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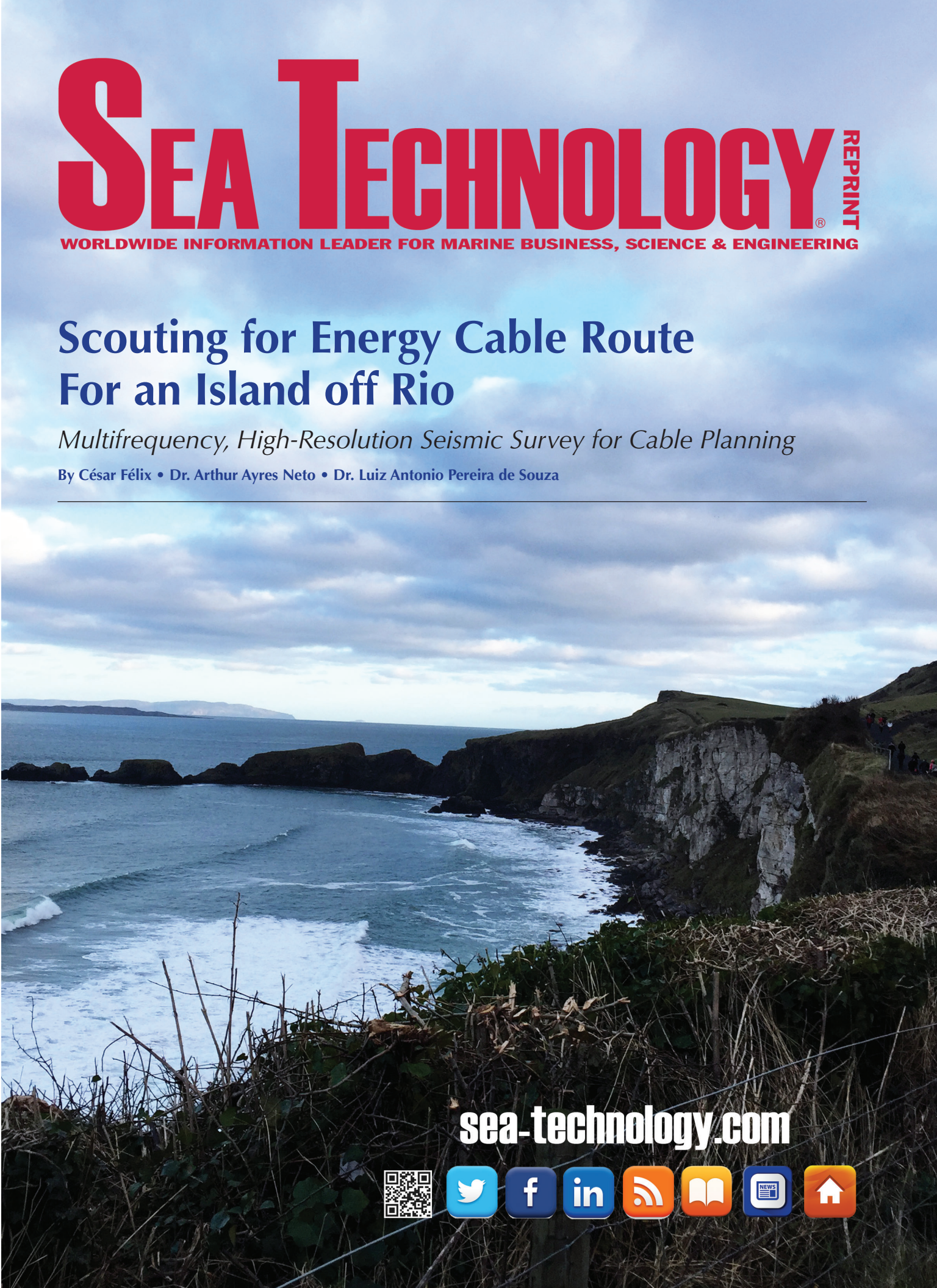

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One of the most effective methods of protecting submarine energy and telecommunication cables from damage caused by other seabed users is to bury them on the seafloor. However, the success of this burial is strongly dependent on proper planning and the seabed geology along the cable route.

Route surveys for cable-laying projects are conducted with a suite of three basic systems: multibeam echosounders (for morphological mapping); side scan sonar (for definition of superficial sediment distribution and location of other cables or pipelines, shipwrecks, anchors and man-made debris of significant dimension); and high-resolution seismic (for investigations below the seafloor, including shallow gas and rocky basement). Magnetometers may play an important role in these projects. Additionally, geological cores for geotechnical testing and correlation with geophysical attributes may be collected.

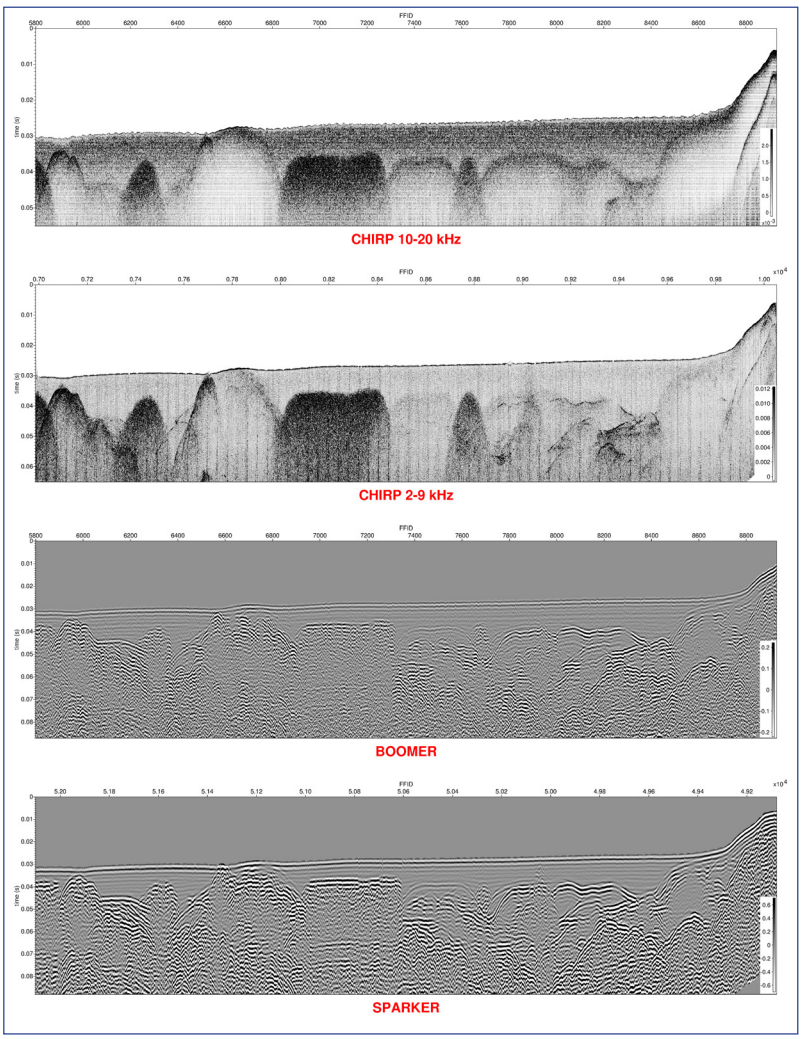
We used a geophysical approach based on multifrequency, high-resolution seismic survey for the installation of an energy cable in a relatively small area on the southeast coast of Rio de Janeiro, Brazil. The area is environmentally sensitive and is a site for fishing and tourism, with intense boat traffic. There are also two important harbors receiving very large bulk carriers and oil tankers.

Site and Project Background

Ilha Grande is the biggest island along the coast of the state of Rio de Janeiro. It has approximately 3,000 inhabitants, schools, hospitals, a fire department and a police station. The economy is based on fishing and tourism, with more than 300 hotels and restaurants located on the island.

The island's power supply relies on a connection made by a system of cables first installed in the 1980s. Today there are four cables: only one of them is in service (IS), and three are out of service (OOS). Their positions were unknown; plus, fragments of cables existed due to maintenance carried out through the years.

With the increasing energy demand and the need for



Examples of the multifrequency, single-channel seismic survey method.

modern fiber-optic communications, Lestcon Engenharia, a Brazilian company specializing in submarine construction, was assigned to build and trench a new cable between the island and the mainland. The proposed route position list (RPL) comprises a 4.7-km-long, 300-m-wide corridor with a maximum water depth of 35 m.

The objective of the survey was to map the seabed in order to define the detailed route of the cable, avoiding rock outcrops and subcrops (presence of rock within the burial target depth), debris and the existing cables in the corridor.

Survey Methodology

A Kongsberg GeoAcoustics 250-kHz interferometer was employed to acquire bathymetric data and detect seabed texture changes through backscatter analysis. Backscatter was also used to correct OOS positions mapped with the side scan sonar (SSS), once a pole-mounted interferometer had better position accuracy compared to SSS layback. SSS data were acquired with an EdgeTech 4125 sonar operating with 400 and 900 kHz at 75-m range.

A single-pass multifrequency (MF) high-resolution seismic signal was obtained by simultaneously operating a 10- to 20-kHz chirp, 2- to 8-kHz chirp and a 75-J boomer system. A 75-J sparker was acquired only in the centerline along the proposed RPL. The dual-frequency chirp sub-bottom profiler is manufactured by Oy Meridata Finland Ltd., and the boomer, sparker and hydrophone are manufactured by SIG. The post-lay survey was conducted with a Kongsberg GeoPulse sub-bottom profiler with a central frequency of 3.5 kHz and a Teledyne Odom Hydrographic M1 multibeam system.

The seismic systems were integrated using Meridata MDCS data acquisition software, which relies on intelligent trigger management employing advanced temporal and spectral multiplexing techniques to enable single-pass operations using multiple sound sources at the same time, without interfering crosstalk between the different acoustic subsystems.

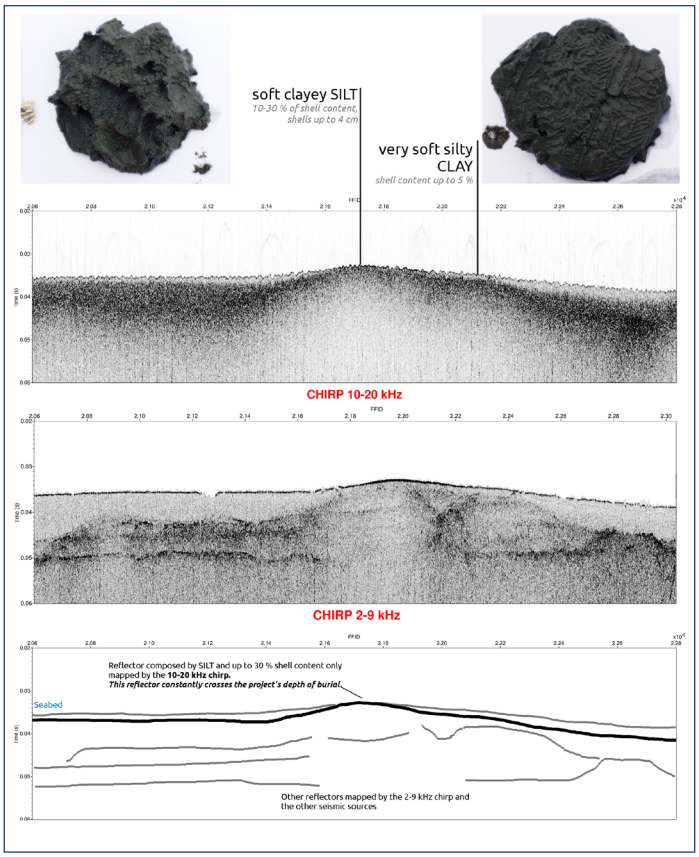
All culture, vector and processed data were loaded into IHS Kingdom Software for interpretation. Seismic data were processed with the Seismic Unix package.

Results

The interferometric bathymetry and side scan data have covered 100 percent of the survey corridor, allowing not only mapping of the seabed morphology with a digital elevation model (DEM), but also showing route obstructions and providing a reliable seabed composition assessment through the backscatter intensity values.

Seabed composition could be inferred by the comparison of sonographic reflection patterns with five grab samples. In some cases, because of sediment similarities, the contact between different types of seabed was not well defined either by interferometer backscatter or side scan acoustic images. These differences must be considered and charted for cable installation because of the methods of cable burial (jetting and trenching).

The SSS data were also used to identify debris, such as a disposal area and an 8-m metal pipe, and areas where seabed scars are evident. These scars indicate trawling fishing gear, which must be considered when planning the cable route.



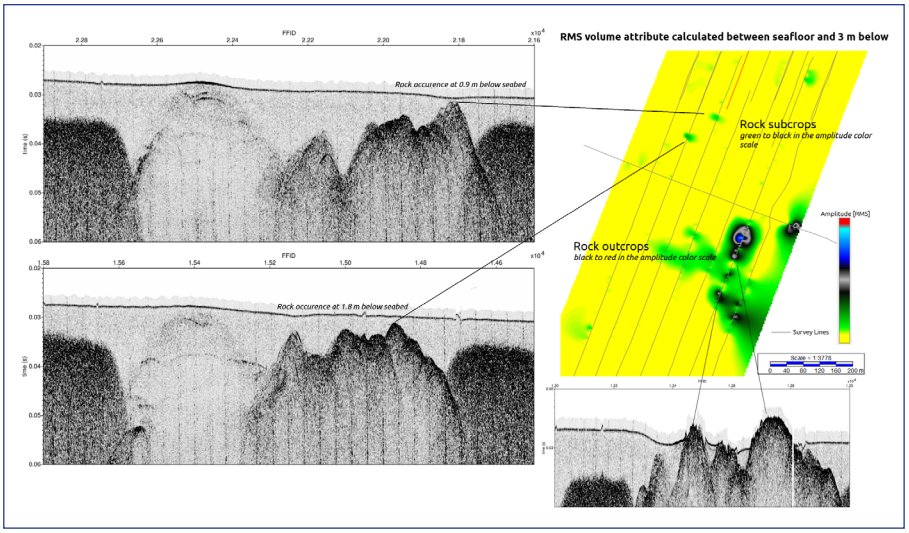
Slight distinction in soil composition detected by the high-frequency chirp.

The sonograms also made it possible to map previously laid cables at the route corridor and provided an idea of the present conditions of these cables. The four previously laid cables, three OOS and one IS, were placed on the seabed without any burial or seabed assessment and were found gathered by one side of the route corridor, commonly passing above rock outcrops, which very likely is the source of some of the cable faults throughout the years. Also, some pieces of cable could be linked directly to seabed scars, indicating that the effects of fishing on cable must be considered.

The general recommendation is to perform clearance of OOS cables in burial areas prior to the cable lay operation. All of the OOS cables inside the burial sections should be located and cut before the plowing and trenching operations. However, the difficulty in this case is that due to the lack of proper planning and installation of the previous cables, one cannot tell which cable is the IS with only this survey approach.

The key benefits of performing a multifrequency seismic survey for cable installation is that sub-bottom geological features can be defined in different scales. As a common practice in the industry, only one seismic system is required for route surveys, most commonly utilizing one operating system with a lower frequency range able to provide penetration in sandy sediments. This is normally an impulsive system like a boomer or sparker, which has a frequency spectrum initiating below 2 kHz with lower levels of resolution (typically around 30 to 50 centimeters).

For a cable burial of 1 to 1.5 m, it is important to recognize geological layers by the decimeter level. Employing this



Example of the seismic attribute RMS calculated within the seafloor and the project's depth of burial limit identifying subcropping rock.

method, one can investigate thicker layers and the occurrence of rock subcrops. In this project, two high-frequency chirp systems (2 to 8 kHz and 10 to 20 kHz) were employed to provide nominal resolution of less than 10 cm. This made it possible to resolve very thin superficial layers, with low impedance contrast, as well as boundaries between distinct sediments on the seabed, which were not clear on the backscatter and side scan mosaics.

The multifrequency seismic data also showed that errors in the interpretation of exposed structures could be avoided. For example, the 900-kHz side scan mosaic and chirp data revealed an obstruction defined by a very rugged and high-amplitude object that could be easily mistaken for a rock outcrop. However, when analyzing the boomer or sparker sections, it was possible to see that the rocky baseline was much deeper below the seafloor, indicating that it was not a rock outcrop.

The opposite situation was also observed. While boomer and sparker data showed a homogenous superficial layer up to 2-m thick, the chirp data were able to identify that part of the area was covered by a thin muddy layer, with low impedance contrast relative to the layer below, but with consistent differences in its composition (mud and bioclastic mud, respectively), with implications for the trenching process. The higher resolution data also helped evaluate the exact position of the rocky basement when it was too close to the seafloor (with an uncertainty of 50 cm). This minimized changes on the planned route and helped to define in which places the trenching could be done without reaching the project's burial depth.

Conclusion

Nowadays, shallow, high-resolution 3D seismic surveys are on their way to becoming a major practice in subsea engineering projects. This means that projects put more resources into geophysical survey in order to have a full, detailed geologic model of the interest area. In addition, these surveys reduce the financial resources to be spent on geotechnical surveys, which are much more expensive.

In cable route surveys where engineers must have precise information about the shallow sub-bottom geology, the single-frequency approach is not ideal. With multifrequency, high-resolution 3D surveys, the combination of the information given by each system's different frequencies can lead to better interpretation of the seafloor for better planning.

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