New Seep Technology

Proper detection and analysis of hydrocarbon seepage can narrow the search for oil and gas and reduce the drilling risk in deep water plays.

Thomas Smith, Associate Editor

"Conventional seismic data provides an indication of seepage and migration pathways. However, better resolution is often needed to distinguish routine bathymetric features for seep features. Using an Autonomous Underwater Vehicle (AUV) geophysical survey," explains Bruce Samuel of C & C Technologies in Lafayette, Louisiana. "We are able to detect morphological characteristics that resulted from hydrocarbon seeps, he says."

The benefit of detailed surveys

Every petroliferous basin exhibits indications of migrating hydrocarbons. Detection of seabed hydrocarbons can yield evidence for a basin's key petroleum system elements such as source type and age, maturity or maturation of the source beds, and migration of hydrocarbons from the source beds. Seeps can also provide information about the contents (both fill and phase) of a subsurface reservoir, thereby reducing drilling risk, which is particularly important for expensive deep water exploration.

The success of seafloor hydrocarbon coring programs is greatly improved when using high-resolution Autonomous Underwater Vehicle (AUV) geophysical data to identify seepage features. Detailed seabed maps can now be constructed from this data allowing seafloor coring sites to be pre-selected directly over suspected seepage. Past surveys relied only on 2D and 3D seismic data to identify seepage features. The more subtle features that were often missed are easily identified from a detailed AUV survey. When combined with deeper geological features (such as faults, salt diapers, and structures) identified on conventional seismic data, a link can often be established between reservoirs and the seafloor seeps.

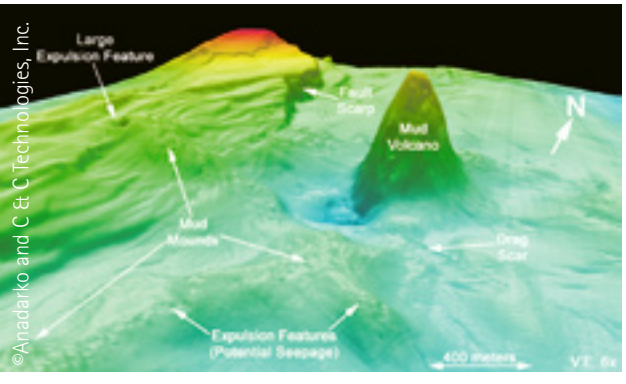
Seep Activity

Offshore New Orleans, a lot is happening in the near surface sediments. First of all, there are oil and gas seeps that support unique communities of animals in the deep ocean. The animals live off bacteria that feed on hydrogen sulfide gas, a by-product of the seepage. Also, there are mud volcanoes, fault scarps, pockmarks, shallow gas wipe out zones and gas chimneys depicted on seismic data that result from such seepage.

"The near surface expression of hydrocarbon seepage is controlled by rate and volume of petroleum generation, migration and pathways, and the near-surface conditions," says Dr. Michael Abrams, author of numerous technical papers covering seep sampling and analysis and now manager of petroleum geochemistry with Apache Corporation. "Understanding the regional seepage system and what affects the signature of anomalies associated with seepage is vital in evaluating the significance of any anomaly."

Photo: C & C Technologies, Inc.

An Autonomous Underwater Vehicle (AUV) is an un-tethered and un-manned submersible used for the collection of high-resolution remote sensing data. This AUV is carrying a wide variety of equipment that include multi-beam and side scan sonars. Other equipment includes cameras, current meters, hydrocarbon sniffers, and sub-bottom profilers.



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This digital terrain map was generated by an Autonomous Underwater Vehicle (AUV) side scan sonar draped over multibeam bathymetry. Seafloor seepage features missed in 3D seismic bathymetric data are resolved by the enhanced resolution of this data. The mud volcano, large expulsion feature, and the mud mounds are all seep features confirmed from coring data.

Macro- and microseepage

"Basins with high sedimentation rates and active tectonism, like the Gulf of Mexico, South Trinidad, South Caspian Sea, and the Santa Barbara Channel off the California coast, tend to have large-scale active *macroseepage*. Rapid sedimentation can cause overpressured zones, steep fluid gradients, diapirism (like mud volcanoes) and active hydrocarbon generation," explains Dr. Abrams. "Less active basins, like the Bering Sea, Chukchi Sea, and parts of the North Sea have more passive *microseepage*. Here, petroleum migration is dependent on the availability of relatively permeable, sandy carrier beds, regional dip, and major basinal faults."

Hydrocarbon migration can take place nearly vertically when there are faults or

Photo: Harry Roberts, Louisiana State U.

Interesting animal communities like these tube worms survive along active seeps in the Gulf of Mexico.

diapirs present to act as a pathway for the hydrocarbons. Basin flow dynamics can lead to lateral displacement of hydrocarbons. Both physical (hydrates, permafrost, or impermeable shale) and biological (bacterial alteration and in situ hydrocarbon generation) processes can alter or even block seepage. These processes have an effect on both the locations of a seep relative to the source and sample quality.

The advantage of AUV

Recovering representative samples is a very important part of any seabed seep survey. Sampling should target key migration pathways which focus migrating hydrocarbons into the shallow section, as well as near surface indicators of leakage such as mud volcanoes, pockmarks, scarps and shallow gas zones.

In fact, by using the combination of high resolution multibeam bathymetry, side scan sonar, and sub-bottom profiling, all of which can be obtained from the AUV, Bruce and his coauthor, Harry Dembicki, Jr. of Anadarko Petroleum, were able to locate seep features more accurately than can be sampled in deep water areas.

Their study was the first to use an AUV survey to identify hydrocarbon seep features and actually core the pre-selected areas. The seabed geochemical survey was conducted as part of the University of Utah's Energy and Geoscience Institute (EGI) surface *Geochemical Calibration Study* (GCS) west of the Marco Polo field in a deep water sub-basin in the Gulf of Mexico, an area of macro-hydrocarbon seepage. By coring suspected potential seepage, areas of reduced hydrocarbon concentration, and areas of no seepage (for control points), they were able to ground-truth what they had mapped from the AUV data.

"Features that might be missed on conventional seismic data are easily detected using the AUV high resolution data," claims Dr. Dembicki. "Being able to accurately detect and sample seeps can substantially reduce the dry hole risk in expensive deepwater exploration."

In fact, predicting the hydrocarbon charge and phase depends on accurately locating and mapping the surface morphology, along with sampling directly above migration pathways. Samples taken from the near-surface seep features may contain gas, water, and oil. The fluids still need to be analyzed to confirm that the potential migration pathways are associated with specific hydrocarbon generation and migration.

Adding Confidence

Being able to accurately pre-select and core hydrocarbon seepage enhances the ability to identify background vs. anomalous signatures. New sample preservation and analysis will add confidence to the interpretation.

"Our survey near the Marco Polo field left little doubt in identifying anomalies," says Dr. Dembicki. "Cores targeted on suspected seep features yielded samples with visible oil. We obtained a 100% success rate sampling the high concentrations of seepage using the AUV data along with conventional seismic imaging. Previous seafloor coring surveys in this area achieved only a 16.6% success."

Some samples were also charged with hydrogen sulfide formed from biodegradation of the oil. Even these cores retained chemical characteristics that could be tied to oil reservoired in the Marco Polo field. As suspected, cores sited away from the major seeps provided mixed results while others were nearly barren.

"In identifying anomalies, the importance of proper sample preservation, analysis, and interpretation must be stressed as well," says Dr. Abrams. "Sometimes interpretations have mistaken reworked source rock, transported hydrocarbons, and background variation for real seep signals yielding misleading and confusing results. The SGC research project examined current and new methods to remove migrated gas and liquid hydrocarbons. Early data from the study have shown that some extraction methods actually alter the original hydrocarbon compositions leading to systematic errors."

"For any seep survey and interpretation to be meaningful, understanding basin geology and petroleum dynamics of that basin is critical," says Michael Abrams. "By integrating the near-surface and subsurface data, surface geochemistry can be used as a predictive tool to reduce drilling risk."