

Black Sea: Offshore Challenges & Solutions

The Black Sea

Unlike most offshore oil plays, the Black Sea provides an unique array of environmental conditions. These features include an anoxic environment below 200 meters, high concentrations of sulfate reducing bacteria (SRBs), methane vents, and geological instabilities. These conditions create diverse challenges to subsea equipment and pipelines that are unique within the offshore oil and gas basins of the world.

As the number of projects in the Black Sea increase, the chances of these problems impacting field design and operation will become higher. However, to date there is limited empirical evidence on which to base solutions on because it is only recently that exploration and development interest in the Black Sea has increased. This GATEKEEPER will discuss the problems and challenges that arise from this distinct environment and the respective solutions and best practices that must be considered in order to safely and effectively deal with them.

Geological Instabilities

There are multiple factors in the Black sea that create sediment or geological instabilities that must be considered when constructing subsea architecture. These features include a soft sediment basin, methane vents, tectonically active fault lines, and methane hydrates.

To begin with, hydrates are fairly common on the Black Sea floor. However, the presence of these hydrates creates an unstable sea floor where massive rapid sediment transportation can occur. [1] When selecting installation sites for wellheads and subsea infrastructure, it is necessary to not only examine the immediate area for hydrate accumulations, but much further out as well. Hydrates that destabilize may create sediment movement for hundreds of meters around the main deposit.

Produced gas from methane vents can also be stored underneath the hydrate deposits. Hence, any change in hydrate stability has the potential to result in large gas releases. Figure 1 shows the abundance of vents currently discovered in the Black Sea, with the likelihood being that there are still many more yet undiscovered. [2] The figure also provides topographical information which highlights the steep slopes that contribute to the instability. The distribution of vents shows they are focused in areas of large topography changes, further increasing the likelihood of sediment flows.

Earthquakes pose another destabilizing threat. Figure 2 shows the tectonic elements of the Black Sea. On average, the Black Sea experiences one earthquake a year. These earthquakes are generally in the northern and eastern areas of the sea. [3] [4] Earthquakes can cause rapid sediment movement and bury equipment and pipelines. Equipment burial also reduces the effectiveness of cathodic protection systems by lowering potentials and electrochemical capacity, which increases the necessary anode mass needed to achieve whole-life protection.

The most widely reported Black Sea deepwater project, and used as an example throughout this article, is the Blue Stream pipeline by Gazprom. This pipeline extends though the western part of the Black Sea and has encountered many of the listed issues. No published information is available on how Gazprom mitigated sediment instability, but it is known that they had to drill into the mountainside at the shore approach to provide a more gradual gradient for the pipe due to the highly sloping nature of the western area of the Black Sea.

Currently, there are no immediate solutions to preventing rapid sediment movement, so companies must use due diligence to minimize the risk. Mapping areas for equipment laydown to identify soft sediment or possible destabilizing geological features is paramount. Similarly, methane vents can be detected using sonar and acoustic devices. These can help to quickly identify areas of concern so that they can be avoided. [5] From an engineering perspective, standard practice includes the use of over-size mud mats to help reduce movement and burial, even where known seafloor vents and instabilities have been avoided.

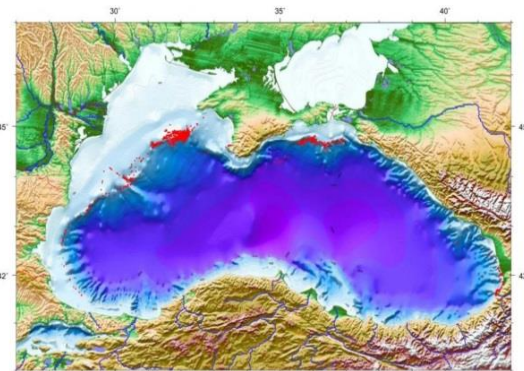


Figure 1: Distribution of Methane Seeps (Red Spots) in the Black Sea



Figure 2: Map with Tectonic Elements of the Black Sea Area

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Subsea infrastructure also needs to be designed to include some inherent motion tolerance and be subject to robust survey and span remediation programs.

Anoxic Environment

The Black Sea at depths greater than 150 to 200 meters (500 to 650 feet) is devoid of oxygen and complex life. This accounts for over 75% of the entire Black Sea, making it the largest anoxic water basin in the world.

This anoxic environment is created because there is no vertical current in the Black Sea. Without vertical current there is no means for appreciable oxygen levels to penetrate below 200 meters. [5]

This lack of oxygen has the potential to be particularly problematic in the transition zones between the depleted and oxygenated layers. This difference will create an imbalance in oxygen concentrations that can lead to the formation of a differential aeration corrosion cell.

Corrosion will occur at areas of lower oxygen concentration. This imbalance will require an uneven amount of sacrificial anodes for pipelines and risers transitioning through this zone and create a need for additional anode mass beyond typically accepted standard practice. Additionally, literature has shown that an increased H₂S concentration in sediment can lead to severe localized corrosion and significantly reduced capacities of aluminum-based anodes. Similar work has also confirmed the poor performance of aluminum anodes and provided validation that zinc-based anodes are likely to be the best option under Black Sea conditions. [6]

To mitigate the risk of corrosion, sacrificial anodes are used in combination with protective coatings. This dual system should provide significant protection against the anoxic environment. Cathodic protection modeling should be implemented to ensure that corrosion does not occur.

Additionally, the coating system selected should be able to handle the various challenges faced, including the anoxic environment. Finally, careful attention should be made to the coating system's performance to account for high concentrations of SRB, which are known detrimental bacteria.

Sulfate Reducing Bacteria

The final distinctive feature associated with the Black Sea is the higher presence of SRB, hydrogen sulfide, and other sulfides. In the oil and gas sector, sulfides have generally only been an issue internally, arising from H₂S or SRB in the reservoir. Its presence externally is largely a new problem.

Sulfides are known to increase cracking risk, especially with welded areas. They also reduce the effectiveness of many coatings and increase cathodic protection requirements by modifying the

protection potential that the steel must be shifted to in order to achieve protection from corrosion.

The Blue Stream pipeline was constructed in 2005 and a sizeable amount of research was executed to determine the sulfide risks to the pipe and its welds. Measurements showed that the seawater contained up to 11 ppm and the soil up to 1,200 ppm of hydrogen sulfide. [7] Extensive testing was done on the pipe, welds, coatings, and cathodic protection system before construction commenced. The exact details of these tests and materials chosen are not public information. However, the Blue Stream pipeline has been in service since February of 2005 without major incident. The successful implementation and continued service of the Blue Stream pipeline has shown that the presence of SRB and sulfides in the Black Sea can be overcome, but companies must include these concerns in the design phase.

Conclusions

A combination of qualified materials, CP, and protective coatings is recommended to provide a long term, economical and robust protection system against external corrosion and hydrogen stress corrosion cracking in the Black Sea subsea environment.

Based on current data, carbon steel that complies with NACE MR0175/ISO 15156 sour-service standards is considered a fit for purpose material selection. Carbon steel that is sour-service compliant will be better prepared for the potential of sour service conditions due to the naturally occurring H₂S in the Black Sea. Based on the relative ease of demonstrating sour-service compliance, this is likely to limit pipeline steels to the X65 strength grade. Demonstrating and maintaining sour-service compliance can become significantly more onerous for strength grades of X70 and above.

Sacrificial anodes should be zinc-based, rather than the aluminum-based composition typically used for subsea projects elsewhere in the world. This is required due to the low oxygen content in the water and the presence of H₂S, both of which can interfere with aluminum anode performance. This is likely to result in a design that requires substantially more anode mass than equivalent structures elsewhere in the world. Furthermore, specific attention should be paid when designing the entire system. The environment surrounding the subsea architecture will vary significantly from the standard industry conditions that are assumed to apply elsewhere in the world and this will need to be accounted for to provide a fit for purpose CP system.

The conditions in the Black Sea are not anticipated to drive coating condition directly. However, the use of coatings with increased life and abrasion resistance provides a means to minimize anode mass in comparison to standard fusion-bonded epoxy (FBE) coatings or FBE with a concrete weight coating. This may require a shift to the use of coatings such as three-layer polypropylene instead of FBE, even for situations where insulation properties are not paramount for coating selection.

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