S. Department of State
- ▶ Army Corps of Engineers
- ▶ U.S. Geological Survey

Related National Academy Reports

- ▶ Climate Intervention in an Earth Systems Science Framework: Proceedings of a Workshop—in Brief (2024)
- ▶ Planning the Future Space Weather Operations and Research Infrastructure: Proceedings of a Workshop (2021)
- ▶ Managing Materials for a Twenty-first Century Military (2008)
- ▶ Minerals, Critical Minerals, and the U.S. Economy (2008)
- ▶ Climate Security in Central America: Proceedings of a Workshop (2005)

Non-Partisan Non-Profit Expertise

- ▶ American Association of Petroleum Geologists
- ▶ American Institute of Professional Geologists
- ▶ American Geophysical Union
- ▶ American Institute of Hydrology
- ▶ Association of American State Geologists
- ▶ Association of Environmental and Engineering Geologists
- ▶ Geological Society of America
- ▶ National Groundwater Association
- ▶ National Sand, Stone, and Gravel Association
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- ▶ Society of Exploration Geophysicists
- ▶ Society for Mining, Metallurgy, and Exploration

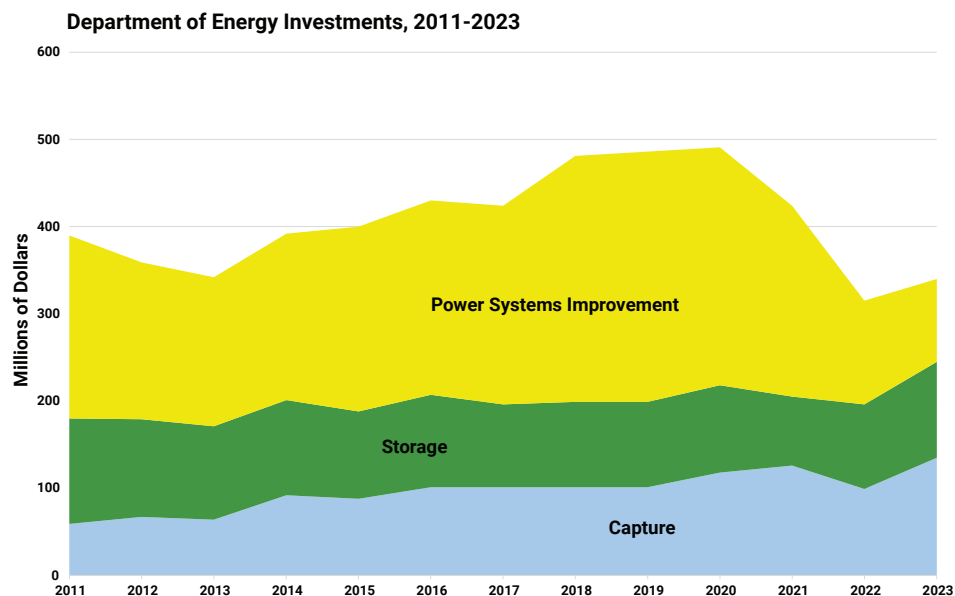
Geosciences Partnering in Innovating the Future



GEOSCIENCES IMPACT ON INNOVATION

Geoscientists and the geosciences contribute significantly to innovation, particularly in the United States, by driving advancements in critical sectors such as energy, raw materials, environmental management, and natural disaster preparedness. Through their work in understanding earth systems, geoscientists develop new methods for energy extraction and conservation, contributing to the sustainability and efficiency of resources like oil, natural gas, and renewables. Their research into geological formations and processes informs safer construction practices, mineral extraction, groundwater exploration, land-use

planning, and mitigating risks from earthquakes, landslides, and other geohazards. Additionally, geoscientists play a crucial role in addressing environmental challenges, pioneering techniques for carbon capture and storage, and improving water resource management. These innovations not only bolster the U.S. economy but also enhance its resilience against environmental and climatic shifts, making geosciences a vital field for policy and investment focus. It also offers a tangible pathway to bolster the STEM workforce through inspiring talent looking to improve how we live in the world through new technologies and methods.



The U.S. Department of Energy has been investing in technological approaches to reducing the carbon footprint of the U.S. economy. These approaches have included improving the carbon efficiency of power systems, and increasingly on capturing and permanently storing carbon before it enters the atmosphere.

Energy Exploration and Extraction

Geoscientists innovate in methods to locate and efficiently extract natural resources, including oil, gas, and geothermal energy, which are vital for the nation's energy independence.

Environmental Protection and Restoration

Geoscientists utilize geological knowledge to restore degraded landscapes, manage waste disposal, and rehabilitate ecosystems affected by industrial activities.

Water Resources Management

Hydrogeologists ensure secure and sustainable groundwater quantity, quality, and distribution, which are critical for agriculture, industry, drinking water, and urban development.

Advanced Material Development

Geoscientists discover and characterize new mineral deposits increasingly in extreme environments, that can be used in technology and manufacturing, driving technological advances. Geoscientists are particularly focused on extractive material processes which are central to utilizing new raw material sources and advanced recycling.

Hazard Assessment and Mitigation

Geologists and geophysicists develop predictive models and tools to assess and mitigate risks associated with natural disasters like earthquakes, volcanoes, and landslides, enhancing public safety and infrastructure resilience.

Climate Change Research

Geoscientists investigate the geological record to understand past climate changes and predict future trends, contributing to strategies for adaptation and mitigation.

Carbon Capture and Storage

Geologists and geochemists lead efforts in the geological sequestration of carbon dioxide to combat climate change and reduce greenhouse gas emissions and enhance the recovery of oil and natural gas and critical minerals.

Coastal and Marine Geosciences

Oceanographers and marine geologists enhance the understanding of coastal processes and marine ecosystems, important for managing coastal development, protecting marine biodiversity, and supporting fisheries. Advanced knowledge of marine geology is needed for anchoring renewable energy infrastructure, such as wind turbines.

EXEMPLARS OF IMPACTS OF GEOSCIENCE ON INNOVATION

Geoscientists use advanced geophysical and geochemical techniques to discover and evaluate mineral deposits essential for manufacturing, technology, and construction industries. Innovations in this field have led to more efficient extraction methods that are less invasive and more environmentally sensitive. Innovations in operating in extreme environments, whether in deep water, polar environments, or extreme depths into the crust, have opened new possibilities for accessing minerals and hydrocarbons located in previously untapped locations and doing so with modern, environmentally sustainable practices from the start. Hydraulic fracturing of low-permeability rock formations has led to a revolution in natural gas production, making the U.S. a world leader.

Geoscientists are at the forefront of exploring geoengineering solutions, such

as artificial enhancement of rock weathering or crustal injection, to remove carbon dioxide from the atmosphere and mitigate the effects of climate change. By mapping and analyzing the distribution and quality of natural resources, geoscientists develop sustainable management practices that minimize environmental impact

and help balance ecological needs with human usage. Geoscientists contribute to the renewable energy sector by assessing geothermal energy potential and improving the extraction and management of these resources. They also play a critical role in locating and evaluating sites suitable for wind and solar energy farms.





CASE STUDIES

In the past decade, geoscientists have driven innovations in hydraulic fracturing and horizontal drilling technologies. These advancements have unlocked vast reserves of shale gas, particularly in formations like the Marcellus Shale in Pennsylvania, significantly boosting the U.S. energy supply and reducing reliance on imported oil, while reducing net carbon emissions.

In the central U.S., geoscientists study the Ogallala Aquifer to implement sustainable water use strategies that address concerns over the rapid depletion of this critical water resource supporting one of the world's largest agricultural economies.

The Illinois Basin-Decatur Project captures CO₂ from ethanol production and stores it in saline aquifers. This project, supported by geoscientific research, showcases practical applications of carbon capture and storage technology.

Geoscientists have identified economically viable concentrations of rare earth elements in coal byproducts, leading to methods for extracting these critical materials used in high-tech devices, thus reducing dependency on imported materials.

In response to land loss and hurricane damage, geoscientists have developed models and techniques for coastal restoration in Louisiana, including river diversions to rebuild wetlands and barrier islands, crucial for protecting coastal communities and ecosystems.



EXAMPLES OF RELEVANT LEGISLATION AND POLICY

Executive Orders

- ▶ **14008:** Directive on climate change directly involves innovation in geosciences through its focus on clean energy technologies, sustainability, and environmental protection. It mandates significant investment in climate-related scientific research and the deployment of technologies that will leverage geoscientific knowledge.

Congressional Legislation

- ▶ **117th — S. 1260:** U.S. Innovation and Competition Act (USICA). While not enacted into law as a whole, various components of this comprehensive package were integrated into other legislation, including the CHIPS and Science Act. USICA originally included significant funding for basic and advanced research, enhancing America's competitiveness in science and technology, including environmental and earth sciences.
- ▶ **117th — H.R. 4521:** America COMPETES Act of 2022. This is another legislative effort, like USICA, aiming to significantly boost U.S. capabilities in technology and scientific research. It includes support for STEM education and workforce development, which would inherently support the geosciences sector.

Relevant Federal Agencies

- ▶ National Science Foundation
- ▶ U.S. Department of Energy
- ▶ National Institute of Standards and Technology

Related National Academy Reports

- ▶ Climate Intervention in an Earth Systems Science Framework: Proceedings of a Workshop-in Brief (2024)
- ▶ Foundational Research Gaps and Future Directions for Digital Twins (2024)
- ▶ Progress and Priorities in Ocean Drilling: In Search of Earth's Past and Future (2024)
- ▶ Supporting Black Students Through Their Science, Engineering, and Medicine Career Journeys: Proceedings of a Workshop (2024)
- ▶ Accelerating Decarbonization in the United States: Technology, Policy, and Societal Dimensions (2023)

Non-Partisan Non-Profit Expertise

- ▶ American Association of Petroleum Geologists
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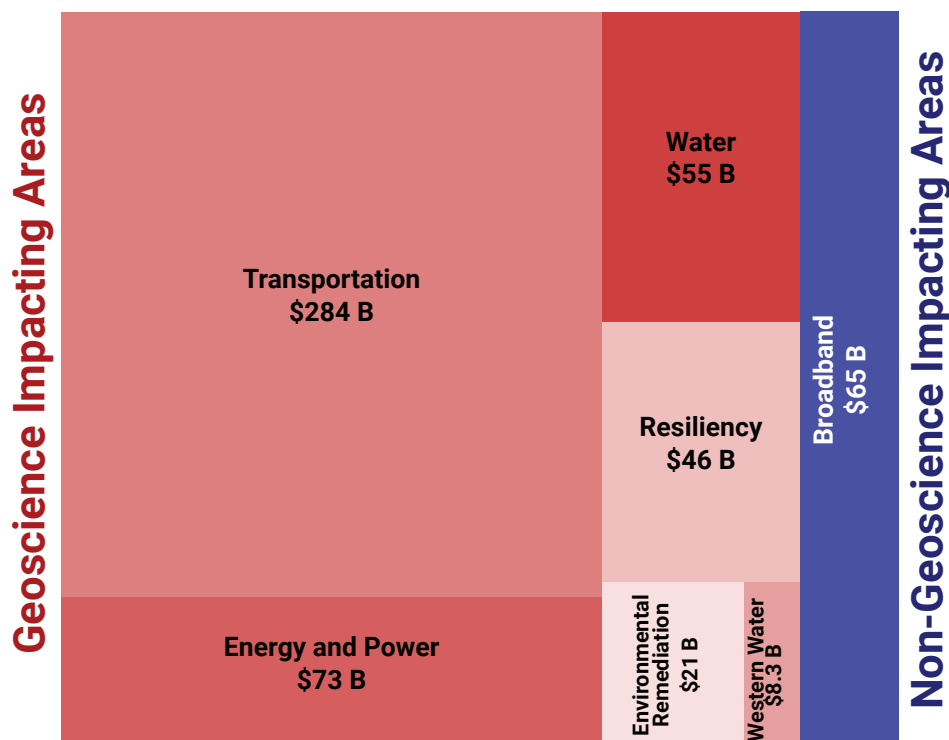
Geoscience Solutions for Future Infrastructure



GEOSCIENCES IMPACT ON INFRASTRUCTURE

The geosciences are vital for the development of resilient and sustainable infrastructure because they reveal important information about the formation and location of the raw materials needed for its manufacture and construction. Geoscientists incorporate geology, hydrology, and environmental science to determine the best locations for infrastructure projects, evaluate natural hazards, and ensure the sustainability of natural resources. Their skills enable the design of infrastructure that can resist natural disasters such as earthquakes, floods, and landslides, thereby protecting human lives and investments. Moreover, geoscientific research supports the innovative use of materials and techniques that minimize environmental impact, such as identifying local sources of construction aggregate to lower carbon footprints. By incorporating geoscience knowledge into infrastructure planning and development, we can achieve not only more durable and cost-effective facilities but also foster environmental stewardship and resilience against the changing climate.

Funding Distribution in the Infrastructure Bill



Successful development and management of infrastructure is reliant on geoscientists to ensure access to necessary resources, stability of the land, protection of the environment, and the ability to predict weather that impacts transport and the built environment. The Infrastructure Investment and Jobs Act allocated investments across a wide range of needs, and many of those sectors (red hues) are underpinned by geoscientific expertise to ensure success.

On Stable Ground

Topographic and geologic information informs where infrastructure can be safely located as well as sites for the safe disposal of infrastructure waste products.

Safe and Sustainable Development

Environmental geologists provide the guidance and information needed to ensure projects can be built safely and sustainably.

Building for the Long-Haul

The design and construction of bridges, roads, pipelines, aqueducts, and levees are directly influenced by numerous geologic factors, including the structural integrity of the substrate and the subsurface conditions upon which the structures will be built.

Waste Management

Geoscientists contribute to the design and monitoring of waste disposal sites, including landfills and hazardous waste containment facilities. They ensure that these sites do not contaminate groundwater or soil and assess remediation options for contaminated sites, making them safe for future use or development.

Critical Minerals for All Development

Geologic resource information is required to locate new sources of needed critical minerals and other raw materials.

Locating for Future Energy

Climate scientists develop projections for long-term climate trends for improved planning for wind and solar energy developments, as well as the energy transmission infrastructure that will be critical for building a 21st century energy grid.

Wise Development for Reduced Risk and Cost

Incorporating geoscience information into infrastructure construction maximizes the safety and efficiency of our systems, saving money and reducing risks.

Urban Planning and Smart Cities

Geoscientific data and analysis support urban planning by providing insights into land use, natural resource availability, and environmental constraints. This information is crucial for the sustainable development of smart cities, which aim to optimize resource use, reduce pollution, and improve residents' quality of life.

EXEMPLARS OF IMPACTS OF GEOSCIENCE ON INFRASTRUCTURE

As the Nation transitions its energy portfolio, geoscience research can significantly aid in maximizing the economic return on investment through incorporation of geological information for construction of solar, wind, geothermal, hydroelectric, and nuclear power developments to reduce costs and construction time.

Residential and business structures in both cities and rural areas require stable foundations to ensure long-term stability and sustainability as well as protect against natural hazards such as earthquakes, wind, flooding, landslides, sinkholes, and erosion.

Water can cause extreme problems for infrastructure. For example, saline water associated with rising sea-levels can react with concrete-supported infrastructure,

weakening the concrete and corroding support steel, leading to reduced useful lifetimes. Urban areas contain a high percentage of impermeable surfaces, and thus need hydrologic modelling and design to manage storm water and runoff. This is

critical information for developing resilient and cost-effective city and suburban landscapes. Creative designs will be needed to make new infrastructure as efficient and adaptable as possible to counter the uncertainties related to climate change.





CASE STUDIES

The construction of the new span of the San Francisco-Oakland Bay Bridge, completed in 2013, required extensive geological surveys to source and utilize materials capable of withstanding seismic events, leading to the selection of specific high-strength steel and concrete formulations.

The implementation of the Los Angeles County Flood Control District's Enhanced Watershed Management Program (EWMP) utilizes geological and hydrological data to mitigate flood risks while improving water quality through naturalized detention basins and green infrastructure.

The restoration of the Florida Everglades through the Comprehensive Everglades Restoration Plan (CERP) involves geological assessments to guide the re-routing of water flow and the restoration of natural water filtration systems, aiming to preserve this unique ecosystem.

The development of the Ivanpah Solar Power Facility in California's Mojave Desert was preceded by detailed geological and environmental studies to ensure minimal impact on the desert ecosystem while harnessing solar energy efficiently.



EXAMPLES OF RELEVANT LEGISLATION AND POLICY

Executive Orders

- ▶ **E.O. 13956:** Aims to modernize water resource management and infrastructure particularly to improve water storage capacity and drought resilience.

Congressional Legislation

- ▶ **117th — H.R. 5376:** The Inflation Reduction Act spurred on massive investments in new infrastructure efforts across the United States.
- ▶ **118th — H.R. 302:** Direction for the department of energy to provide assistance programs for graduate students and post-grad researchers in pursuance of research focused on cyber security and energy infrastructure.

Relevant Federal Agencies

- ▶ Environmental Protection Agency
- ▶ U.S. Department of Transportation
- ▶ Army Corps of Engineers

Related National Academy Reports

- ▶ Transforming EPA Science to Meet Today's and Tomorrow's Challenges (2023)
- ▶ Benefits, Applications, and Opportunities of Natural Infrastructure: Proceedings of a Workshop—in Brief (2022)
- ▶ Climate-Resilient Supply Chains: Proceedings of a Workshop—in Brief (2022)
- ▶ Planning the Future Space Weather Operations and Research Infrastructure: Proceedings of a Workshop (2021)

Non-Partisan Non-Profit Expertise

- ▶ American Association of Geographers
- ▶ American Association of Petroleum Geologists
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- ▶ American Institute of Professional Geoscientists
- ▶ Association of American State Geologists
- ▶ Association of Environmental and Engineering Geologists
- ▶ Mineralogical Society of America
- ▶ National Groundwater Association
- ▶ National Sand, Stone, and Gravel Association
- ▶ Society of Economic Geologists
- ▶ Society of Exploration Geophysicists
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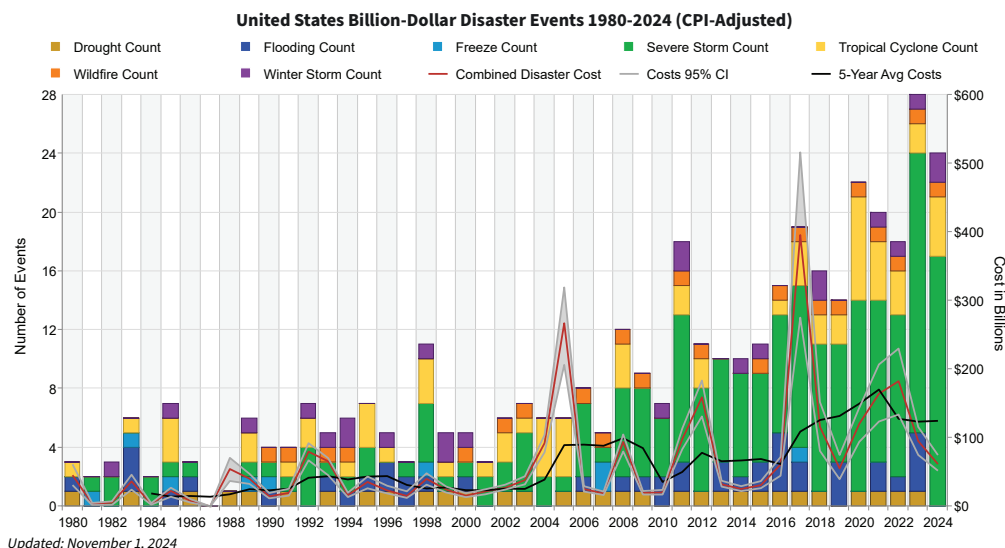
Geoscience Protecting the Public



GEOSCIENCES IMPACT ON PUBLIC SAFETY AND WELLNESS

The geosciences, which address issues across air, land, and oceans, are key to the United States' approach to managing natural hazards and improving public and environmental health. Geoscience uses mapping and analysis of Earth's complex systems to provide vital data that helps with emergency readiness and climate adaptation strategies. For example, precise weather forecasts allow for proactive actions to minimize natural disaster impacts, lowering potential damage to communities. Long-term environmental observations help detect changes in climate trends, directing public health actions to deal with emerging issues such as heatwaves or the spread of infectious disease. Also, geoscience research supports urban planning and infrastructure development, reducing risks

from sea-level rise, drought, earthquakes, and other geophysical hazards. These scientific findings are important for anticipating and alleviating the impacts of natural disasters such as wildfires, which affect air quality and create serious respiratory health problems. Moreover, the study of Earth's systems helps tackle the problems caused by mineral dusts and environmental pollutants, especially in urban areas where industrial activity and high population density increase exposure risks. The incorporation of geoscientific research into public policy and health initiatives is essential for predicting, coping with, and recovering from environmental challenges, ultimately protecting economic activity, food supply stability, the environment and citizen well-being.



Since 1980 the United States has faced an increased number of natural disaster-related events. Though the economic impacts of these disasters have increased, they have not increased as fast as the frequency of events, partially driven by improved forecasting, risk management, and infrastructure resilience thanks in large part to contributions by geoscientists driving our understanding of these events.

Earthquake Risk Assessment

Geologists and seismologists analyze faults and past seismic activity to forecast future earthquake risk, helping to inform building codes, urban planning, and disaster preparedness strategies.

Flood Prediction and Management

Geoscientists study river behaviors, human modifications to channels and weather patterns to predict floods, contributing to the design of flood defenses, and land-use planning to minimize impact on human health and property.

Climate Change Impact Assessments

Climate scientists analyze long-term weather patterns and trends to forecast changes in climate that can affect public health, infrastructure, agriculture, and water supplies, aiding in developing adaptation strategies.

Hazardous Materials Management

The study of how pollutants like heavy metals and chemical wastes behave in the soil and groundwater enables geoscientists to advise on the containment, clean-up, and environmental health impacts of these hazardous materials.

Volcanic Eruption Monitoring

By studying volcanoes, geologists can predict eruptions and provide warnings to minimize loss of life and health impacts from ash, gases, and landslides, which are critical for nearby communities, the safety of air transport. Volcanoes can impact global weather and thus agricultural productivity.

Wildfire Risk and Management

Through the study of landscape, ecology, and fire history, geoscientists help predict wildfire occurrences and develop strategies for controlled burns and land management that reduce the risk of large, uncontrollable fires, thereby protecting air quality and reducing the risk of landslides and erosion of valuable soils.

Air Quality Monitoring

Geoscientists play a role in studying how natural events like dust storms and volcanic eruptions affect air quality. They also examine the dispersion of pollutants in urban areas, which is essential for public health advisories and regulatory measures.

Coastal Erosion and Sea Level Rise

Oceanographers, geomorphologists, and geophysicists help predict changes in sea levels and storm surges, which are vital for coastal urban planning, protecting water quality, preserving ecosystems, and preventing loss of life from flooding.

EXEMPLARS OF IMPACTS OF GEOSCIENCE ON NATURAL HAZARDS AND PUBLIC HEALTH

Geoscientists, particularly seismologists and oceanographers, play a vital role in the development and operation of tsunami warning systems. These systems utilize networks of seismic and ocean sensors to detect undersea earthquakes that could potentially trigger tsunamis. By analyzing the seismic activity and water column changes in real-time, geoscientists can predict the arrival times and potential impact of tsunamis on coastal areas. This early warning capability is crucial for evacuating populations at risk, thus saving lives and reducing loss of infrastructure from these destructive natural events.

Geoscientists contribute significantly to monitoring and improving urban air quality by studying the sources and dispersion patterns of pollutants. This involves tracking particulates from both natural sources, like volcanic ash, and human-made sources, such as vehicle emissions and industrial pollutants. By modeling how these particles travel through the atmosphere under various weather conditions, geoscientists help public health officials develop strategies for reducing exposure to harmful air pollutants, advising on the best times for outdoor activities and guiding policies on emissions reductions.

Hydrogeologists specialize in understanding the movement and storage of groundwater. Their expertise is crucial in preventing groundwater contamination, a major public health issue, especially in areas dependent on well water. By mapping aquifers and identifying contamination risks from agricultural runoff, industrial processes, and improper waste disposal, hydrogeologists help design effective safeguards and remediation strategies. These measures ensure the safety of drinking water supplies and protect aquatic ecosystems from the harmful effects of pollution.



CASE STUDIES

Following major wildfires in the Western United States, the U.S. Geological Survey conducts hazard assessments to map the potential for post-fire debris flows. This geoscientific activity is crucial for emergency response and urban planning, as it predicts areas at risk of mudslides after a wildfire, thus protecting lives and property by facilitating timely evacuations and infrastructure protections.

Geoscientists contribute to hurricane preparedness by mapping coastal vulnerabilities to sea-level rise and storm surges. Tools like the [Delaware Coastal Flood Monitoring System](#) that produces interactive inundation maps illustrate potential flooding scenarios under various sea level conditions, storm surge, and tidal conditions, aiding in the strategic planning for coastal infrastructure and community safety measures against hurricanes and coastal flooding and provide knowledge on risk assessment in support of land use planning.

In the Northeastern United States, increased frequency of wildfires due to climate change poses significant risks. Geoscientists work on forecasting the occurrence and spread of wildfires, enabling better preparedness and response strategies that help protect public health and community resilience. The Northeast-Midwest Wildfire Risk Assessment Portal provides comprehensive data, user-friendly applications, and planning tools aimed at wildfire risk reduction. This tool helps federal, state, Tribal, and local communities prioritize areas for mitigation treatments, community education, and tactical analyses to effectively manage and reduce the risks associated with wildfires. The portal is a collaborative effort to streamline wildfire management across diverse jurisdictions in the Northeast and Midwest U.S.

In highly seismic zones, geoscientists assess and map earthquake risks, helping cities like Los Angeles

to develop and enforce building codes that improve infrastructure resilience. By predicting the intensity and superimposing this risk relative to key geologic features such as rock type, potential impacts of seismic activity are determined which can be used to significantly reduce the risks to human life and health in earthquake-prone areas. The USGS Shake-Alert® earthquake early warning system operating in the northwest U.S. provides a warning message in the critical seconds before the shaking arrives from a strong earthquake.

Geoscientists play a key role in flood risk management by mapping and modeling how water flows through landscapes and where floodplains are located. They combine data from different sources, such as topography, hydrology, and meteorology, to forecast where and how severe flooding might occur. Geoscientists collaborate with urban planners and civil engineers to develop infrastructure such as dams, levees, and drainage systems that can reduce the effects of floods. They also assist in community planning efforts, ensuring that development projects are strategically situated to avoid high-risk areas. This proactive planning is essential for lowering economic losses and protecting communities, especially in areas that are susceptible to sudden or severe flooding events. For instance, the Ala Wai Canal Flood Risk Management Project is a comprehensive effort to lessen flooding risks in the Ala Wai Watershed, which encompasses the economically vital Waikīkī District. This area is not only a major tourist attraction but also a significant economic center for the state of Hawaii. The U.S. Army Corps of Engineers, along with state and local partners, has been conducting a detailed study and plan to enhance flood conveyance infrastructure, which is crucial due to the high risk of flooding from aging systems. This project is vital for safeguarding a densely populated and economically important area from disastrous flooding events.



EXAMPLES OF RELEVANT LEGISLATION AND POLICY

Executive Orders

- ▶ **14008:** This order is comprehensive, focusing on integrating climate resilience into U.S. foreign policy and national security, establishing a White House Office of Domestic Climate Policy for a coordinated approach to climate challenges, and emphasizing the restoration of scientific integrity across federal decision-making. It highlights the need for clean energy transitions and environmental justice.
- ▶ **13990:** Signed to ensure science-based decision-making in federal agencies and to address the health and environmental impacts of industrial pollution. It specifically directs the review and potential revision of regulations related to public health and environmental protections, including those impacting air and water quality.

Congressional Legislation

- ▶ **117th — H.R. 3684 Infrastructure Investment and Jobs Act:** This major legislation includes provisions for climate resilience, clean energy, and water system improvements. It represents significant federal investment aimed at enhancing infrastructure in ways that also address environmental challenges.
- ▶ **117th — H.R. 5376 Inflation Reduction Act:** Enacted in August 2022, this legislation commits nearly \$369 billion to climate and clean energy efforts. It's designed to reduce emissions, promote clean energy use, and enhance environmental justice initiatives through various funding mechanisms and tax incentives.
- ▶ **118th — H.R. 7916 Removing Nitrate and Arsenic in Drinking Water Act:** Amend the Safe Drinking Water Act to provide grants for nitrate and arsenic reduction projects.

Relevant Federal Agencies

- ▶ U.S. Geological Survey
- ▶ Federal Emergency Management Agency
- ▶ Environmental Protection Agency

Key National Academy Reports

- ▶ Affordability of National Flood Insurance Program Premiums: Report 2 (2016)
- ▶ Assisted Resettlement and Community Viability on Louisiana's Gulf Coast: Proceedings of a Workshop (2023)
- ▶ Benefits, Applications, and Opportunities of Natural Infrastructure: Proceedings of a Workshop—in Brief (2022)
- ▶ Climate Resilience and Benefit-Cost Analysis: A Handbook for Airports (2019)
- ▶ Framing the Challenge of Urban Flooding in the United States (2019)
- ▶ Implications of the California Wildfires for Health, Communities, and Preparedness: Proceedings of a Workshop (2020)

Non-Partisan Non-Profit Expertise

- ▶ American Geophysical Union
- ▶ American Institute of Hydrology
- ▶ American Institute of Professional Geologists
- ▶ Association of American State Geologists
- ▶ Association of Environmental and Engineering Geologists
- ▶ Geological Society of America
- ▶ National Groundwater Association
- ▶ Soil Science Society of America
- ▶ Seismological Society of America
- ▶ U.S. Permafrost Association

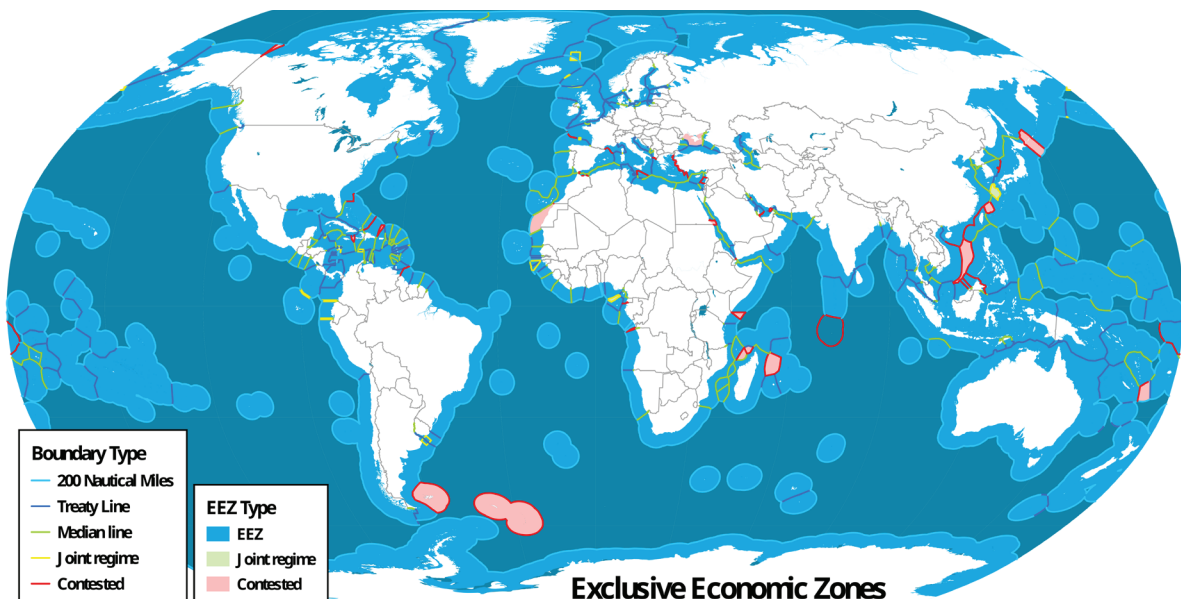
Geoscience's Role in Building U.S. Influence Across the World



GEOSCIENCES IMPACT ON DIPLOMACY

The geosciences are integral to U.S. diplomacy and international relations efforts, particularly as a scientific basis for addressing complex global issues like water availability, resource-related trade, and climate impacts. Issues of environment, resources, and climate are not confined to political boundaries. For instance, insights from climate science and meteorology are crucial for forecasting and mitigating the impacts of climate change, including shifts in water cycles that affect water availability and societal stability worldwide. Changes in the oceans can influence global

weather patterns, the health of fisheries, and large-scale ecological dynamics such as coral bleaching. While issues related to the distribution, availability, and wise management of resources such as water and minerals can lead to conflict—when well-managed they can be catalysts for stability and trade. By integrating these geoscientific insights into diplomatic strategies, the U.S. can enhance international cooperation, promote stability, and support sustainable management of global resources amidst changing political and climatic conditions.



Dr. Jean-Paul Rodrigue, Dept. of Global Studies & Geography, Hofstra University
Source: Flanders Marine Institute (2019), Maritime Boundaries Geodatabase: Maritime Boundaries and Exclusive Economic Zones (200NM), version 11.

Though the Exclusive Economic Zones are nominally defined by a 200-mile limit, the definition of what starts the claimed area is defined by the underlying geology, which combined with political dynamics leads to numerous areas where economic claims are contested, especially in critical areas such as Asia.

Climate Change Agreements

Geoscientists provide essential information that shapes international climate policies and agreements. Their research helps to understand emissions impacts, global temperature trends, and the effectiveness of proposed mitigation strategies.

Disaster Preparedness and Response

Geoscientists support international disaster response strategies by identifying natural hazards like earthquakes, tsunamis, and volcanic eruptions, enabling better preparedness and collaborative international response efforts.

Maritime Boundaries and Oceanography

Oceanographers contribute to negotiations on maritime boundaries and the management of marine resources, including fisheries and mineral rights, which are vital for maintaining international maritime cooperation and legal frameworks.

Atmospheric Pollution Control

Meteorologists and climate scientists provide critical data for international discussions on air quality and pollution control, helping to frame agreements that address cross-border pollution issues.

Water Resource Management

Geoscience expertise aids in the negotiation of transboundary water treaties and management strategies, essential for regions sharing water bodies and aquifers, ensuring equitable and sustainable use of water resources and conflict reduction.

Energy Resource Diplomacy

Knowledge of geology is crucial in discussions about the exploration and exploitation of oil, gas, and mineral resources, determining accurate assessments of reserves, and helping to form agreements that are economically beneficial while minimizing environmental impact.

Polar Region Affairs

Geoscientists are vital in shaping policies related to polar regions where issues ranging from climate research to territorial claims and resource exploitation require informed scientific input to guide international cooperation and treaties.

Nuclear Arms Control

Geoscientists lead the monitoring of underground nuclear tests. Their expertise supports international treaties like the Comprehensive Nuclear-Test-Ban Treaty (CTBT). This monitoring involves detecting and analyzing seismic activities that distinguish nuclear explosions from natural seismic events and maintains transparency and trust among nations in nuclear disarmament discussions.

EXEMPLARS OF IMPACTS OF GEOSCIENCE ON DIPLOMACY

Geoscientists specializing in hydrogeology are crucial in the negotiation and implementation of transboundary water treaties. An example is the U.S.-Mexico Transboundary Aquifer Assessment Program, where American and Mexican geoscientists collaborate to assess and manage water resources that span the border. This program relies on hydrological data to make informed decisions about water allocation, usage, and conservation, addressing both countries' needs while ensuring sustainable water management practices. Such cooperation not only enhances water security but also strengthens diplomatic relations by promoting mutual interests and conflict resolution.

Seismologists contribute directly to international security and nuclear arms control by monitoring seismic activities associated with nuclear tests. Their expertise supports the verification processes under the Comprehensive Nuclear-Test-Ban Treaty (CTBT), which aims to eliminate nuclear explosions by all states. By detecting and analyzing seismic waves generated

by underground nuclear tests, seismologists provide crucial evidence needed to enforce compliance with the treaty. This scientific monitoring helps maintain international peace and stability by preventing the proliferation of nuclear weapons and ensuring that countries adhere to their disarmament commitments.

Geoscientists play a pivotal role in shaping international climate policy through their contributions to the Intergovernmental Panel on Climate Change (IPCC). The IPCC gathers and synthesizes the latest geoscientific research on climate change, including data on atmospheric temperatures, oceanic cycles, and carbon sinks. This comprehensive body of knowledge helps in formulating global climate agreements by providing policymakers with a clear understanding of climate trends, potential impacts, and mitigation strategies. For instance, geoscientists' input was instrumental in the development and adoption of the Paris Agreement, where nations committed to limit global warming to below 2 degrees Celsius above pre-industrial levels.



CASE STUDIES

The Volcano Disaster Assistance Program (VDAP), a partnership between the U.S. Geological Survey and USAID, provides expertise in volcano monitoring and disaster response worldwide. This program enhances volcanic crisis preparedness, helping vulnerable communities mitigate the impacts of volcanic eruptions and improving international relations through cooperative disaster management.

A 1990s water sharing initiative brought together the U.S., Israel, Jordan, and Palestine to improve water security in the Middle East. By sharing water data and resources, the project fostered collaboration and peacebuilding, highlighting the role of scientific cooperation in resolving regional conflicts over natural resources.

U.S. geoscientists working with international organizations developed the Guarani Aquifer Agreement that facilitated the development of joint management plans for one of the largest trans-boundary aquifers in the world. This cooperation among Argentina, Brazil, Paraguay, and Uruguay promoted sustainable water usage and regional collaboration.

U.S. geoscientists supported the Extractive Industries Transparency Initiative through numerous programs supported by USAID within the Democratic Republic of Congo to improve sustainability of mines and reduce the flow of conflict minerals by enhancing transparency and governance in the extractive sector. This effort has been crucial for promoting sustainable management and stability in resource-rich regions.



EXECUTIVE ORDERS AND LEGISLATION AND POLICY

Executive Orders

- ▶ **14008:** Addresses the global climate crisis through coordinating domestic and international approaches.

Congressional Legislation

- ▶ **118th—H.R. 5874:** Reauthorizes the United States-Mexico transboundary aquifer assessment program.
- ▶ **118th—H.R. 4443:** A bill that both addresses the trade of minerals from the Democratic Republic of Congo relative to child labor and the relationship between the U.S. and Chinese interests in strategic minerals.
- ▶ **118th—S.458:** Establishes programs within Department of Energy and Interior, as well as with the Export-Import Bank to help secure mineral supplies for European partner nations and to coordinate with Mexico and Canada as partners in this effort to secure material independence for Europe from Russia.

Select Relevant Federal Agencies

- ▶ U.S. Department of State
- ▶ U.S. Department of Defense
- ▶ U.S. Department of Energy

Recent National Academy Reports

- ▶ Advancing Sustainability of U.S.-Mexico Transboundary Drylands: Proceedings of a Workshop (2018)

- ▶ China-U.S. Scientific Engagement: Key Issues and Possible Solutions for Sustainability and Planetary Health: Proceedings of a Workshop—in Brief (2023)
- ▶ Climate Security in South Asia: Proceedings of a Workshop (2023)
- ▶ Innovation, Global Value Chains, and Globalization Measurement: Proceedings of a Workshop (2022)
- ▶ Operationalizing Sustainable Development to Benefit People and the Planet (2022)

Non-Partisan Non-Profit Expertise

- ▶ American Association of Petroleum Geologists
- ▶ American Geophysical Union
- ▶ American Institute of Hydrology
- ▶ American Institute of Professional Geologists
- ▶ American Meteorological Society
- ▶ Association of American State Geologists
- ▶ Association of Environmental and Engineering Geologists
- ▶ Center for Ocean Leadership
- ▶ Geological Society of America
- ▶ Mineralogical Society of America
- ▶ National Groundwater Association
- ▶ Society of Economic Geologists
- ▶ Society of Exploration Geophysicists
- ▶ Society for Mining, Metallurgy, and Exploration
- ▶ Soil Science Society of America