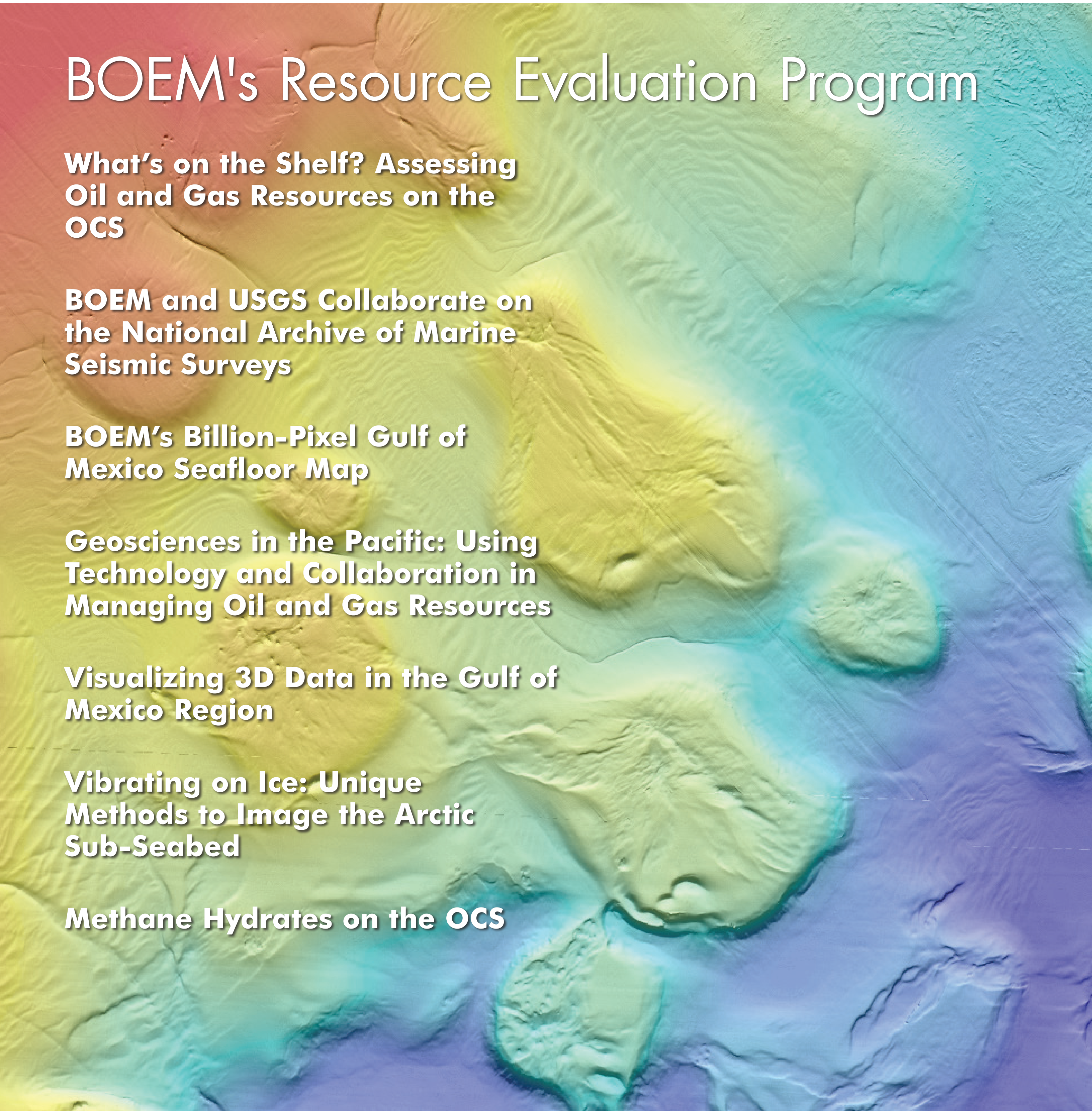
BOEM OCEAN SCIENCE

THE SCIENCE & TECHNOLOGY JOURNAL OF THE BUREAU OF OCEAN ENERGY MANAGEMENT

VOLUME 15 ISSUE 2 • DECEMBER/JANUARY/FEBRUARY/MARCH 2018



BOEM's Resource Evaluation Program

What's on the Shelf? Assessing Oil and Gas Resources on the OCS

BOEM and USGS Collaborate on the National Archive of Marine Seismic Surveys

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BOEM OCEAN SCIENCE is published by the Bureau of Ocean Energy Management to communicate recent ocean science, technological information, and issues of interest related to offshore energy recovery, marine minerals, and ocean stewardship.

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ON THE COVER

Seafloor bathymetry map from the East Breaks protraction area off Texas showing where salt diapirs push up the seafloor creating discrete mounds. Image by Bill Shedd and Kody Kramer, BOEM.

All photos courtesy of the Bureau of Ocean Energy Management unless otherwise noted.

Publication services provided by The C3 Group and Schatz Strategy Group.

Frequently Used Abbreviations

2D	Two Dimensional
3D	Three Dimensional
G&G	Geological and Geophysical
GOM	Gulf of Mexico
MH	Methane Hydrates
NAMSS	National Archive of Marine Seismic Surveys
OCS	Outer Continental Shelf
UERR	Undiscovered Economically Recoverable Resource
USGS	United States Geological Survey
UTRR	Undiscovered Technically Recoverable Resource

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For More Information

Check out the Bureau of Ocean Energy Management website at **www.boem.gov**.

The Acting Director's Message

In this issue, we are providing an overview of a critical element of BOEM's mission, our Resource Evaluation Program. Resource assessments are a crucial component of energy policy analyses and provide important information about the potential of U.S. offshore areas as sources of oil and natural gas.

Information that the Resource Evaluation Team provides is indispensable as BOEM develops the National Outer Continental Shelf Oil and Gas Leasing Program. Identification of the areas of the Outer Continental Shelf (OCS) that are most promising for oil and gas development is important to the Secretary of the Interior as he makes decisions about which areas to consider for future leasing.

The program's independent estimates of oil and gas reserves and resources are also vital to determining whether bids submitted by companies are large enough to warrant the award of leases in every lease sale BOEM holds. This is essential to ensure the taxpayer receives fair market value for the rights conveyed with each lease.

Other responsibilities of the Resource Evaluation Program include:

- Regulating, via its permitting process, pre-lease exploration (primarily seismic surveys) and prospecting operations on the OCS;
- Conducting worst case discharge analyses;
- Evaluating potential risks of natural and manmade hazards on the OCS; and
- Assessing in-place methane hydrate resources on the OCS.

As the Nation continues to pursue an all-of-the-above energy strategy, oil and natural gas resources will likely remain a vital component of our energy portfolio in the coming decades.

Petroleum resources are considered finite since they do not renew at a rate remotely approaching their rate of consumption. Since petroleum is an important driver of the Nation's economy, there is considerable interest in the magnitude of the domestic resource base from which future discoveries and production will occur.

In general, risk and uncertainty in estimates of undiscovered oil and natural gas are greatest for frontier areas that have seen little or no past exploratory effort. For areas that have been extensively explored and are in a mature development stage, many of the geologic and economic risks have been reduced or eliminated and the degree of uncertainty in possible outcomes narrowed substantially. However, even in some mature producing areas such as the Gulf of Mexico (GOM), considerable uncertainty remains about petroleum potential at greater drilling depths.

In spite of these inherent uncertainties, resource assessments are valuable input to developing energy policy and planning.

I hope you'll enjoy learning more about the important work of the Resource Evaluation Program in this edition of *BOEM Ocean Science*.

—Walter D. Cruickshank

Vibroseis trucks preparing to collect seismic data offshore Alaska.

What's on the Shelf? Assessing Oil and Gas Resources on the OCS

BOEM's National Assessment of Undiscovered Oil and Gas Resources on the Outer Continental Shelf (OCS) is one of the flagship products from the Resource Evaluation Division. Every five years, BOEM geoscientists and engineers from the Alaska, Gulf of Mexico (GOM), and Pacific regions jointly develop a National Assessment. Each region creates a regional assessment of undiscovered resources and publishes its own assessment report. The data from these reports are then aggregated up to a national level and published in a report that covers each of the 26 OCS planning areas. The regional reports include all relevant geologic and engineering data to provide the public with estimates of undiscovered technically and economically recoverable resources (UTRR and UERR, respectively). Data sources include historical discovery and production data for mature areas like the GOM region, as well as geologic and production data from more frontier regions like the Arctic and Atlantic OCS.

The 2016 assessment marks the seventh official release of this product, providing a continuous and updated inventory spanning more than 30 years. The information has already been included in the 2017–2022 Proposed Program, and will support the development of the upcoming 2019–2024 National Program.

How are assessments typically done?

Typically, the National Assessment begins two years prior to the anticipated release of the results. This two-year mark provides a cutoff date for any new information that is considered in the assessment effort. However, this does not necessarily mean that it takes two years to do a full and complete assessment of the U.S. OCS. Gathering relevant new empirical data from recent analog (or similar) known fields from other parts of the world, new oil and gas discoveries on the OCS, new geological and geophysical (G&G) survey data, as well as reimaging old data, all occur over the three years before the cutoff date. The 2016 assessment incorporates a geologic play-based approach toward analyzing hydrocarbon potential. Geologic plays are, in short, a group of oil and gas accumulations (also referred to as pools) within an area that share a common history of hydrocarbon generation, migration, and entrapment. BOEM's play-based approach utilizes a six-step model that simulates oil and gas accumulations based on the geologic parameters the user provides for the model, and then aggregates those accumulations to estimate undiscovered hydrocarbon resources for one individual play. BOEM assesses 154 geological plays across the OCS. Play Teams, comprising BOEM geoscientists and engineers, compile the data and information needed for the assessment model runs. The simulation of oil and gas accumulations is the first step for the National Assessment. Users provide information such as assumed oil and gas recovery factors, average area of a pool, etc. These factors are input into our assessment model, and generate a distribution of various accumulation sizes that may be found within a geologic play. Due to the inherent uncertainty of predicting "undiscovered" or yet-to-find resources, the BOEM model requires the user to identify some value of exploration risk that resources will exist. The application of risk allows BOEM to generate a distribution of oil and gas fields that are believed to exist in each play. Finally, the simulated accumulations are ranked from largest to smallest, and aggregated to estimate UTRR. BOEM builds upon the estimate of geologic resources by applying engineering and economic parameters to generate a value of resources that can be developed in certain price environments. This is the estimate of undiscovered economically recoverable resources, or UERR. The UERR is a critical estimate that provides the foundation for the economic valuation of planning areas at various stages of the National Program development. The values for both UTRR and UERR are aggregated from different plays within an area to obtain resource estimates for planning areas, OCS regions, and even the entire U.S. OCS. For the 2016 assessment, BOEM estimated a mean undiscovered resource that includes 90.55 billion barrels of oil and 327.58 trillion cubic feet of gas across the entire U.S. OCS. Of this total, roughly 48 billion barrels of oil and 142 trillion cubic feet of gas are located on the GOM OCS. On a UERR basis, the oil and gas that can be recovered at $100/barrel and $5.34/thousand cubic feet of gas are 71.47 billion barrels and 148.05 trillion cubic feet, respectively.

What's next for the assessment?

Work for the 2021 assessment of undiscovered resources has begun. Since January 1, 2014, there have already been some noteworthy developments in many of the OCS regions that will affect BOEM's assumptions and be included in the assessment model.

—Joseph Maloney, Resource Evaluation Division

For More Information

National Assessment

https://www.boem.gov/2016-National-Assessment-Fact-Sheet/

BOEM Resource Evaluation Program

https://www.boem.gov/Resource-Evaluation-Program/

BOEM and USGS Collaborate on the National Archive of Marine Seismic Surveys

Open access to non-proprietary seismic reflection data benefits academic and government research, as well as the exploration industry. In 2004, U.S. Geological Survey (USGS) Coastal and Marine Geology Program geophysicists began developing a web-based data archive to enable free downloading of marine and industry seismic data made available for public release. The National Archive of Marine Seismic Surveys (NAMSS) website provides interactive map capabilities and selectable search options for publicly available seismic surveys within the U.S. Exclusive Economic Zone.

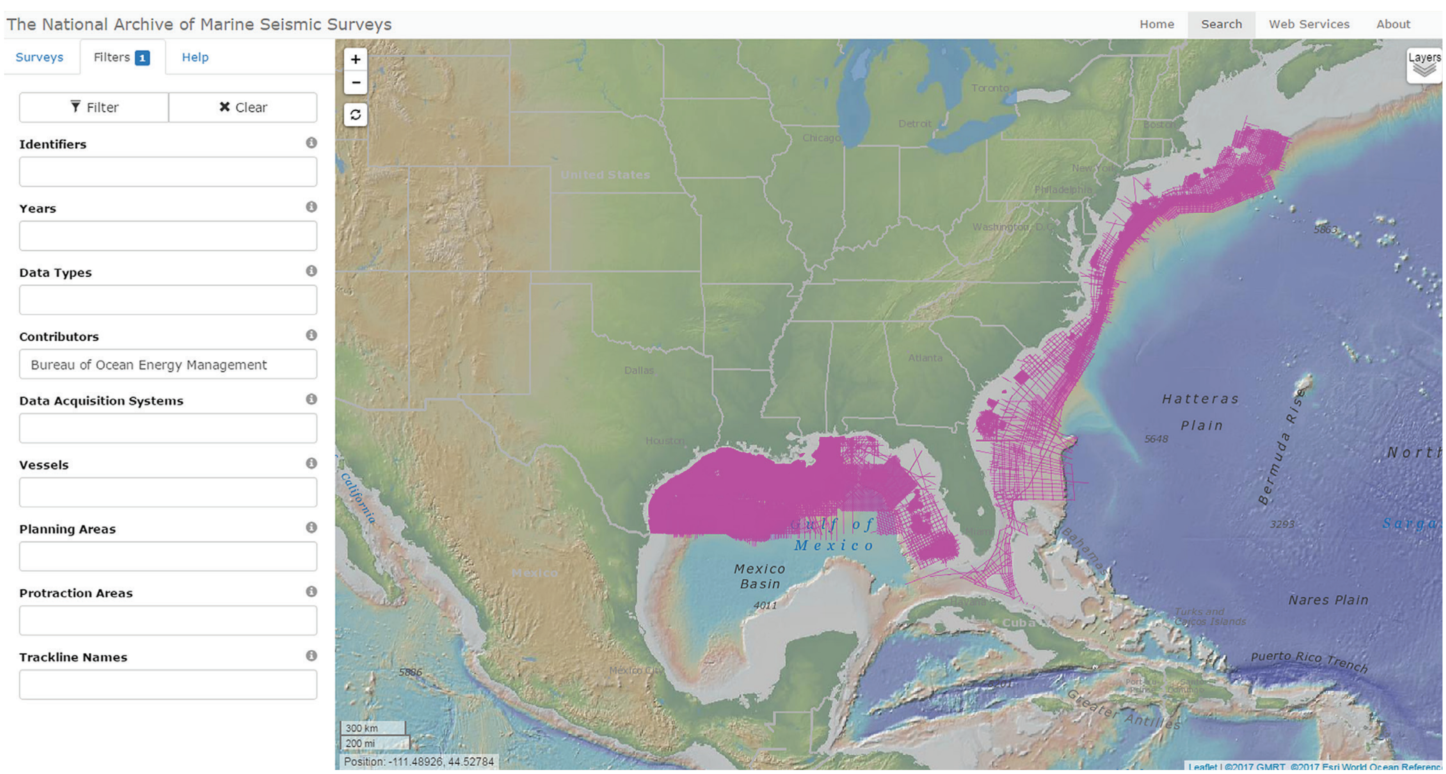
BOEM obtains and analyzes industry-submitted proprietary geological and geophysical data that are necessary to determine where potential concentrations of oil and gas resources and reserves are located, the volume of the accumulations, and the economic value of the resources and reserves. BOEM has a regulatory requirement to release marine seismic survey data to the public 25 years after the permit for data acquisition was issued. In 2011, BOEM and the USGS signed an addendum to the existing Memorandum of Understanding stating that BOEM may "provide publicly available seismic data and information to NAMSS and utilize their services to satisfy BOEM data release obligation..."

Data release may include seismic data in seg-y format or as TIFF image files, navigation files, velocity data, and data release announcements. BOEM then entered into an Interagency Agreement with the USGS to provide funding for the USGS to maintain and continue development of the NAMSS website and to add BOEM seismic surveys to the archive as these surveys become available for public release. The USGS modified NAMSS to accommodate 3D seismic data and other BOEM requests, including adding a search filter utility, and adding the option to display protraction area (a named grouping of lease blocks, such as Garden Banks or Walker Ridge) and lease block boundaries. The USGS is now uploading surveys submitted by BOEM's Alaska, Pacific, and Gulf of Mexico Region (GOMR) offices. The NAMSS currently holds more than 3 terabytes of data from almost 700 marine seismic surveys, including more than 120,000 square kilometers (km) of three-dimensional (3D) seismic data and approximately 2.3 million km of two-dimensional (2D) data with the majority of these surveys contributed by BOEM. BOEM expects this data volume to rapidly increase over the coming years in terms of number of surveys and total terabytes.

—Matthew Wilson and John Johnson,
GOMR Office of Resource Evaluation

For More Information

National Archive of Marine Seismic Surveys (NAMSS)
https://walrus.wr.usgs.gov/namss/search/



Example map showing Atlantic and Gulf of Mexico 2D and 3D seismic data available for downloading from the NAMSS website.

BOEM's Billion-Pixel Gulf of Mexico Seafloor Map

Spanning much of the deepwater Northern Gulf of Mexico (GOM), BOEM's new seafloor map has received rave reviews in the public and academic spheres. Originally published in *EOS*, a weekly online science news magazine published by the American Geophysical Union, the bathymetry map has been featured in *National Geographic*, *The Smithsonian*, *Oil & Gas Journal*, and even the financial magazine *Forbes*. ESRI's ArcGIS Online, where BOEM hosts the seafloor grid data for public access, had registered nearly 1,400 downloads by the beginning of July 2017.

With a resolution as fine as 149 square meters per pixel, about equal to the areal footprint of an American single-family house, BOEM's bathymetry map is at a minimum sixteen times higher resolution than the map historically used for the Northern GOM. There are 1.4 billion house-sized pixels in the new map, making this a giga-pixel map.

The Product of a Tragedy

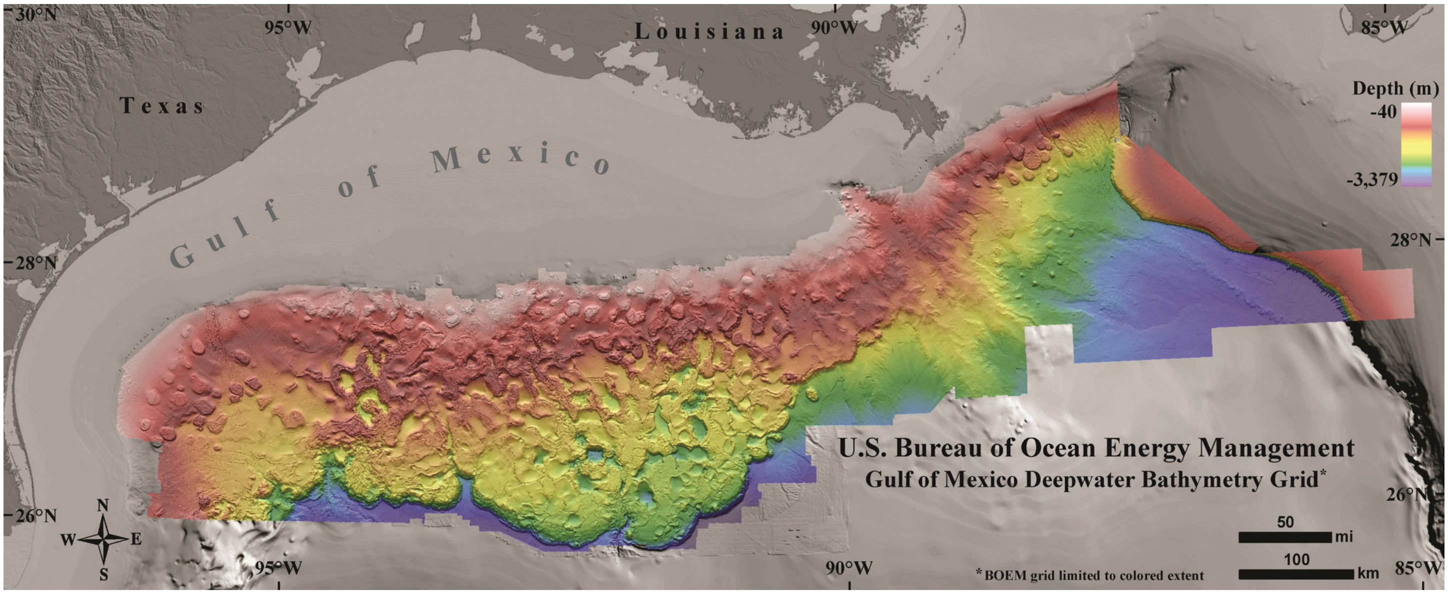
After the 2010 *Deepwater Horizon* disaster and oil spill in the GOM, BOEM was contacted by marine biologists working with the National Oceanic and Atmospheric Administration's (NOAA's) Natural Resource Damage Assessment (NRDA) team. The scientists requested that BOEM create a semi-regional map of the area of seafloor that may have been affected by the oil plume after sinking, due to treatment with chemical dispersant.

Since 1998, BOEM's William (Bill) Shedd has led an effort to map the GOM seafloor using oil and gas industry-acquired 3D seismic surveys. Since that time and after more than 200 surveys, he and his team have mapped the seafloor and shallow subsurface (or "water bottom"). The BOEM seismic survey database covers 350,000 square kilometers of the GOM as of 2017, an area larger than the state of New Mexico, with the oldest surveys dating back to the 1980s. Shedd realized that the seismic acoustic amplitude response of the water bottom, or how hard or soft the seafloor is, can indicate natural oil and gas seeps, and outcrops of carbonate hardgrounds. Bacteria in the muddy seafloor consume and oxidize the hydrocarbon, which ultimately forms authigenic carbonate. Over tens and hundreds of thousands of years, the bacterial carbonate can accumulate into extensive pavements and rocky outcrops on the seafloor that provide substrate for benthic organisms to live on. Those hardgrounds are what the geophysicists image, and were what the NRDA marine biologists sought.

The outcrops provide a habitat for lush cold-water coral ecosystems, as the base of the coral needs a hard substrate upon which to attach and grow. At many of the outcrops, the natural fissures underneath the seafloor still actively deliver oil and gas to the seafloor surface, feeding another type of fauna collectively known as chemosynthetic organisms. These include clams and tubeworms, some of which have been estimated to be 200 years old. BOEM has a responsibility to protect these deepwater communities from oil and gas activities.

Increasing Our Understanding

Using the seafloor maps created by Shedd and within an area-of-interest defined by the NRDA biologists, BOEM's Kody Kramer devised a method to assess, sort, and combine overlapping surveys of different vintages into a single seafloor map, at much higher resolution than had been previously



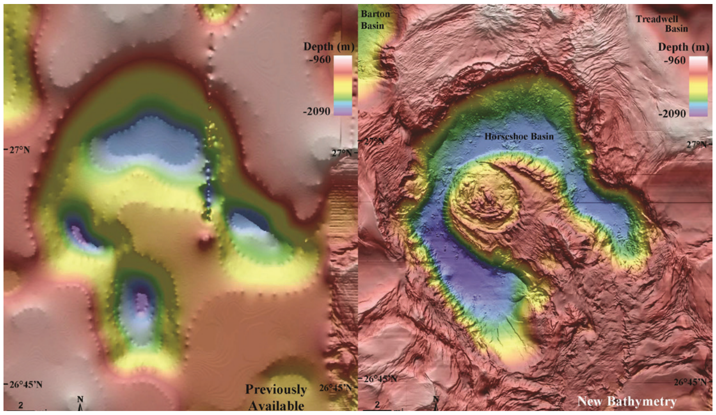
Map displaying BOEM's Gulf of Mexico seafloor grid (rainbow colored portion). NOAA's more expansive, but less resolute, historical map appears in gray.

available from NOAA and Texas A&M University. Using this new method, Shedd and Kramer decided to apply it to all of the mapped areas in the GOM.

After several months, the team created the clearest regional picture of the Northern GOM basin to date. The new dataset clearly provides to the scientific community important new insight into the complex geomorphology of the Gulf, where salt tectonics have dominated the past 200 million years and sculpted one of the world's most dynamic sedimentary basins. It is also a valuable tool for anyone requiring bathymetric data to model ocean currents or temperature variations; plan manned, autonomous underwater, or remotely operated vehicle dives; or conduct other scientific inquiries.

Responsible Regulation

BOEM has an important regulatory and environmental responsibility to protect sensitive corals and chemosynthetic communities from potential damage caused by oil and gas-related bottom-disturbing activities. These include laying pipeline and communications cables, dropping anchors for drilling rigs and production platforms, and drilling wells. Often, the first few hundred feet of a new well are drilled without using a riser, meaning the drilling fluid and borehole cuttings



A comparison of the legacy seafloor data (left) acquired and processed by NOAA and Texas A&M in the 1990s, versus the new BOEM bathymetry map (right) using industry 3D seismic surveys.

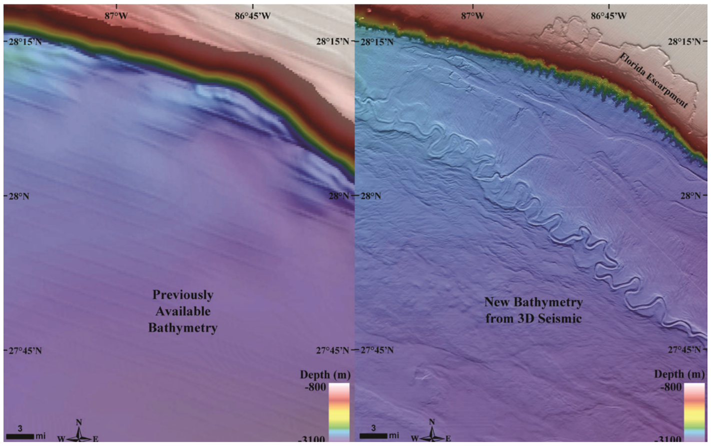
do not return to the rig; instead, they form a mound or elongate plume of sediment on the seafloor. If not carefully planned, ocean bottom currents can spread the mud and cuttings to nearby coral and chemo communities, damaging the sensitive habitats. BOEM uses the extensive seismic database to identify potential hard ground areas, and exclude them from oil and gas-related activities.

Ongoing Activities

BOEM continues to incorporate new 3D seismic surveys as they come in for areas where no previous survey coverage had existed. The map is being expanded further north into the Gulf's shallow waters, where feasible. BOEM is proud to contribute data and knowledge to help with important scientific endeavors as part of our responsibility to be good stewards of Federal lands for the American people.

—Kody Kramer, GOMR Office of Resource Evaluation

In memory of Kody Kramer, 1985–2018. A brilliant scientist, dedicated colleague, and friend who made a remarkable contribution to science.



New details about the geologic processes shaping the Gulf of Mexico are revealed. Joshua Channel in the Lloyd Ridge protraction area, absent from the previous dataset (left), shows up clearly using 3D seismic data (right).

Kody Kramer (left) and Bill Shedd in front of the BOEM bathymetry map.

For More Information

BOEM's Bathymetry Map

https://www.boem.gov/Gulf-of-Mexico-Deepwater-Bathymetry/

BOEM's Water Bottom Seismic Anomalies

https://www.boem.gov/Seismic-Water-Bottom-Anomalies-Map-Gallery/

Geosciences in the Pacific: Using Technology and Collaboration in Managing Oil and Gas Resources

Federal offshore oil and gas production began off the coast of southern California nearly 50 years ago. Today, BOEM's Pacific Outer Continental Shelf (OCS) Region continues to contribute to the U.S. energy portfolio by supporting development of conventional energy resources on existing OCS leases. With the help of cutting-edge technology and innovative collaboration with academia and other stakeholders, BOEM ensures the best available science is used in studying and managing federal oil and gas resources offshore California.

In order to effectively manage the mature oil and gas fields in the Pacific Region, BOEM geoscientists and engineers collaborate to build an integrated reservoir model for each field that is consistent with all available geologic, geophysical, and engineering data. This model forms the basis for resource management decisions and practices.

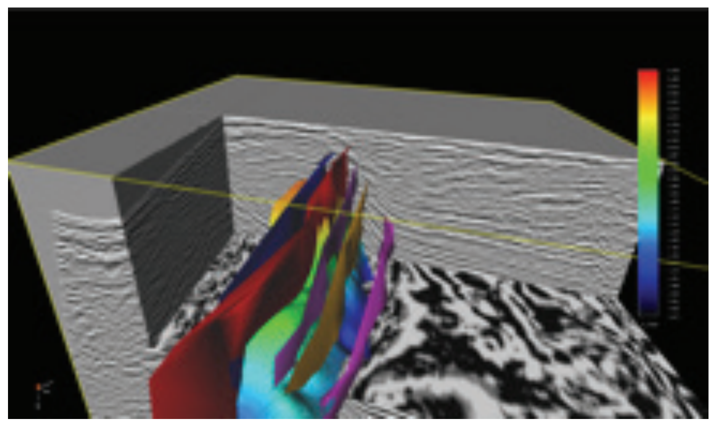
Did You Know?

As of October 1, 2016, more than 1.34 billion barrels of oil and more than 1.84 trillion cubic feet of natural gas have been produced from federal leases offshore southern California.

Integrated Reservoir Management

Integrated reservoir management is the application of available geologic, geophysical, and engineering data; technology; and expert knowledge to a reservoir system in order to regulate operations and maximize the economic value of the reservoir. The reservoir model is characterized by static geological and geophysical (G&G) properties and engineering data. Engineering data typically includes information about the reservoir and the wells drilled into it. The reservoir information includes some dynamic properties that change with time such as fluid composition, pressure, and production rates. History matching is performed to adjust the geological model and its parameters (e.g., permeability and porosity) such that the initial reservoir model is able to reasonably replicate the well-flow rate and pressure histories. Conventional history matching is an iterative trial-and-error process that produces a non-unique solution as different combinations of input parameters may produce similar results. The greatest challenge for the petroleum engineer is obtaining an accurate history-matched model that honors uncertainty in input data. BOEM uses a prudent choice of input parameters based on regional experience to obtain the most optimal match to observed production rates and reservoir pressure data. The final result is a new calibrated reservoir model that honors both static and dynamic behavior of the reservoir over time.

G&G data describe the reservoir's structure, formation thickness, geologic faults, and rock composition. These reservoir properties influence the producibility of hydrocarbons. A variety of data types are required to characterize the subsurface reservoir complexities. Reservoir data varies in abundance, accuracy, precision, and coverage. For example, seismic data provide extensive areal coverage and subsurface imaging that can help identify faults and folds. However, seismic data have limited resolution. As a result, small-scale features may go unnoticed. These finer details can be provided by small rock samples cut from the reservoir. High-resolution measurements, though, are limited to small areas directly around the well bore. These samples may be the only visual evidence of the rocks comprising the reservoir. Often, many of the characteristics required to develop a model of the reservoir cannot be directly measured; they must be inferred from available data. Such inference requires skill and judgement to reconcile various data types and make a consistent interpretation.

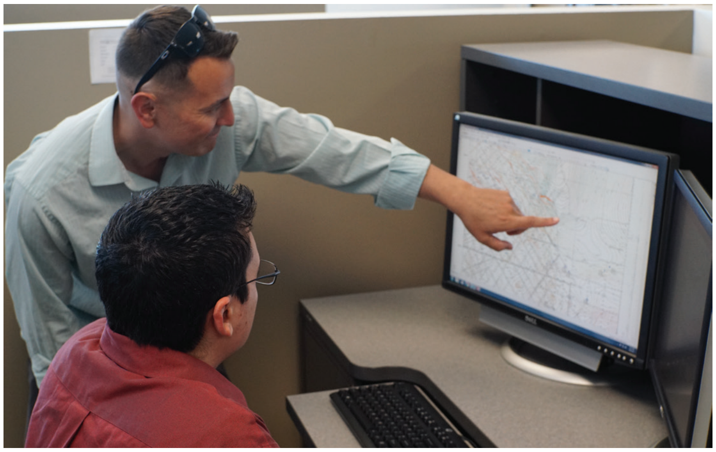


Model of the subsurface displaying fault planes intersecting a geologic horizon interpreted from a 3D seismic cube.

BOEM's Pacific OCS Region is applying technological advances such as Machine Learning (ML) to enhance the efficiency and objectivity of these interpretations.

Machine Learning

Machine Learning is rapidly being adopted across various industries to help find solutions by extracting useful information from large datasets. ML excels at identifying subtle but quantifiable relationships among seemingly disparate data types. These relationships are often imperceptible by traditional analytical methods. BOEM is leveraging large, in-house G&G datasets using various types of cutting-edge ML applications. To make non-proprietary data available to the public and ensure the public receives fair value for their resources, it is crucial to maximize the utility of these large and diverse datasets.



BOEM geologist Mark Leung points out geologic map features of interest as they are digitized at the Center for Geographic Studies, California State University Northridge.

California State University, Northridge - Center for Geographic Studies: Cooperative Agreement

BOEM often collaborates with various academic institutions and stakeholders on mission-critical scientific endeavors. One of the most recent efforts is a cooperative agreement with the Center for Geographic Studies at the California State University, Northridge. The goals of this effort are to create a more efficient, accessible, and organized G&G dataset, as well as enhance storage, retrieval, and analytical capabilities of regional geoscientific data. Improvements will include the development of an intuitive and effective geospatial database framework, conversion of map data to a standard electronic file format, implementation of data normalization and consistency, and development of industry-standard metadata.

Analog Reservoir Outcrop Analysis

In addition to its innovative approaches, BOEM's Pacific OCS Region also studies onshore rock outcrops to infer reservoir characteristics. This more traditional approach provides insight about offshore subsurface reservoirs that are not directly observable. BOEM scientists and engineers study these analogous outcrops to better understand small-scale features that may be present in the offshore reservoirs. In southern California's Santa Barbara Channel, many of the subsurface reservoir formations can be readily observed onshore. For example, the Monterey Formation, the most important source of oil in California, breaches the surface in some areas along the coast. Observing and studying onshore exposures of this geologically complex formation can help geologists, geophysicists, and petroleum engineers identify features that are too small to be resolved with seismic surveys. Information from these outcrop studies is integrated with other available regional information and used to inform BOEM's G&G interpretations and modeling.

BOEM's geoscientists and engineers use an integrated, multidisciplinary approach to create robust models of subsurface oil and gas reservoirs offshore California, and continue to refine and update its models as new data and tools become available. This approach provides information that is needed to support BOEM's mission-critical functions of oil and gas resource evaluation, reserves inventory, and worst-case discharge analyses. BOEM strives to provide policy makers with the best available information to inform offshore energy decisions.

—Chima Ojukwu, Kevin Smith, and Mark Leung,
Pacific OCS Region, Office of Strategic Resources

BOEM engineer Chima Ojukwu explains how natural fractures in the Monterey formation influence reservoir permeability.

BOEM geoscientists take note of a faulted anticline (fold) typical of subsurface oil and gas reservoirs (top and bottom images).

For More Information

Pacific Facts and Figures

https://www.bsee.gov/stats-facts/offshore-information/pacific-facts-and-figures

Visualizing 3D Data in the Gulf of Mexico Region

In 2003, BOEM recognized a need to develop a visualization room in the Gulf of Mexico Region (GOMR). Visualization technology allows for faster and more accurate evaluation and validation of geologic resource interpretations, and enhances multidisciplinary teamwork, project review, and data quality assurance. Visualization rooms have been in use in the private sector since 1997, and many oil and gas companies have installed them for in-house use.

BOEM formed a team to determine the requirements necessary to build a visualization room. After acquiring funding, the GOMR awarded a contract to build the first version of its visualization room. The room was scheduled for construction and installation in 2005, but was delayed as a result of building damage sustained during Hurricane Katrina. After a two-year delay, the contractor completed the room construction and equipment installation in 2007.

After several years of regular use, the GOMR found it necessary to "lifecycle" existing projectors and peripheral equipment that technicians determined were at "end of life," and decided to update the visualization room. In 2014, a contractor installed the current configuration that is used now.

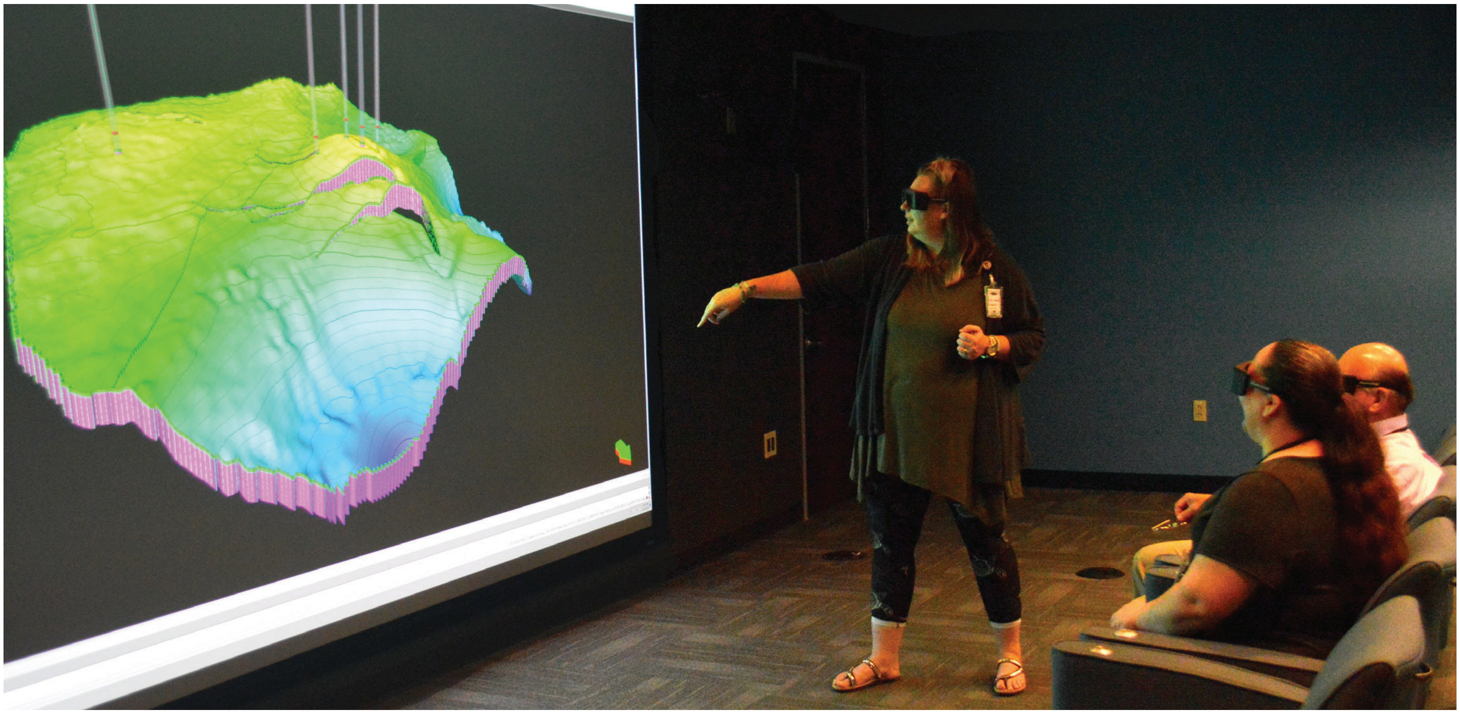
The dominant component of the current system is the Christie Mirage 4K25 projector. The Mirage is a 25,000 lumen 4K resolution projector that is capable of projecting content in 3D by utilizing active 3D glasses. The main projection screen in the room measures roughly 14 feet wide and 8 feet tall. The combination of the screen size and the high-resolution projector results in a dramatic display environment.

3D visualization effectively conveys complex concepts to audiences of diverse backgrounds. An example is a simple contour map of a subsurface geological structure. A geoscientist looks at the contour lines and sees a structural feature. A non-geoscientist usually just sees lines in a pattern. When the contours and surface are displayed in 3D, everyone recognizes the same features, which facilitates communication and helps build common ground.

The 3D content that the visualization room displays comes from a number of sources. The Geologic Interpretative Tools (GIT) applications, GeoFrame and Petrel, provide the capability to display a variety of data types in three dimensions, such as 3D seismic data. The equipment in the visualization room also provides the capability to view 3D video, similar to a movie theater. BOEM's 3D videos include footage of deepwater GOM shipwrecks filmed using a remotely operated vehicle equipped with stereoscopic cameras.

The GOMR has thus made good on the original vision for the visualization room, and used it as part of numerous meetings with stakeholders including Congressional and Department of the Interior delegations, internal customers, non-government organizations, industry, training, workshops, and workgroup collaborations. In addition to its utility for viewing various types of 3D data, the visualization room is also a valuable stakeholder engagement tool.

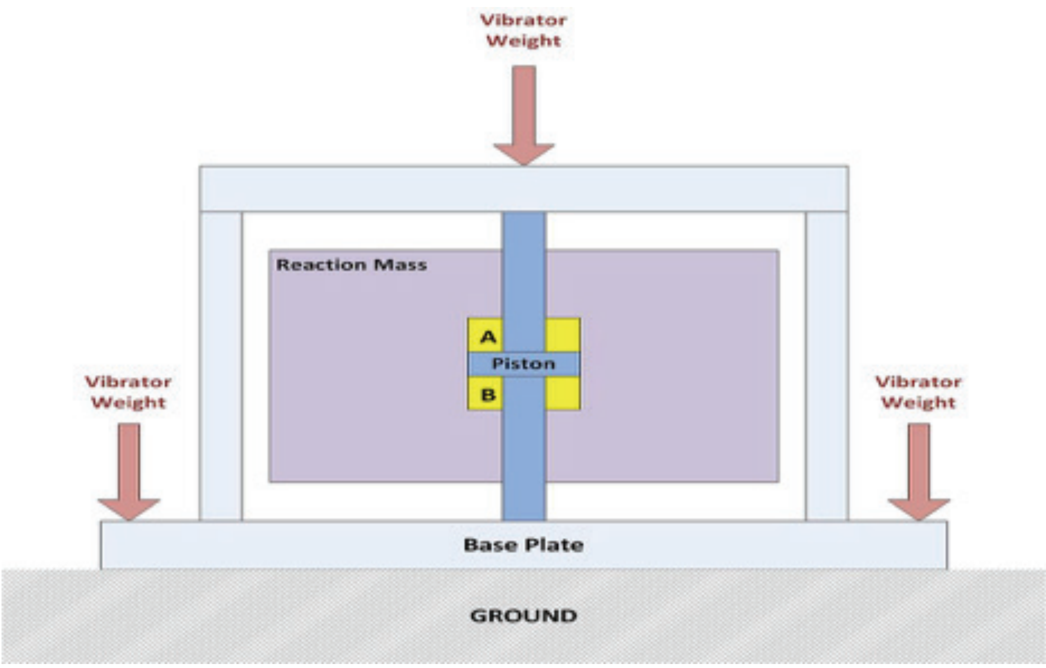
—William (Scott) Edwards,
GOMR Office of Resource Evaluation



Dramatic image in 3D seen by utilizing active 3D glasses

Vibrating on Ice: Unique Methods to Image the Arctic Sub-Seabed

On-ice vibroseis is a seismic method that images sub-ice geology and obtains its physical properties. These unique operations for 2D/3D seismic surveys are conducted during winter in the Arctic (primarily along the coast of the Beaufort Sea) when shore-fast sea ice is thickest. The best ice conditions generally exist from mid-January to mid-May, but vary from year to year in quality and quantity. On-ice operations are most commonly used on land-fast ice (ice attached to the shoreline). However, the vibroseis equipment can be used in areas of stable offshore pack ice when wind and current conditions are very low to nonexistent. At least 3.9-ft.-thick (1.2-m-) sea ice is required to support the heavy vehicles used offshore. The possible hazards of on-ice surveys include extreme cold weather, polar bear predation, and the possibility of heavy equipment falling through the ice.



Principle of operation of a seismic vibrator shaker.

Advance survey crews move ahead of the operation to mark the sound-source receiver points in the ice. Occasionally, bulldozers are needed to build snow ramps to smooth rough ice within the survey area. Next, trained seal-lair sniffing dogs search along the work areas and camp site to locate seal dens in water depths greater than 9.8 ft. (3 m) to prevent harm to seals and their pups. Several vehicles are normally used for a typical operation including vibroseis trucks, sound receiver trucks, and the living quarters (called the cat train) for the workers.

The cat train, the survey crew's living quarters, follows behind as the work progresses over the survey area.

After the advance crew marks the source receiver points, geophones (sound receivers) are placed along the surveyed receiver lines. When all geophones are in place, vibrator trucks move to the beginning of a surveyed source line, some distance away from the receiver line, and begin generating low frequency vibrations. The vibrator trucks move to the beginning of the line and move along the source line which is at some distance from a receiver line. The vibrators begin shaking the surface by deploying a shaker-piston system to generate low-frequency vibrations. Typically, each vibrator vibrates four times at a location before moving to the next location on the source line. The process is repeated along each surveyed receiver and source line.

—Susan Banet, Alaska OCS Region,
Office of Resource Evaluation

Receiver truck scouting and laying out the line.

Methane Hydrates on the OCS

For more than a decade, BOEM has dedicated resources to a Methane Hydrate (MH) program with the goal of providing a better understanding of this unconventional natural gas resource on the Outer Continental Shelf (OCS). Gas hydrates (GH) are ice-like crystalline substances occurring in nature where a solid water lattice accommodates gas molecules (primarily methane, the major component of natural gas) in a cage-like structure, also known as clathrate. GHs form under conditions of relatively high pressure and low temperatures, such as those found in the shallow subsurface under many of the world's oceans.

The primary focus of BOEM's MH program has been on the development of an OCS resource assessment model and the compilation of relevant and necessary information, unique to each of the OCS regions, required to run the model. Through these assessment efforts and through the investment and involvement in adjunct research activities and projects BOEM has made significant advances in understanding this potential resource. While MH resources have not yet been commercially produced on the U.S. OCS, the current program investment positions BOEM to be responsible stewards of this resource in the future and prevents the potential need of a rapid scaling-up of MH expertise.

Assessing Methane Hydrate Resources

As MH resources have been categorically excluded from the historical BOEM National Assessments of undiscovered technically and undiscovered economically recoverable resources (UTRR and UERR, respectively) due to their unconventional nature, BOEM has maintained a separate effort to assess GH on the OCS.

BOEM's current GH resource assessment effort began in 2003 with the assembly of a diverse group of government, academic, and industry scientists to develop a new assessment methodology that reflected the current understanding of hydrate distribution in the marine environment. Over the course of several years, and with the cooperation of external contractors and BOEM's regional offices, BOEM developed a methodology and modeling approach that resulted in the 2008 publication of an assessment of in-place GH resources on the Gulf of Mexico (GOM) OCS. BOEM then moved forward with an assessment of the Atlantic and Pacific OCS that resulted in the 2012 publication of a comprehensive assessment of in-place GH resources of the Lower 48 U.S. OCS.

The BOEM MH program participates as unfunded contributors to a variety of projects, and occasionally directly funds unique field research and modeling efforts. Participation in these projects serves a number of purposes, but ultimately each provides a direct return to BOEM through additional data and information that enhances our own ability to assess GH resources on the OCS. Significant BOEM-funded field projects include cooperative agreements with Scripps Institution of Oceanography to collect controlled source electromagnetic data on the Pacific and GOM OCS; interagency agreements with the USGS to collect high-resolution and multi-component seismic data in the GOM; and cooperative agreements with the University of Mississippi to develop a permanent observatory to monitor the dissociation and accumulation of GHs and impacts on the adjacent seafloor, water column, and marine biota.

BOEM has also participated in projects with other universities that share an interest in MH research, including Louisiana State University, Ohio State University, and the Basin and Petroleum Systems Modeling group at Stanford University.

Gas hydrates recovered from the Gulf of Mexico. Photo by USGS.

Gulf of Mexico Gas Hydrate Joint Industry Project

BOEM was a founding member of the Department of Energy-funded, Chevron-operated Joint Industry Project (JIP) in the GOM. The Leg I drilling program (2005) visited sites in Keathley Canyon and Atwater Valley and discovered GH in shale reservoirs. For Leg II (2009), BOEM scientists played a significant role in the site selection process and as members of the onboard science party. The Leg II drilling program focused on finding GH at high saturations in sand reservoirs, and successfully did so at sites in the Walker Ridge and Green Canyon (GC) protraction areas. The successful site selection approach and drilling/logging technologies set a benchmark that has been replicated in GH drilling programs around the world. Additional objectives of the cruise were to extend knowledge to sand systems, calibrate seismic and well data to identify sites likely to contain GHs, inform the BOEM hydrate assessment, and test alternative exploration models.

Pressure Coring MH in the GOM

While the Chevron JIP formally ended after Leg II, the DOE recently made an award valued at over $50 million to fund the next phase of GH drilling on the U.S. OCS. The University of Texas at Austin (UT) leads the program, with BOEM serving in a scientific advisory role to help guide the site selection process and assist in the development and deployment of the scientific plan. The scientific advisory team was created to identify and evaluate sites that have a high probability of containing high-saturation natural GH reservoirs for which there is significant existing data to complement the planned research expedition.

The first phase of the UT project was conducted in May 2017 aboard the Helix *Q4000* semi-submersible rig, which mobilized in Brownsville, TX, on May 1. Two wells were drilled at the GC 955 site in a drilling and coring campaign designed to assess the nature and occurrence of GHs in the deepwater GOM. Pressure cores were collected from geological formations where the preservation of in situ pressures during recovery maintains the physical, chemical, and biological components of the MH system. Data gathered during this phase of the project will help scientists more accurately estimate the occurrence and distribution of marine hydrates and lay the groundwork for future production efforts.

Operations at GC 955 were completed on May 24 with a total of 12 pressure cores collected at the GC 955-H005 well site. No geophysical logging was feasible at the site, given the design of the bottom-hole assembly. The final six coring runs recovered 31.8 ft. (9.7 m) of sediment, with 17.2 ft. (5.2 m) collected at or above hydrate stability pressure. Recovery of samples under pressure was generally very good in the GH-bearing layers and poor where GH was not present.

The Helix *Q4000* semi-submersible drilling rig in the GOM.

The science team then moved operations ashore to a temporary core handling and processing facility in Port Fourchon, LA. Here, the 20 most scientifically valuable and highest quality 3.28-ft. (1-m) sections of core were processed and transferred (under pressure) to the UT cold storage lab. Sub-samples will be allocated among various laboratories for advanced analysis. The cores have been imaged and logged under pressure, samples have been de-gassed to understand hydrate concentration and gas chemistry, and microbiological and porewater analyses have been performed on the cores. The log and core data will provide a foundation for scientific exploration by the hydrate research community.

Next Phase of MH Drilling in the GOM

The UT project has recently been approved for International Ocean Discovery Program (IODP) Expedition 386 which will occur in the year 2020 from the research vessel *JOIDES Resolution* in the GOM. This 56-day drilling, coring, logging, and testing program will again focus on coarse-grained MH systems, visiting several known sites and exploring for new MH accumulations. BOEM has been involved with the planning of this expedition through characterization of the subsurface in the site-selection efforts.

Future

MH research thus far has focused on documenting the geologic parameters that control their occurrence and stability, identifying hazards associated with MHs, assessing the volume of natural gas in naturally occurring systems, and assessing the ability to technically produce MHs from marine reservoirs. Ultimately, we are interested in developing a better understanding of the ability to sustain gas production via MH production tests.

—Matt Frye and Stephen Palmes,
Resource Evaluation Division

For More Information

BOEM's Gas Hydrate Studies

https://www.boem.gov/Gas-Hydrates/

BOEM's Gas Hydrate Assessments

https://www.boem.gov/Gas-Hydrates-Resource-Assessment/

Spotlight on A Scientist: Harry Akers

What is your job at BOEM?

I am a petroleum engineer in the Resource Evaluation Program in Anchorage, Alaska. I moved to the Anchorage office in 1976. I am largely responsible for the MONTECARLO or range of values (MONTCAR) economic simulation program used nationally to determine fair market value and adequacy bids received in Federal OCS lease sales. If industry bids do not measure up to the values obtained by MONTCAR, they may be deemed inadequate and rejected.

Why did you decide to work for BOEM?

Since 1963 I have been interested in computers and in "crunching numbers," as they call analyzing data. My petroleum engineering background coupled with computer skills were factors that were needed for resource evaluation work, and so I was spotted and hired by then-Gulf of Mexico Regional Director Rod Pearcy and started working in the Conservation Division of the U.S. Geological Survey, in Metairie, LA in 1974. In 1976, I transferred to the Alaska Region office. I was very pleased with the transfer as I had wanted to live in Alaska since working on the Arctic ice in 1971.

What role do you play in BOEM's Resource Evaluation Program?

I maintain the computer model and develop upgrades to it as Headquarters and Regional users identify new needs. Unlike a simple programmer, I often work from just an oral statement like "We need the program do such-and-such under a certain set of circumstances." I have to decide how to do it. Because I am recognized as the authority on MONTCAR, I have to be ready to answer any question that arises. Since the inception of MONTCAR in 1974, nearly 29,000 tracts have been evaluated for fair market value with more than $70 billion in accepted bonus bids received by the government.

How has your educational background and experience prepared you for the work you do?

My educational background (at the Colorado School of Mines and the University of Colorado) stopped in 1956. In those days-and for years afterwards-there were only mechanical calculators. However, as I think back on those 60+ years, I realize that I learned the most fundamental thing about engineering reasoning:-pay attention to the dimensions of your problem! A volume per unit of time, multiplied by an interval of time, is a volume. A force, spread over an area, is a pressure, and so on. That kind of information is more important than knowing how to design distillation equipment!

I was hooked on computing when a programmer from Dow's Computations Department taught a brief course on Algorithmic Language in 1963. I was just passing by the room, overheard a few words, and hovered around the door. I heard only a part of the lecture, but I got and did the class assignment, and many more, from that day onwards.

Harry Akers. Photo by Jenna Lee, BOEM Alaska OCS Region

What do you find most rewarding about your work?

In 1949, when I was 16 and got a Cushman motor scooter, I was thrilled by the thought that a machine could obey me. I had the same feeling in 1963 when I found that I could make a machine do calculations and printing for me. Of course, the thrill of that kind of activity wears off. Something more lasting is the sense of accomplishment and problem-solving. I start with an oral (sometimes written, but never complete in detail) statement. As I proceed to code it, I run into problems, and must either design a solution myself or go back to the person who posed the problem in the first place. Often there is something that neither of us thought of when the problem was first presented to me. Eventually, a solution comes forth, and I feel satisfied! I also like explaining how the program works and what a user must do.

Note: On May 1, 2015, Harry Akers received the Department of the Interior's (DOI) Distinguished Service Award – the highest honorary recognition in DOI.

Continuous Learning on the Outcrop: BOEM Earth Scientists Take to the Field

Over nine days in June 2017, 26 geologists, geophysicists, and petroleum engineers from BOEM's Gulf of Mexico Office of Resource Evaluation in New Orleans, LA, and headquarters Resource Evaluation Division in Sterling, VA, visited outcrops in West Virginia, Virginia, and Kentucky to learn about black shales and shallow-water deltas in the central Appalachians. Near Titusville, PA, the oil and gas industry began in 1859 with Colonel Edwin Drake's 70-ft-deep well. Today, the oil and gas industry includes offshore energy development, which BOEM regulates on the Federal Outer Continental Shelf.

Contact with rocks is an important part of geologists' continuing education. BOEM geoscientists who daily use workstations and specialized software with 3D seismic and well log data are grounded by field experiences like this. Placing rock exposures in highway cuts and quarries within the context of the continental-scale tectonic and climatic settings of the past helps to enhance an earth scientist's perspective and aid in the interpretation of geological and geophysical data. It is a special opportunity to relate the real world to BOEM's daily work: reviewing and approving industry's plans, exploration, and field developments that are based on remotely-sensed data, 3D seismic data, and well logs.

Since 2015, BOEM has organized two such field trips; the first, the "Deepwater Clastics" trip, examined deepwater paleoenvironments in the Ouachita Mountains of Arkansas and Oklahoma in 2015 and 2016. BOEM geoscientists visited a geologic setting where sediments were deposited directly into a deep trough along the edge of the southern continental margin about 360 million years ago. Sediments deposited here are analogous to the deepwater GOM where most of today's industry exploration and development occurs. The second trip, "Black Shales and Deltas," in June 2017 examined deltaic and marine margin paleoenvironments in the central Appalachians of West Virginia, Virginia, and Kentucky. The ancient environments of this geologic setting are analogous to those traversed during a boat ride from nearly any Louisiana bayou into the GOM; crossing deltas and the continental shelf to the edge of the continental margin in 600 ft. of water.

For the first leg of the 2017 trip, the group visited rocks preserving basin plain, outer shelf, deltaic, and coastal plain paleoenvironments of latest Devonian-early Mississippian age (375 million years ago) in the Virginias. The second leg of the trip visited coal seams and shallow-water deltas of Pennsylvanian age (300 million years ago) in the Pocohontas basin of eastern Kentucky. BOEM oil and gas geoscientists were able to handle coal, the other major fossil fuel. The trip crossed the Appalachian basin, but it also crossed 70 million years of time—a period when the Earth was in transition between a "greenhouse" climate of warmer oceans and higher atmospheric carbon dioxide content to an "icehouse" climate of cooler oceans, lower carbon dioxide content, and continental glaciation. Evidence of these long-duration changes in the Earth's climate is reflected in the rocks.

—Tom Bjerstedt,
GOMR Office of Resource Evaluation

BOEM geoscientists examine the Fire Clay Coal near Hazard, KY. Photo by Randy Broussard.

Lisa Kennedy points out trace fossils to Tom Bjerstedt near Bluefield, WV. Photo by Greg Shin.

BOEM geoscientists examine siltstone turbidites and trace fossils in Morehead, KY. Photo by Greg Shin.

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BOEM's Renewable Energy Program - Picking up Momentum

BOEM's renewable energy program has seen a string of accomplishments since adopting final regulations in 2009. The progress is propelling a robust offshore wind energy future to supply millions of U.S. homes.

The Block Island Wind Farm off Rhode Island.

To date, BOEM has issued 13 leases totaling almost 1.4 million acres in Federal waters. Industry-wide confidence in U.S offshore wind markets continues to grow thanks to decreasing global costs, stronger state policy commitments, and the Department's commitment to American energy.

Residents of Rhode Island's Block Island, customers of the Nation's first offshore windfarm developed by Deepwater Wind, began to see benefits in December 2016. Similarly, other states are expected to see low, long-term fixed costs, reduced electricity prices, and improved energy security.

Recently, Massachusetts, New York, New Jersey, Connecticut, Rhode Island and Maryland have pursued policies to incentivize the development of offshore wind. These policies include procurement targets for offshore wind and offshore renewable energy credits that could support over 8,500 megawatts.

To further reduce the cost of offshore wind and build a supply chain, industry will require a pipeline of projects. In the Atlantic, BOEM is proposing a wind energy auction for areas offshore Massachusetts totaling nearly 390,000 acres; is seeking information and nominations for areas within the New York Bight region, a shallow-water area between Long Island and the New Jersey coast; and is seeking feedback on areas in the Atlantic that may be suitable for future offshore wind development. BOEM is also working closely with the states of California and Hawaii to identify areas that may be suitable for floating wind energy development in the Pacific.

These and other measures are in the works to make the leasing and approval process more predictable and flexible while still analyzing environmental impacts of proposed projects. BOEM will continue to build off this momentum to shepherd in a new offshore wind era in the United States.

For More Information

Renewable Energy Regulatory Framework
https://www.boem.gov/Regulatory-Framework/