The Role of Geophysics in Offshore Geotechnical Site Characterizations in the Energy Transition Era: from Oil & Gas to Renewables

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Summary

Offshore geotechnical site characterizations aim to assess the engineering properties of shallow sediments/soils (around the top 400 ft below the seafloor) and to quantify their geospatial variability to ensure the safe, reliable, and economic design of offshore infrastructure. The current state-of-the-art workflows for offshore site characterizations rely heavily on geophysical and geotechnical (G&G) data integration. This integration essentially guides the planning and execution of geotechnical site investigations based on subsurface conformity and variability (Aubeny et al., 2013; Doyle, 1998; Jeanjean et al., 2006; Newlin, 2003). Without this integration, it would be difficult to optimize soil borings, determine seabed-founded structure locations, select in-situ testing locations, and it would be cost-prohibitive to conduct the otherwise necessary closely sampled geotechnical investigations over large areas. Therefore, the motivation of this abstract is to provide thoughts on further improvement of the quantitative G&G integration with a final goal of characterizing the geospatial variability near seafloor subsurface for the geotechnical engineering purpose. Brief introduction on the current challenges and opportunities for future improvements are provided.

Introduction

Even though both types of G&G data are collected digitally and integrated closely during offshore site characterization projects, the current practice for this G&G integration has largely been qualitative in nature, e.g., seismic images are well suited for identifying soil stratigraphical conformity and variability, but largely incapable of determining the geospatial variability of soil engineering properties (e.g., unit weight, soil strength). It has been challenging and requires multi-disciplinary teamwork to derive quantitative soil properties using geophysical data. In addition, in a typical offshore development cycle, it is challenging to balance project maturity with the lead time to acquire, process, interpret, and integrate G&G data, because the cost of G&G data can be over tens of millions of dollars with a total schedule of one to two years for a typical oil & gas support project, and up to five years for a phased, large offshore wind project.

Opportunities for the near future

Advances in seismic acquisition and interpretation methods, machine learning algorithms, and computational power have begun to provide opportunities to quantitatively integrate G&G data with the ambition to directly infer, from the more affordable geophysical data, the detailed geotechnical properties that are required for offshore foundation design specs and to quantify the spatial geotechnical property variability of the site (Chen et al., 2020, Chen et al., 2021, Vardy et al., 2018, Vardy et al., 2017, Vardy 2015). In the energy transition era that our industry has entered, the recent momentum the offshore wind industry has gained provides additional motivation to further advance exploiting the fundamental rock physics linkage between both types of G&G data to derive site characterization synergies. While significant progress has been made recently, based on our experience more needs to be done:

1. Further simplify the seismic data conditioning, processing, and quantitative interpretation workflows that were originally focused on imaging and characterization of the deeper hydrocarbon reservoirs so that it can optimally support the geotechnical ground model development focusing on near seafloor features.

2. Develop reliable algorithms to extract the source wavelet without well control and to conduct acoustic impedance inversion on high resolution seismic data (frequency > 1 kHz).

3. Improve the extraction and interpretation of seismic attenuation to help with lithology-specific geotechnical parameter estimation from acoustic impedance, while balancing the tradeoff between resolution and accuracy.

4. Identify and develop suitable machine learning algorithms to both include the aleatory and epistemic uncertainties in the data.

The quantitative G&G integration with the aid of machine learning does not limit itself to geotechnical problems, but naturally extends to identifying and quantifying shallow geohazards and it has the potential to support early detection of possible gas leakage in carbon storage sites. In the energy transition era, the here described application of novel geophysical workflows can bring tremendous values to a variety of opportunities and challenges directly linked to building a resilient and cost-effective renewable energy supply system and the safe operation of CCUS facilities.

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REFERENCES

Aubeny, C., R. Dutt, A. G. Young, J. D. Murff, R. B. Gilbert, and E. Doyle, 2013, An expert panel review of geotechnical site investigation regulations and current industry state of practice: Offshore Technology Conference.

Chen, J., M. Vissinga, Y. Shen, S. Hu, E. Beal, and J. Newlin, 2021, Machine learning–based digital integration of geotechnical and ultrahigh–frequency geophysical data for offshore site characterizations: Journal of Geotechnical and Geoenvironmental Engineering, **147**, 04021160, doi: https://doi.org/10.1061/(ASCE)GT.1943-5606.0002702.

Chen, J. B., L. Q. Sang, B. Willems, J. Newlin, O. Ruden, R. Sarker, and S. Hu, 2020, A machine learning based quantitative integration of geotechnical and geophysical data for deepwater site characterization: Proceedings of the 4th International Symposium on Frontiers in Offshore Geotechnics.

Doyle, E. H., 1998, The integration of deepwater geohazard evaluations and geotechnical studies: Offshore Technology Conference.

Jeanjean, P., W. Berger III, E. Liedtke, and D. Lanier, 2006, Integrated studies to characterize the Mad Dog Spar anchor locations and plan their installation: Offshore Technology Conference.

Newlin, J., 2003, Suction anchor piles for the Na Kika FDS mooring system part 1: Site characterization and design: International Symposium on Deepwater Mooring Systems, 28–54.

Vardy, M., M. Clare, M. Vanneste, C. Forsberg, and J. Dix, 2018, Seismic inversion for site characterization: When, where and why should we use it? Offshore Technology Conference.

Vardy, M. E., 2015, Deriving shallow-water sediment properties using post-stack acoustic impedance inversion: Near Surface Geophysics, **13**, 143–154, doi: https://doi.org/10.3997/1873-0604.2014045.

Vardy, M. E., M. Vanneste, T. J. Henstock, M. A. Clare, C. F. Forsberg, and G. Provenzano, 2017, State of the art remote characterization of shallow marine sediments: the road to a fully integrated solution: Near Surface Geophysics, **15**, 387–402, doi: https://doi.org/10.3997/1873-0604.2017024.