Smart survey approach: multibeam echo sounder and integrated water column data as an added value for seep hunting

Marco Filippone – Garrett Mitchell

Key words: water column data, multibeam echo sounder, seep hunting, backscatter, integrated data management

SUMMARY

Multibeam echo sounder (MBES) systems have been used to collect bathymetric and seafloor backscatter datasets since the 1990s. Resolution and accuracies of data improved rapidly with every subsequent generation of multibeam models. The current generation of multibeam systems allow for the acquisition of acoustic backscattering from the water column, which can be used for various academic and commercial applications. Water column mapping is well defined by the Centre for Costal and Ocean Mapping – Joint Hydrographic Centre (CCOM-JHC) as acoustic remote sensing, which is used to explore hydro acoustic scatterers within the marine environment that are found between the ocean surface and the seafloor. Acoustic scattering found in the water column includes various geophysical and biophysical phenomena from due to density impedance contrasts of various scales depending on frequency. Different disciplines and industries are using water column imaging (WCI) for applications in fishery research and the fishing industry (fish stock assessment; Kostylev et al, 2003), environmental sciences (oceanographic structures; Keir Colbo et al. 2014), hydrographic agencies (least depth validation of wrecks; K. Wyllie et al., 2015), and hydrocarbon exploration (Nikolovska et al., 2008; Weber et al., 2014). This paper describes how water column data can be used for seep hunting as an integrated part of a marine geophysical survey and geochemical sampling campaign.

What is a seep? A marine seep occurs when buoyant fluids and gases rise from the denser seafloor sediment into the water column. Marine fluid seepage results from various phenomena as diverse as escaping fluids overpressured by tectonic forces, high-temperature hydrothermal venting, fluids altered in serpentinization reactions, submarine discharge of terrestrial groundwater, and fluids that have been modified by contact with hydrocarbon reservoirs (Figure 1).

Hydrocarbon seeps are a ubiquitous feature in oil and gas-bearing offshore basins. In 1976, Rudesindo Cantarell, a Mexican fisherman, noted seeps that led to the discovery of the giant oil field that now bears his name. It is well known to most in the industry, for instance, that the deep-water Gulf of Mexico is a notoriously leaky petroleum system characterized by more than a thousand hydrocarbon seeps.

Seep hunting is an important component of offshore hydrocarbon exploration and analyzes water column backscatter data to identify petroleum-rich gas bubbles and oil droplets originating from active seafloor hydrocarbon seeps (Figure 2). Though various acoustic mapping techniques such as side-scan sonar and sub-bottom profiling are able to detect bubble clouds in the water column, modern multibeam sonars are able to image these plumes with greater resolution. Advancements in computing power sonar hardware, and software tools allow the detection of mm-size bubbles (depending on frequency) and are able to pinpoint small emission sites on the seafloor.

Evaluating frontier deep-water basins is an expensive proposition with high risks and high rewards. Exploration teams evaluating deep-water basins need to know which concessions to pursue and which to drop. Modern seafloor mapping using MBES sonars and precision geochemical sampling are efficient and affordable tools to support this decision.

1. MULTIBEAM SYSTEMS

The first MBES system was developed in the late 1970s. Though it had limited beams and a limited swath width, it represented a very innovative way to approach bathymetric surveys, which significantly increased the efficiency compared to the commonly used single beam systems. Innovations in MBES mapping systems started in the 1990s with significant improvements in sonar technology, increased computing and processing power and new sonar and software designs (Mayer 2007). Initially, water column data in multibeam mapping were ignored as users were typically only interested in information related to the seafloor. Here the range/timing of the returning wave to the transducer is converted into water depth by applying the speed of sound variations in the water column. Successive pings of sound create a three-dimensional view of the seafloor when depths are gridded. The amplitude of the returning wave can be converted into a backscatter intensity that provides information on the hardness and roughness of the seafloor. This information can be used to deduce the geologic nature of the seafloor, i.e. whether it is mud, sand, or rock. Water column data were generally ignored because it created much larger datasets (up to 1 GB/min with some systems), which were difficult to process, analyse and interpret before modern computing power. With recent advances in computing power and storage, water column datasets are now regularly collected during surveys because of the information they can provide. These midwater datasets can track schools of fish, map biomass, assist hydrographic surveys with potential navigation hazards, and locate leaking gas bubbles or oil droplets into the water column. Commercially, the collection of water column data to locate active hydrocarbon seeps is a market-niche. Maintaining close relationships with hardware and software manufacturers specializing in the mapping of the water column is paramount for survey companies serving this market.

Tradionally, a MBES is primarily used to collect bathymetric data based on calculation of time and angle of each transmit/receiver beam. Simple geometric calculations can be used to determine water depth where the sound velocity profile in the water column is constant. However, the ocean is much more complex because water masses have different salinities, temperatures, and density profiles and geometric ray tracing is required to account for refraction these changes cause for the sound velocity in the water column. Bottom detection algorithms vary by system, and usually involve a combination of two methods. For the nadir and near-nadir beams, signal detection is usually based on estimating the maximum amplitude instant of the signal time envelope (similar to single-beam systems). This approach works less well for oblique grazing angles, due to the extended beam footprint on the seafloor and the random nature of seafloor scattering. In these cases the receive array is typically divided into sub-apertures so that phase-differencing techniques can be used for bottom detection.

A second dataset acquired from a MBES is the seafloor backscatter. The backscatter measurement is recorded as a function of time for each beam within the system, prior to bottom detection, and represents instantaneous changes in scattered intensity that relate to changes in seafloor microscale roughness, changes in seafloor surficial geological characteristics, and or density irregularities within the sediment volume. A seafloor backscatter image from a MBES is created during post-processing by extracting the amplitude of the beam-formed signals at or near the bottom detection, taking into account changes in the insonification angle as a result of the swath angle and seafloor morphology. In this way, the central point of the beam is positioned on the swath, and intensity measurements are distributed around it until the boundary of the next beam is reached. This post-processing approach allows the user to apply corrections to remove angular/range artifacts and significantly improve the quality of the backscatter imagery/data obtained from MBES systems.

Measurements of acoustic backscatter in the water column near the bottom detection originate from full beam time-series of acoustic returns. Modern systems allow the user to record these full time series, providing a record of any acoustic scattering within the water column in addition to the seafloor returns. The ability to record the full water column backscatter dataset depends on the manufacturer; some systems record the original data used for bottom detections in its entirety, while some record a decimated version to reduce the quantity of data that is recorded. Some manufacturers allow the user to record the phase difference data as well.

2. SMART SURVEY APPROACH FOR SEEP HUNTING

2.1. MBES Calibration

The accuracy of MBES systems and their data quality vastly improve with a properly calibrated system. For hydrographic purposes, this includes a bathymetry calibration procedure called patch-test in which the vessel attitude is aligned with the acoustic sensors.

In addition to properly calibrating a MBES for bathymetry, sector-normalized backscatter has been shown to offer superior quality backscatter imagery required for detecting small hydrocarbon seep features on the seafloor. Seafloor backscatter normalization is necessary to achieve a uniform backscatter image across different depths because the MBES intensity signal strength varies with water depth. In a large seafloor survey where different vessels and MBES sonars are deployed, the sector normalization is the only way to achieve a seamless dataset since different MBES systems usually use different signal strengths, data acquisition modes and frequencies. This process can take several days depending on how many modes and frequencies the multibeam uses and what depth range is present in the survey area. During the calibration and survey, frequent sound velocity measurments are important. Backscatter normalization requires a flat and uniform seafloor at the optimal depths for each mode; this has to be taken in account during the calibration planning. During the backscatter calibration each beam intensity is extracted from the raw data and normalized by sector.

2.2. WCI Analysis

Water column analysis allows an accurate detection of gas venting, indicating possible active seeps on the seafloor. This special analysis is done during the interpretation phase of a geophysical surveys using dedicated tools available from commercial software venders like Caris and QPS. QPS Fledermaus has recently added a Feature Detection toolkit into their software that allows for various filtering options to automate seep picking. This new toolset allows the user to quickly filter out noise and beam pattern residuals while exporting hundreds of points interpreted to be bubble plumes (Figure 3). These datasets can then be imported into a 3D environment such as Fledermaus for advanced data visualization.Though semi-automated seep identification processes are now avaliable in commercially-available software packages, professional interpretation experience is still very important to achieve high-quality results.

2.3. Added Value

The smart survey approach for seep hunting includes an emphasis on survey planning in order to optimise the MBES performance specifically for locating hydrocarbon seeps while maintaining high data quality. Elevated survey speeds are desired for large area exploratory surveys, but slow enough to ensure contractual coverage and data density requirements.

Multibeam data processing during seep surveys is performed onboard in semi real-time and includes a GIS project for analysis as part of a preliminary interpretation. Alternatively, data can be transmitted on land (Fugro's Back2Base solution) for QC and processing. Seep specialists use the processed data to map seafloor features, interpret areas that may be indicative for seafloor seepage integrating bathymetry, seafloor backscatter, and midwater backscatter, and determine potential core site for geochemical analyses **(**Figure 4**).** A turnkey project may include geophysical data collection, interpretation, target picking, coring, and onboard geochemistry (gas cromatography). In this way a full package can be collected and delivered to the client at the conclusion of a survey. MBES surveys help innovative oil companies to maximise their deepwater exploration success for a fraction of the cost of a seismic survey.

3. CONCLUSION

The high-resolution data of the seafloor acquired with modern MBES data can be interpreted by specialists at sea (along with previously-acquired regional 2D seismic data) for indications of seafloor seepage. The identified seeps are then sampled by precision-navigated piston or gravity cores. The resulting geochemical analyses help answer critical prospectivity, source, and maturity questions for hydrocarbons, which are essential to assess deepwater prospects.
Over several years innovative offshore interpretation methods have been conducted for offshore oil and gas companies to maximize their exploration success in deepwater.
Hydrocarbon seep surveys have been carried out offshore Madagascar, Mozambique, Kenya, New Zealand, Uruguay, Guyana, Colombia, Nova Scotia, the Gulf of Mexico and Brazil using this approach (Figure 5). Presently, Fugro is involved in the world's largest seep-hunting survey covering an area of 625,000 km^2 in the Gulf of Mexico and the Caribbean in water depths up to 4,500 m. Three dedicated vessels are involved in this survey using Kongsberg EM302 30 kHz and EM122 12 kHz MBES systems **(**Figure 6**).**

Figures :

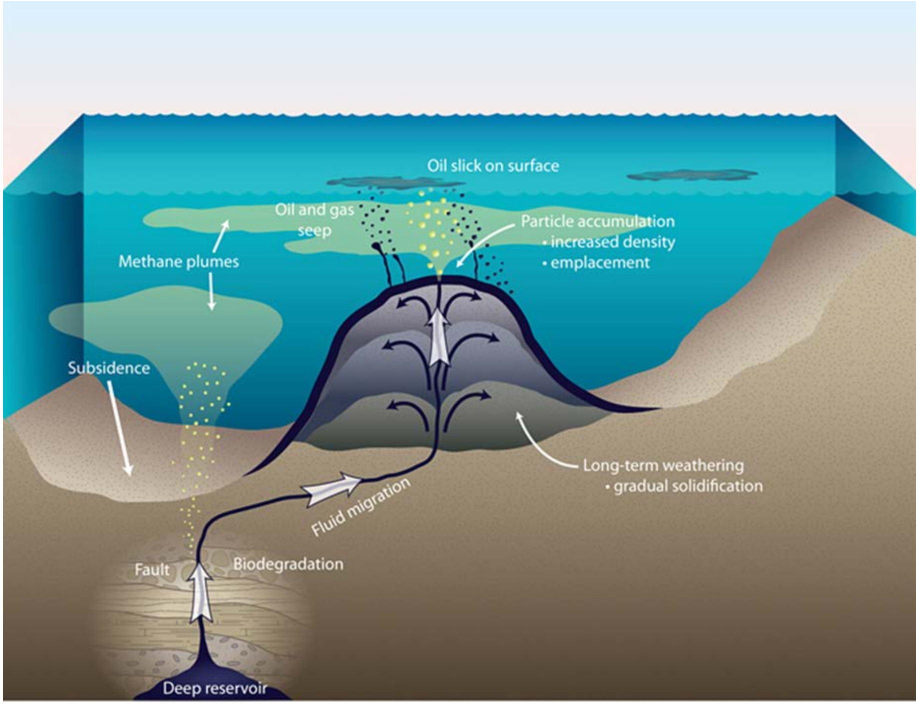

Figure 1 Seep typical configuration

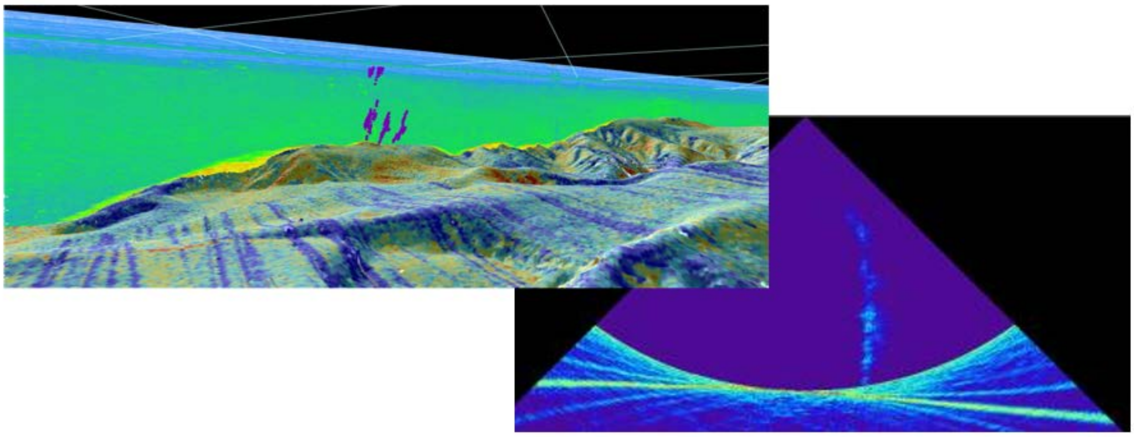

Figure 2 Gas Vent, column image showing discrete, point-source activity from a robust, venting seep.

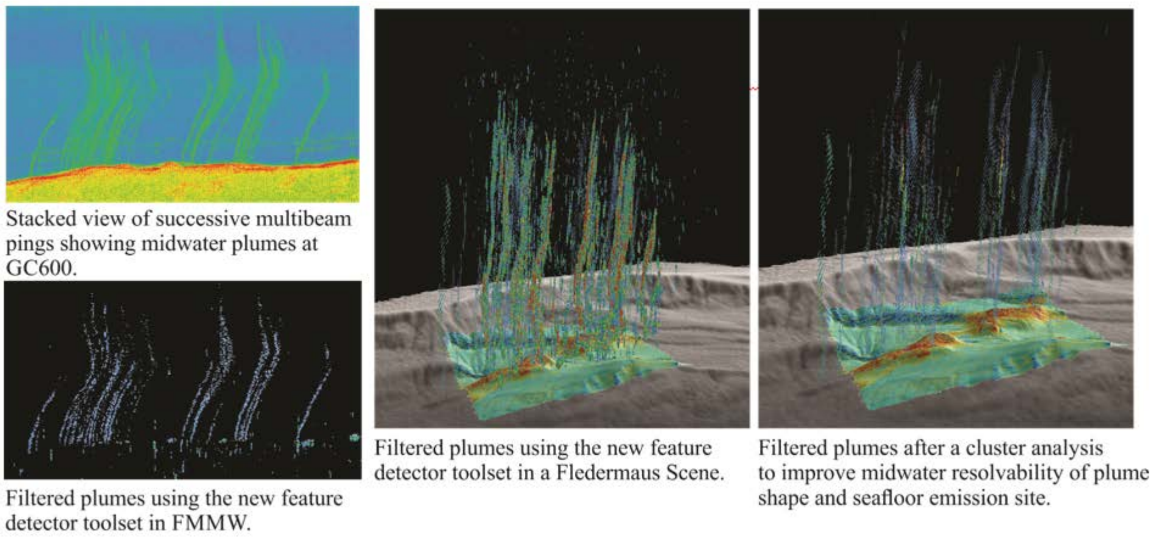

Figure 3 Example of processed water column data using QPS Fladermaus

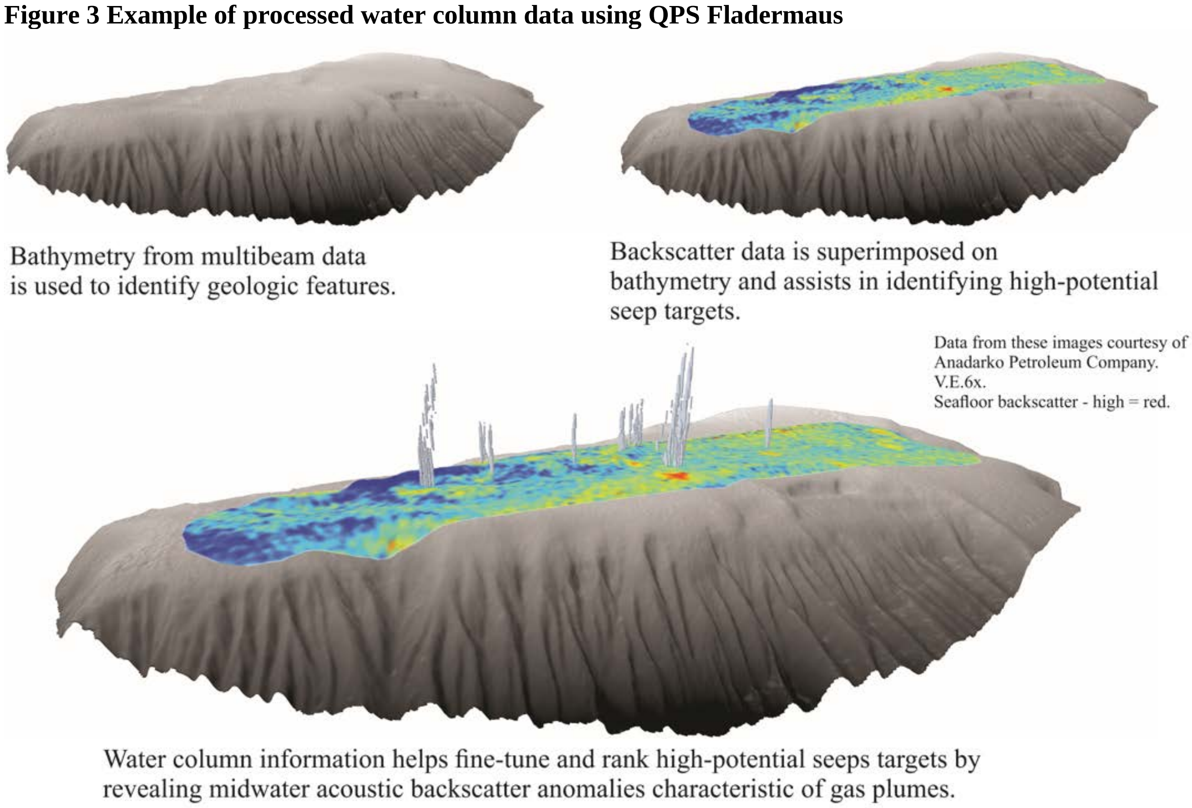

Figure 4 Integrated data management

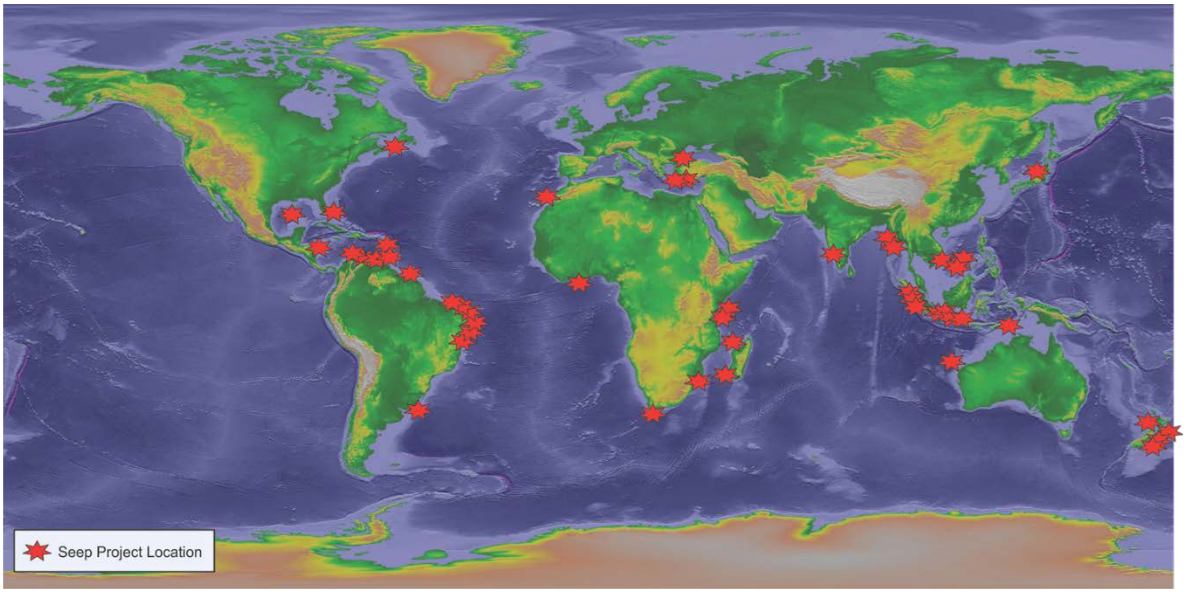

Figure 5 Seep hunting projects

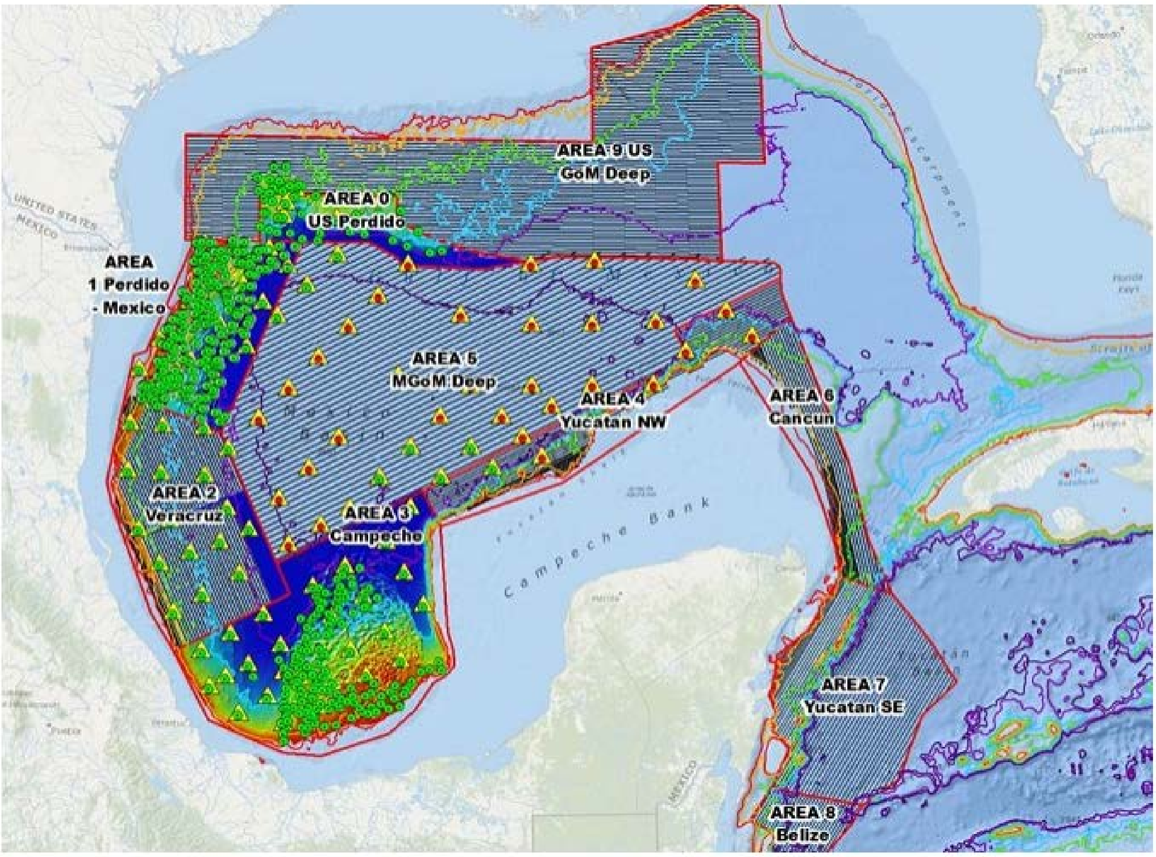

Figure 6 – TGS Gigante 2D: Multibeam, seep and core project

REFERENCES

Books:

Lurton, Xavier: *An Introduction to underwater acoustic*. Springer, UK, 2002.

Journal articles:

Keir Colbo a, Tetjana Ross a, Craig Brown b, Tom Weber : A review of oceanographic applications of water column data from multibeam echosounders. Estuarine, Coastal and Shelf Science, 145, 41-56, 2014.

Mayer, Larry A: Frontiers in Seafloor Mapping and Visualization, Marine Geophysical Researches, 27(1), 7-17, March 2006.

Thomas C. Weber1, Larry Mayer1, Kevin Jerram1, Jonathan Beaudoin1, Yuri Rzhanov1,and Dave Lovalvo2: Acoustic estimates of methane gas flux from the seabed in a 6000 km2 region in the Northern Gulf of Mexico, AGU, 1911-1923, 2014.

Aneta Nikolovska, Heiko Sahling, and Gerhard Bohrmann: Hydroacoustic methodology for detection, localization, and quantification of gas bubbles rising from the seafloor at gas seeps from the eastern Black Sea. AGU and the Geochemical Society, 9 n.10, October 2008.

Dan McConnell, Jamshid Gharib, Jennifer Henderson , Hunter-West Anderson, Danque and Adrian Digby , AOA Geophysics, Inc.; Dan Orange , Black Gold Energy: Seep-hunting in deepwater for frontier basin prospectivity assessment. World Oil Magazine, 229 n.4, April 2008.

Kostylev, V. E., R. C. Courtney, G. Robert, and B. J. Todd. Stock evaluation of giant scallop (Placopecten magellanicus) using high-resolution acoustics for seabed mapping. Fish. Res. 60:479-492, 2003.

K. Wyllie, Weber, T. C., and Armstrong, A. A., “A Review of Wreck Least Depths”, U.S. Hydrographic Conference 2015. National Harbor, MD, 2015

Links:

http://www.fugro.com/our-expertise/our-services/geoconsultancy/exploration-activities-offshore, last accessed on Sept 30, 2016

http://www.fugro.com/media-centre/fugro-world/article/worlds-largest-offshore-seep-hunting-survey, last accessed on Sept 30, 2016.

http://web.tgs.com/cn/agvfw/Gigante, last accessed on Oct 31, 2016.

BIOGRAPHICAL NOTES

Marco Filippone is an IHO Cat. A Project Manager at Fugro OSAE GmbH. He is a hydrographer with degrees from the Naval Academy Pisa University and Genoa University specializing in marine and nautical science first and marine geomatics. As IHO Cat. A surveyor he is involved in large area seafloor mapping with high resolution standards (IHO standars).

Garrett Mitchell is a geoscientist for Fugro Marine GeoServices Inc. in Houston, Texas and works on offshore oil and gas exploration projects that involve the integration of geophysical, geological, and geochemical data to evaluate deep-water offshore frontier basins for hydrocarbon seepage. His background is in marine geology, geophysics, and geography.

CONTACTS

Marco Filippone
Fugro OSAE GmbH / PhD student 3rd year System engineering Genoa University
Am Lehester Deich 24
Bremen
Deutschland
Tel. +491724610722
Email: m.filippone@fugro.com
Website: www.fugro.com