[GC]Integration of Multibeam Bathymetry and Backscatter Data with 2-D Seismic Data*

Satinder Chopra[1], Ritesh Kumar Sharma[1], and Jim Howell[1]

Search and Discovery Article #42376 (2019)
Posted June 10, 2019

*Adapted from the Geophysical Corner column, prepared by the authors, in AAPG Explorer, May, 2019. Editor of Geophysical Corner is Satinder Chopra (schopra@arcis.com). Managing Editor of AAPG Explorer is Brian Ervin. AAPG © 2019. DOI:10.1306/42376Chopra2019

[1]TGS, Calgary, Canada (schopra@arcis.com)

General Statement

The Gulf of Mexico is one of the most prolific oil and gas basins in the world. Understandably, the region is also home to many deeply buried mature source rocks and migration pathways to the surface, which result in petroleum seepage on the seafloor. Seeps occur as gases, liquids, asphalts and tars. These variable mixtures of hydrocarbons generally seep under low pressure and slow rates of release and are altered by chemical processes that happen on the seafloor. Consequently, as seafloor seepage takes place, both the biological and chemical properties of the sediments around the leakage area are altered. As chemically-reduced fluids rise from subsurface depths, they encounter sulphate-rich oxygenating fluids near the seafloor. The ensuing chemical reactions lead to the precipitation of minerals – for example, carbonate precipitates form crystals, nodules and cemented sediments over sedimentary veins and fissures – and this tends to reduce the seepage. The emerging mineral-rich fluids invite microbes, mollusks and clams to feed on them, and these communities located around the seep locations form hard surfaces and appear to be different from the surrounding seafloor. Such hard surfaces are acoustically reflective and thus are detected by the technology available today. It does not have to be a high level of oil seepage from an offshore oilfield to be detected. Active and inactive hydrocarbon seeps on the seafloor can be detected with the technology available today.

Seafloor mounds are commonly seen in the Gulf of Mexico and other petroleum-producing basins where seeps occur. These may be associated with authigenic carbonate, or gas hydrate or mud volcano or pockmarks. Authigenic carbonate mounds are formed where hydrocarbon gas rapidly rises from the sea surface and forms hydrate mounds at those locations. When such fluids temporarily occupy and accumulate in shallow porous sediments, and due to some trigger mechanism rapidly migrate to the seafloor along vertical conduits, they yield mud volcanoes and pockmarks. Many of the abovementioned hydrocarbon fluid seepage processes may be ephemeral across time scales, but the geochemical and biological signals persist within the sediments. When sampled, they exhibit their geochemical constituents as well as indications about their commercial viability.

Bathymetry and Multibeam Backscatter Surveys

Multibeam bathymetry and backscatter surveys provide a comprehensive view of the seafloor in a cost-effective and efficient way, and complement the traditional tools such as seismic, gravity and magnetics. In multibeam backscatter surveys, an array of transmitters is mounted parallel to a ship's keel, which transmits a fan-shaped beam of acoustic energy that would be narrow in the direction of movement of the ship. A similar receiver array, perpendicular to the ship's keel, listens for the reflected energy from a narrow acoustic window parallel to the ship's keel. The intersection of these two narrow fans represents one beam of acoustic energy (Figure 1). This way, the receiver array can detect the incoming acoustic return energy for each transmitted pulse. Hence the technique is referred to as "multibeam echo sounder," in which hundreds of narrow beams (1 degree or less) are spread over a 150-degree swath or more. Survey speeds of around 20 kilometers per hour, water depths of up to 4 kilometers or so, and a daily coverage of 1,000 square kilometers or more are common in such operations.

In Figure 2, we show the multibeam scatter displays at three different locations on the seafloor. High backscatter anomalies are seen in red in Figure 2a and Figure 2b, while an ellipse of high backscatter anomalies surrounds a low backscatter anomaly in blue in Figure 2c. Core samples were retrieved from the indicated locations and tar sediments were noticed in sample 1, hard black tar fragments were recovered in sample 2, and 22 centimeters of black tar was recovered in sample 3. It is anticipated that the tar at this location is softer and is perhaps pooling at the surface, hence exhibiting a low backscatter. Such an observation was made at another location not far from this sample point, where a 67-centimeter sample of sticky black tar was retrieved from a low backscatter location. We will refer back to these samples in the next section.

As evidenced by these displays, the present-day technology implementation with quality navigation and pitch-rolling-heading sensors allows the acquisition of high resolution multibeam surveys. Such surveys provide a comprehensive display of the seafloor and help evaluate geohazards and can identify potential natural hydrocarbon seeps, which can be sampled to provide information on hydrocarbon systems.

The geoscientists on board the acquisition vessel, as they go through the quality control of the multibeam echo sounder records, make judgment calls about pockets from which piston-cores are to be retrieved. To accurately pinpoint the target locations, use is made of the ultra-that guides the piston cores to their targets. As the piston is lowered in the water column, its position is continuously tracked by the survey computer, and geoscientists can track the position and see if it is being lowered on target. If the piston-core is outside of the target when it is 50 meters above the seafloor, the vessel maneuvers make the necessary adjustments to ensure it is lowered on the target.

In Figure 3 we show an example display of how this is done. The entry point for the core is at a depth of 1,387 meters. The piston core history is shown by the colored tracks, with the black and white color exhibiting the older tracks and the green color its position before entry into the seafloor.

Geochemical Analysis

Once the core is recovered from the seafloor, it is visually inspected for evidence of hydrocarbon seepage. Key positions of the cores can be selected for geochemical analyses, which provide insights into the petroleum system about source maturity, source rock and thermal history.

Unaltered oil seeps are characterized by long-chained n-alkanes (C12+) and isoprenoids (C13-C20) including pristane (C19) and phytane (C20). Straight-chain aliphatics are more susceptible to oxidation than branched-chain and cycloalkanes. Higher molecular compounds are often preserved. Such changes result in residual or as unresolved complex mixture of compounds in gas chromatographic analysis. Gas chromatography of C1-C5 and total scanning fluorescence for aromatic hydrocarbons is carried out on core samples. Those samples that exhibit evidence of thermogenic hydrocarbons are put through additional chemical analysis by way of C15+, isotope compositions and biomarkers.

Even though the presence of seeps in an area might not be a deciding factor on where hydrocarbon is present in commercial quantities, this information is significant for an explorationist, as it could be correlated with the available geologic parameters.

Attempts at Integration

Integration of multibeam bathymetry and backscatter data as well as 2-D surface seismic data can help us understand the processes active in a marine basin and potential hydrocarbon seeps if any are in the area. Sampling piston cores from selected locations from zones of potential hydrocarbon seepage as interpreted on backscattered data, as well as their subsampling in terms of geochemical analysis, can significantly impact exploration. The source, migration and maturity of hydrocarbons can also be understood.

In 2015-2016, a regional multiclient 2-D seismic (188,497 kilometers; grid in Figure 3) as well as multibeam echo sounding and coring program were acquired by TGS in the Gulf of Mexico with the objective of seafloor bathymetry analysis, its acoustic reflectivity, shallow subsurface features to identify hydrocarbon seep features on the seafloor and throughout the water column. The seismic survey was acquired using five vessels (and included gravity and magnetic data) with offsets up to 12 kilometers. Separate vessels were used to cover an area of 622,857 square kilometers with multibeam for bathymetry and backscatter over the prospective Perdido Fold Belt as well as the Campeche Bay trends. Other related information includes water depth variation between 750 and 4,000 meters, core targets were selected using multibeam, gas plumes, seismic data, synthetic aperture radar and historic data, and 906 surface geochemical exploration cores were retrieved for analysis.

As an attempt to understand if any seismic signature could be associated with the anomalies seen on the backscatter displays for core samples at locations 1, 2 and 3 (Figure 4), two seismic lines AA’ and BB’ were picked up for processing and subsequent attribute analysis.

The two lines were processed by carrying out amplitude-friendly processing and then put through AVO attribute analysis based on Fatti’s approximation to the Zoeppritz equations. The P- and S-reflectivities are the resultant attributes from this analysis, which are then used together to generate the fluid factor attribute (FF ~ R_P - k$R_{S'}$ where k is a scalar). The fluid stack yields a negative amplitude in the presence of hydrocarbon, or a blue over red on the displays, where blue is negative and red is positive. In Figure 5, we show fluid stack sections for lines AA’ and BB’, where the expected signature is seen at the location of the core samples as highlighted, and in some other locations as well. Though a more prominent blue is seen at the location of sample 1, and just below the seafloor, somewhat less pronounced blue is seen at location 2. Perhaps the reason for this is that the lighter hydrocarbon components are not present anymore on the seafloor at that location, but could be preserved in the lower sections.

We carry this exercise forward in that prestack simultaneous impedance inversion was run on the input seismic data (time window indicated on the display) and examined for further analysis. In Figure 6a, we show a crossplot between P-impedance and VP/VS, and back-project the cluster of points exhibiting lower values of both attributes. Following the basics of rock physics templates, corresponding to anomalous points on the crossplot, two polygons in green and orange have been used for the purpose, and their back-projections on the vertical section (Figure 6b) indicate pockets that could be prospective. Many locations close to the water-bottom also show the orange color.

Conclusion

In conclusion, compared with the other available methods, multibeam echo sounder surveys offer an economically beneficial method for hydrocarbon exploration. Integration of multibeam backscatter surveys along with the core samples and their detailed geochemical analysis with seismic data can provide important structural and stratigraphic interpretation.

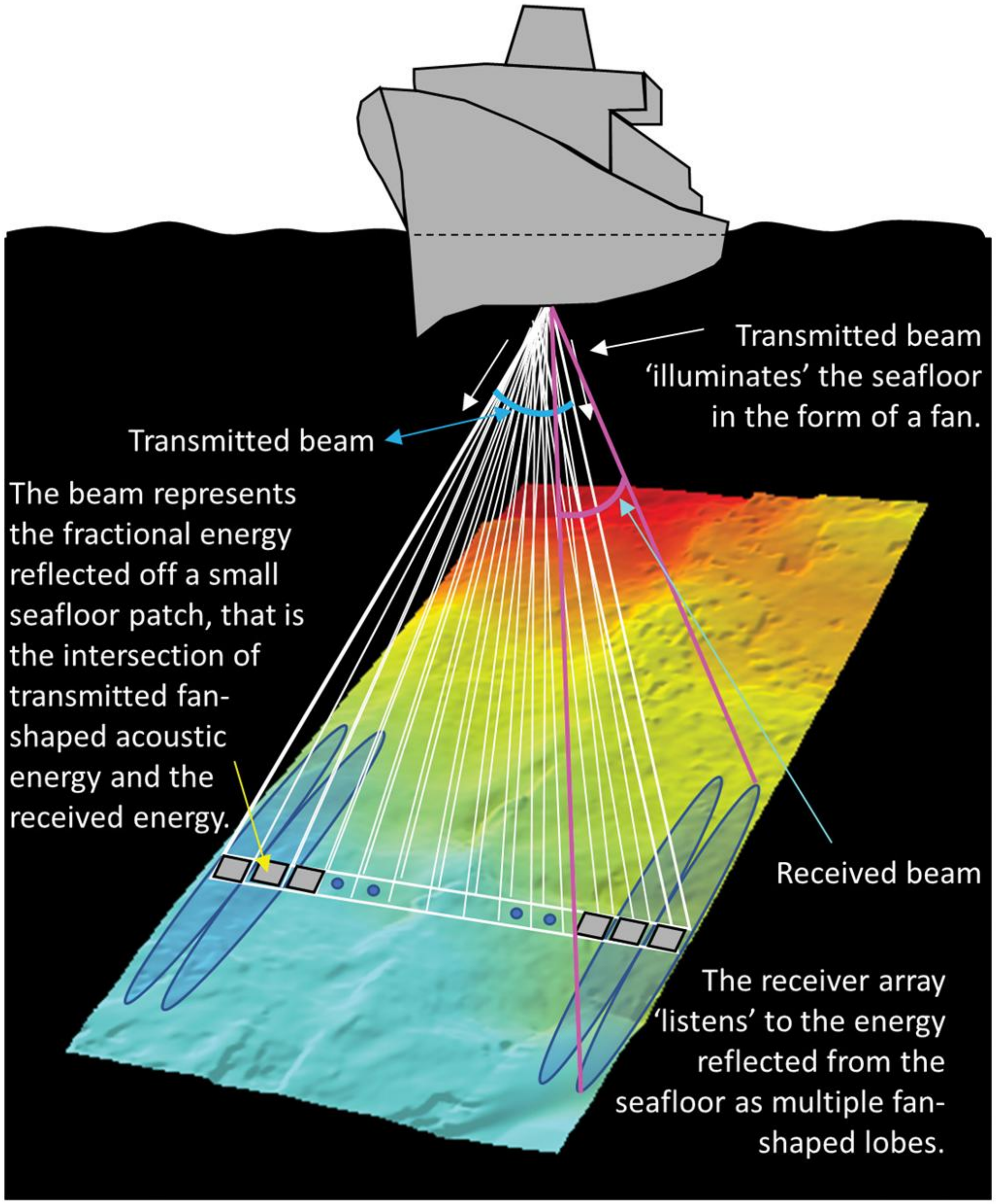

Figure 1. Diagram showing the geometry of multibeam backscatter data acquisition. The location of each beam on the seafloor is calculated from knowledge of the location, the orientation and position of the transmission array at the time of transmission, the orientation and position of the receiver array when the energy returns, the two-way travel time, and the correction for refraction of energy in the water column.

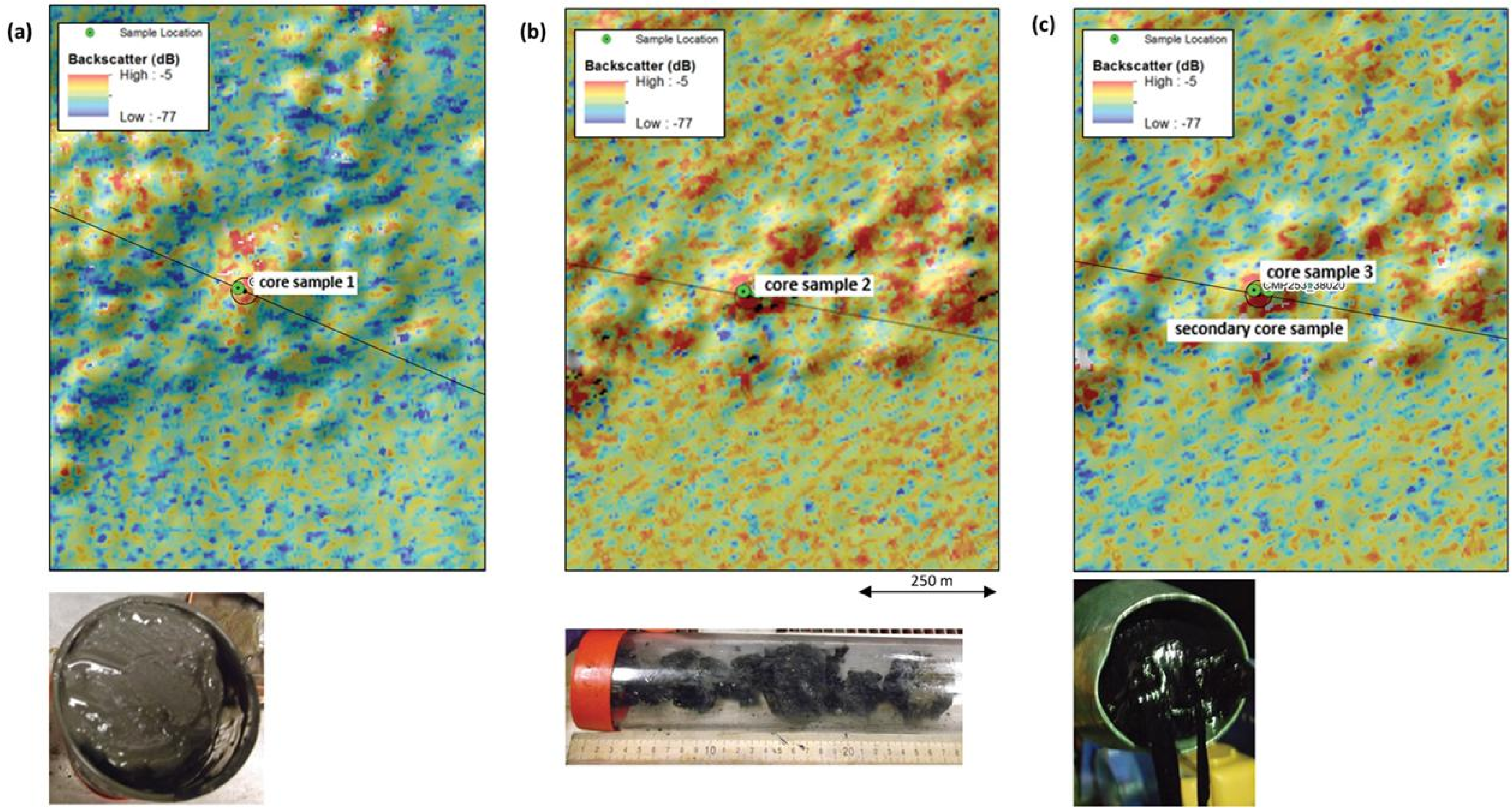

Figure 2. Backscatter displays at the location of core samples and their description. Data courtesy of TGS, Houston. (a) Large area of "popcorn" texture; location targets largest single mount with highest backscatter anomaly. Core is generally soft greenish-gray clay with no forams present and moderate cohesion and water content. Tar sediments on the top section with faint H_2S odor. (b) Large area of "popcorn" texture with high backscatter; location targets a mound (145-meter diameter) with high backscatter anomaly. (c) Unusual elliptical area of very low backscatter rimmed by high backscatter. Recovered 22-centimeters of black tar. Hydrocarbons present; classified as oil seep from Upper Jurassic marine carbonate.

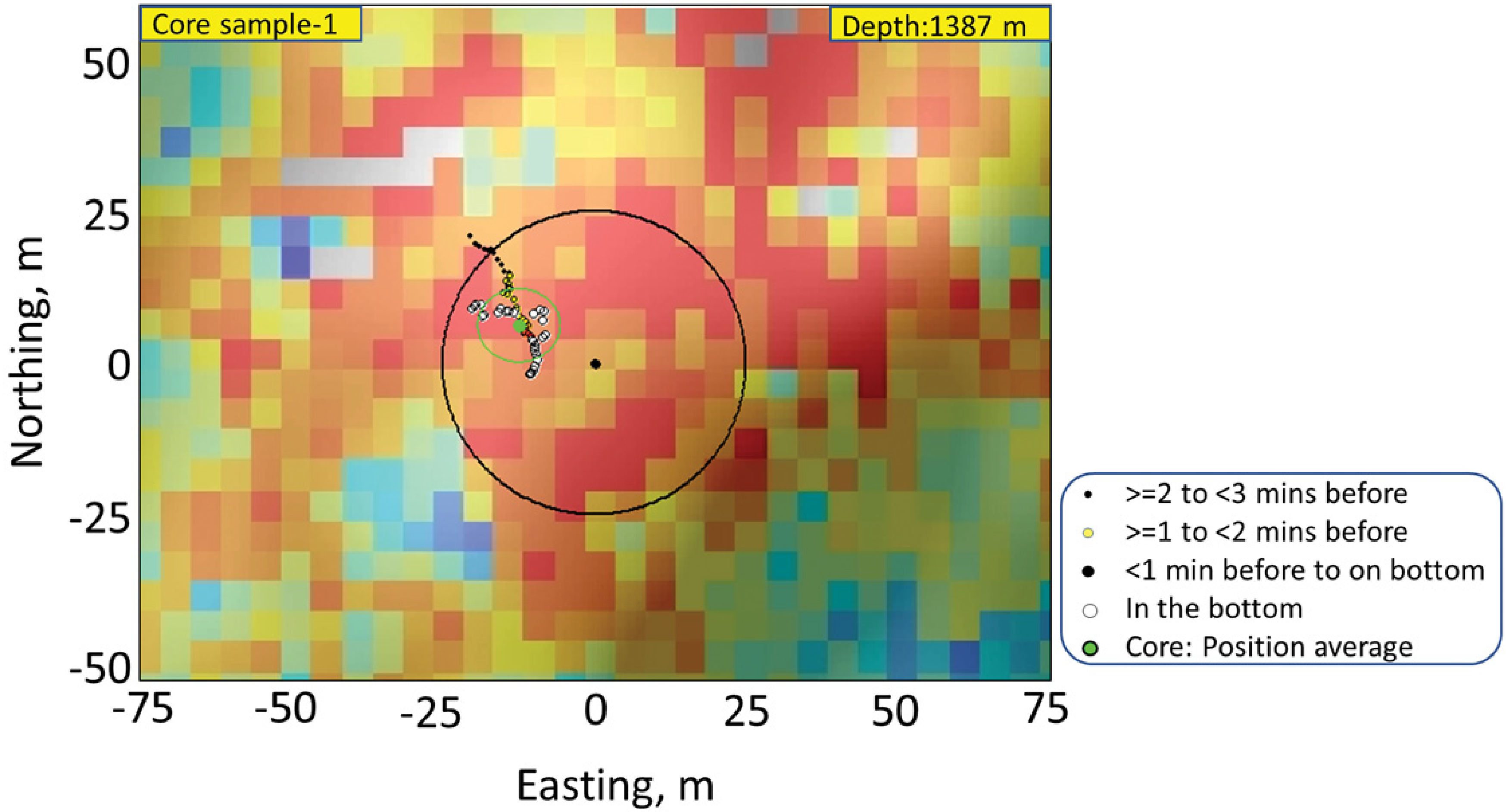

Figure 3. Tracking of the piston-core through the water column. The piston-core is equipped with an ultra-short baseline (USBL) positioning beacon, which can help track the core in three dimensions through the water columns as it is being lowered to the seafloor target. Data courtesy of TGS, Houston.

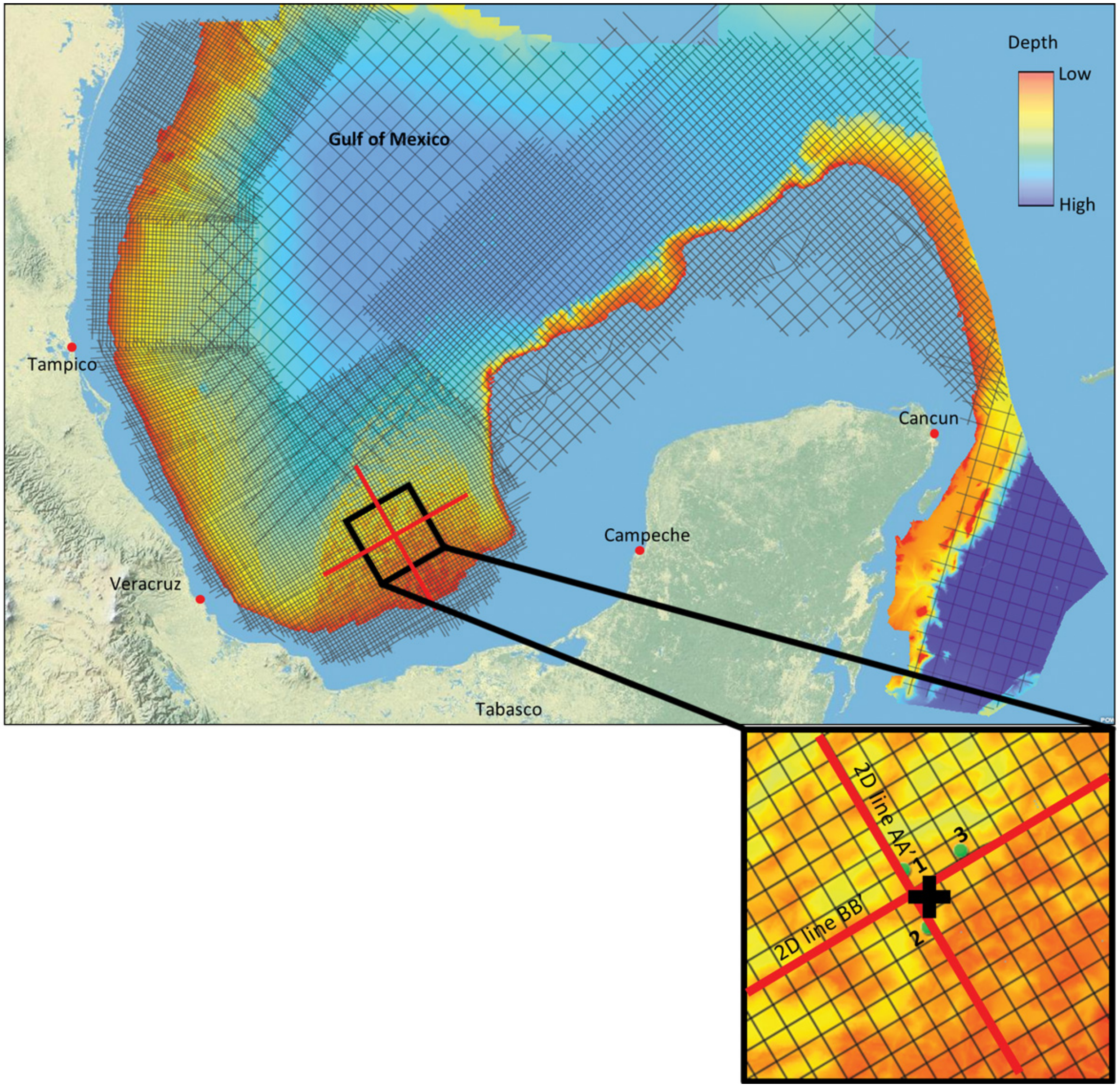

Figure 4. Location map for the Mexican Gulf of Mexico, showing both the acquired regional bathymetry and 2-D seismic datasets. Two of the lines marked in red were used in the present study. The black square shows the test area where three core samples and one well (marked with a black cross) were available.

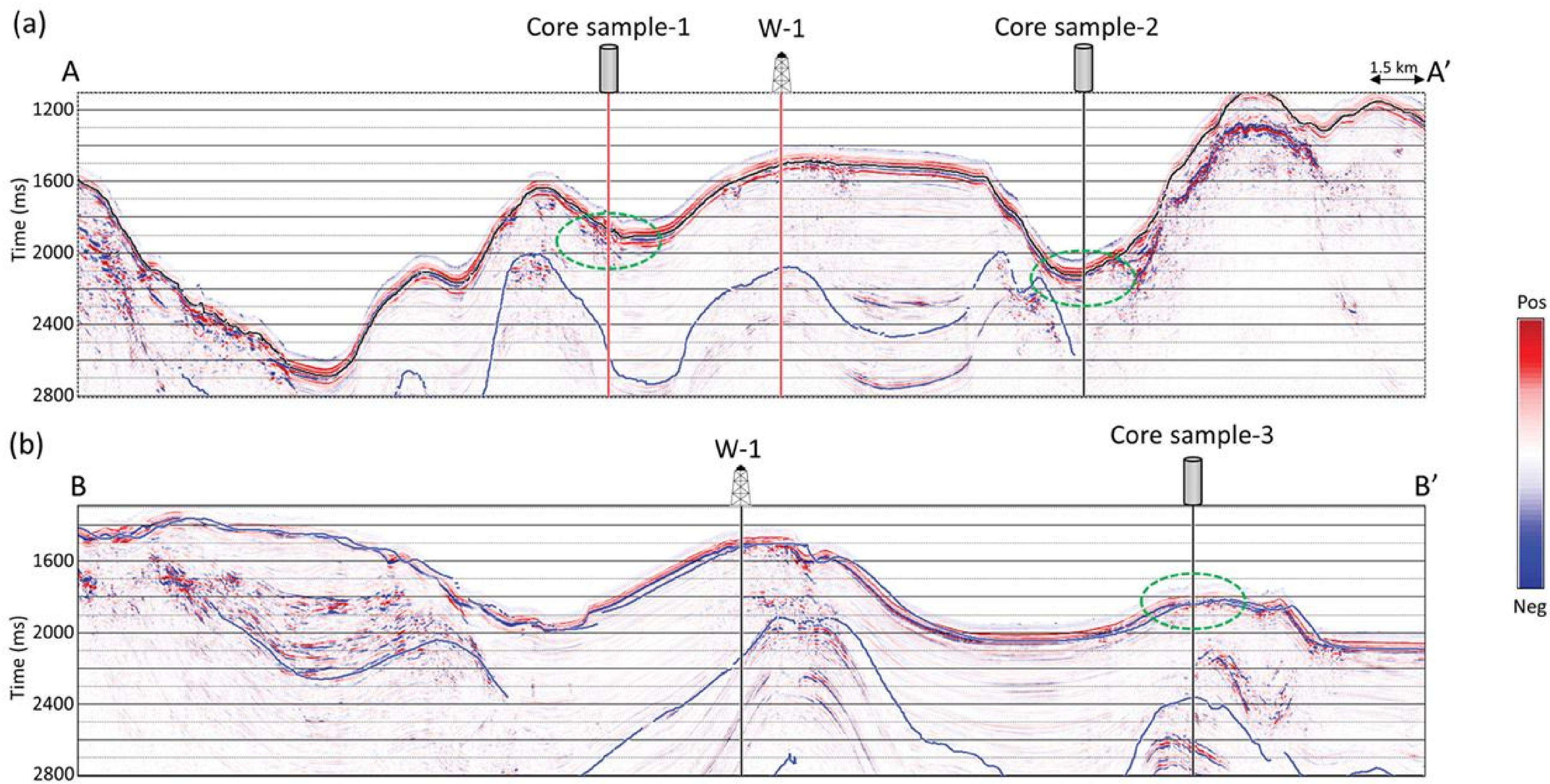

Figure 5. Fluid factor attribute along seismic lines AA’ and BB’ passing through well W-1. The location of the available core samples along the lines is shown. While core sample-1 falls on the line, core sample-2 is projected about 1.2 kilometers. Similarly, core sample 3 is projected 1.65 kilometers. Data courtesy of TGS, Houston.

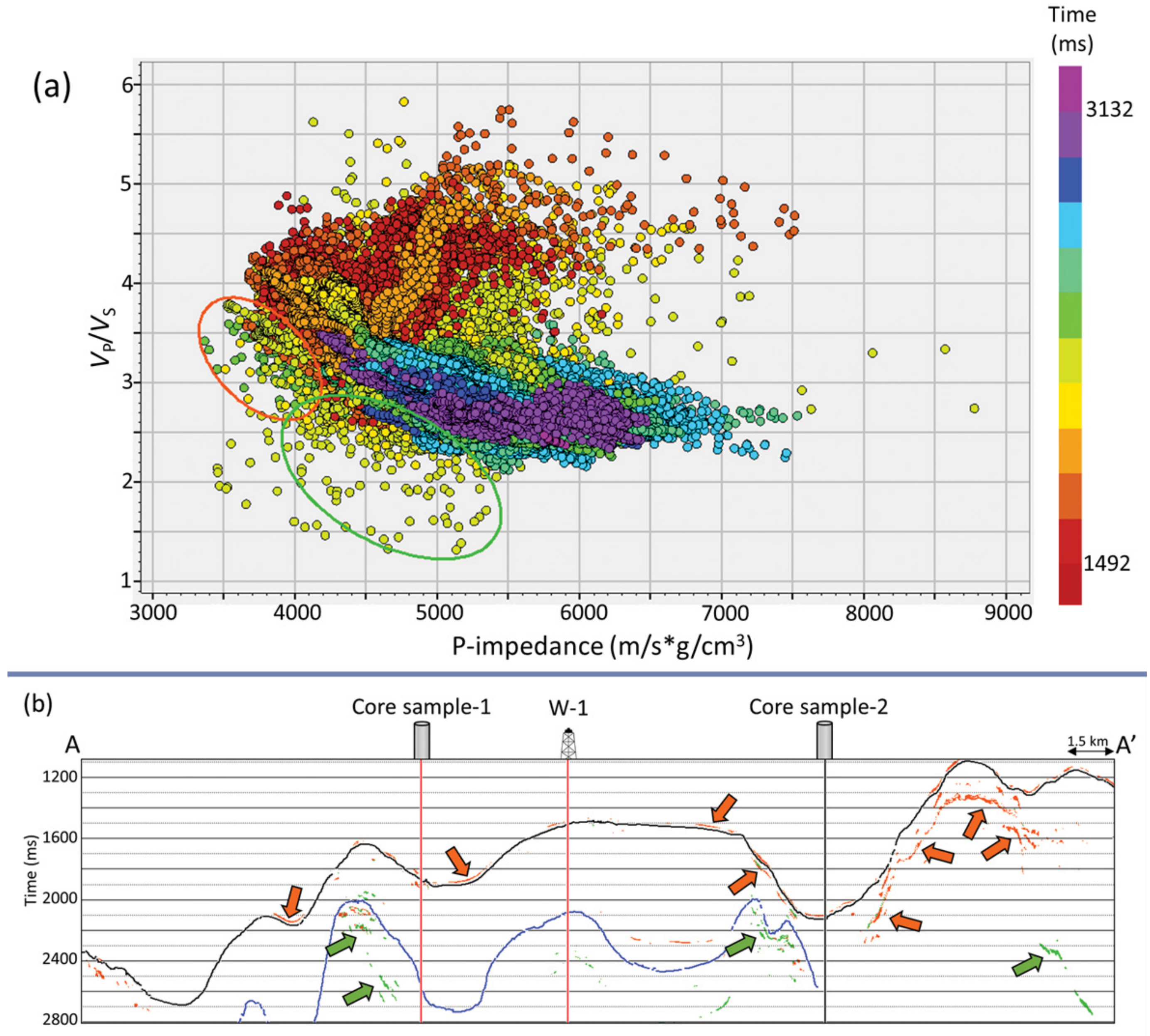

Figure 6. Crossplot of P-impedance versus V_p/V_s attributes. Cluster points with lower values of P-impedance and V_p/V_s could be associated with hydrocarbons; these cluster points are enclosed in the orange and green ellipses and back-projected on the vertical section AA' shown in (b). The block arrows indicate the location of prospective pockets. Data courtesy of TGS, Houston.