Deep-water carbonate concretions and their impact on submarine geohazard and cable burial assessment

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Introduction

Prior knowledge of seabed morphology, shallow geology and soil mechanical characteristics along a planned route is of critical importance to assess product burial in submarine cable routing and engineering. At greater depths, i.e. beyond the continental shelf, the seabed is typically dominated by soft soils (i.e. muds and clays) whose mechanical behaviour generally requires the use of jetting machines for burial to negate or minimise hindrance to cable lay operations. An exception to this "deep-water rule" is represented by calcareous concretions (abbreviated as CC hereafter) which are increasingly recognised as features associated to methane seepage in the form of authigenic carbonates (Hovland and Risk, 2003). The extent and distribution of seepage-associated phenomena are key factors to be considered during geohazard assessment for their geotechnical and ecological implications.

During an Adriatic Sea (Italy) pre-lay survey, conducted during 2016, we discovered extensive outcrops of deep-water CC in areas where the seabed was expected to be characterised by only hemipelagic muds. The presence of CC is relatively well known in the northern and central Adriatic shelf at depths < 200m (Falace et al., 2015; Taviani et al., 2015), while their deep-water counterparts have only been reported from other regions of the Mediterranean (Aloisi et al., 2000). Here we report the main morphological and lithological characteristics of these CC, combined with geotechnical information and tests aimed at assessing the feasibility of utilising either jetting or trenching machines for burial.

Main Results

ROV-mounted, hydro-acoustic sensors (SSS, MBES) and associated visual investigations have revealed extensive sections of seafloor along the Italian continental slope in the southern Adriatic Sea to be affected by CC within the 350 to 1,000m depth range (Fig.1). The CC have mostly sub-metric sizes, rarely attaining 1-2m in height, but not exceeding 1m in average. They show quite variable shapes, from typical carbonate build-ups to otherwise tabular-slab like forms, similar to those observed in other settings e.g. MDAC (Methane Derived Authigenic Carbonates) in the North Sea (Hovland and Judd, 1988). Different distribution patterns (spotty to massive) have been recognised, with associated density varying from tens to hundreds of features over an area of 10m². Seismo-acoustic records (SBP chirp 2-15 kHz) and cores indicate that CC are embedded into well layered Late Pleistocene marine clays (Fig.2) with different degrees of consolidation whose stratal heads are partially exposed on the slope. This evidence, coupled with outcrop patterns observed in plan view, suggest that seepage has been partially controlled by stratal interfaces and therefore has been potentially favoured by strata exposure due to slope instability and removal of the upper hemipelagic layer. The absence of additional gas escape evidence, such as pockmarks on the seabed or acoustic flares within the water column, may preliminary suggest no more active seepage is prevalent.

Both carbonate material and the surrounding sediment matrix were sampled by means of grab samples and vibrocores. PCPT and TRT (Thermal Resistivity) in situ tests were further carried out.

Outside the CC areas, the “background” sediment consists of hemipelagic silty-clay muds. The PCPT’s highlighted very low to low undrained shear strengths with a standard increase in consistency due to lithostatic pressure. In the CC areas, conversely, the seabed consists mainly of calcareous clayey silts with moderate organic matter. Here an increase in cohesion was noted to about 0.5-1.0m below seabed most of the time. The undrained shear strengths, based on the PCPT’s, attained 80-100 kPa, which are values offering little concern, but nevertheless to be considered for productivity with the jetting excavation technique. At the same time, the CC themselves constitute a challenging material to excavate even with trenching techniques. For this reason, an ROV-mounted jet probe has been designed, prototyped and tested. Where the jetting technique has effectively overcome the calcareous crust, a direct correspondence was found between the undrained shear strength recorded by PCPT and the inverse of the speed penetration of the jet-probing test (Fig. 3).

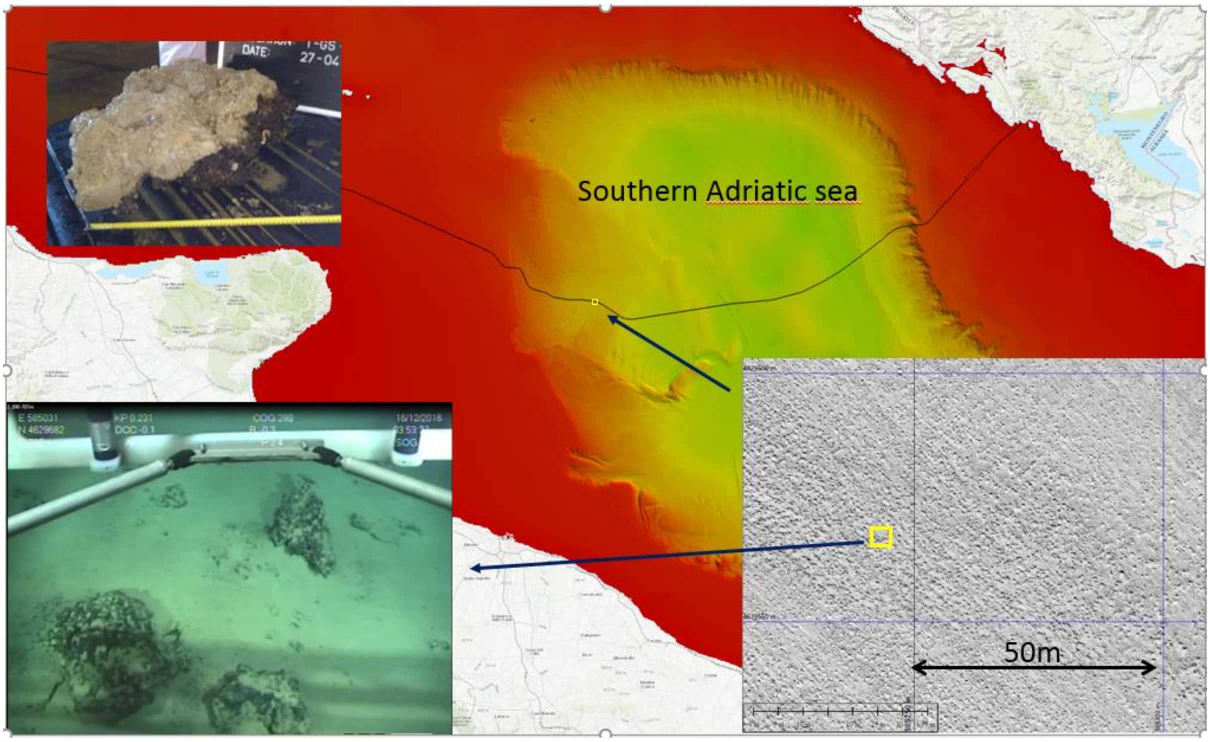

Fig. 1 – Location map with SSS mosaic on CC outcrops (right), ROV-image (bottom left) and sampled material (top left).

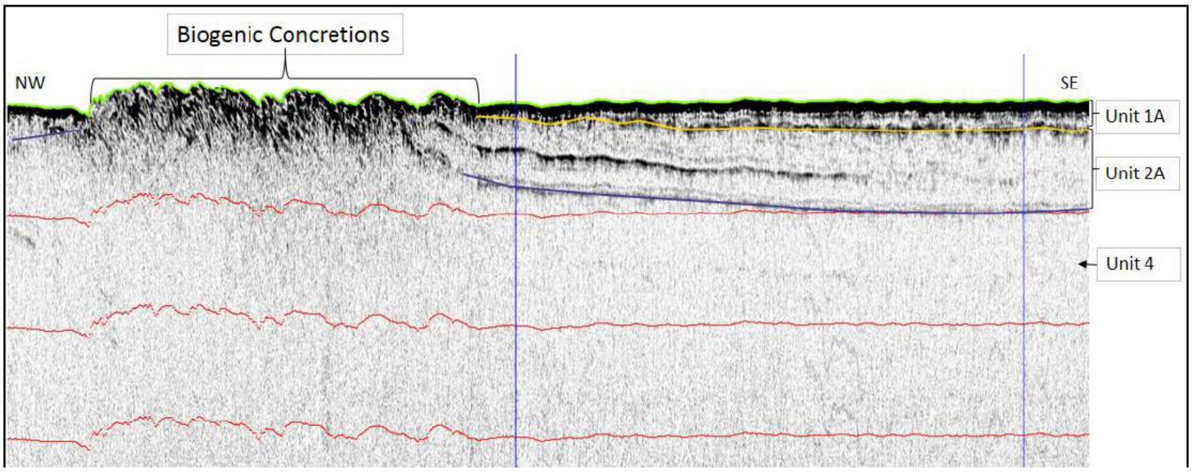

Fig. 2 –SBP record: Clay sequences 2A and 4 hosting CC below hemipelagic muds (sequence 1A).

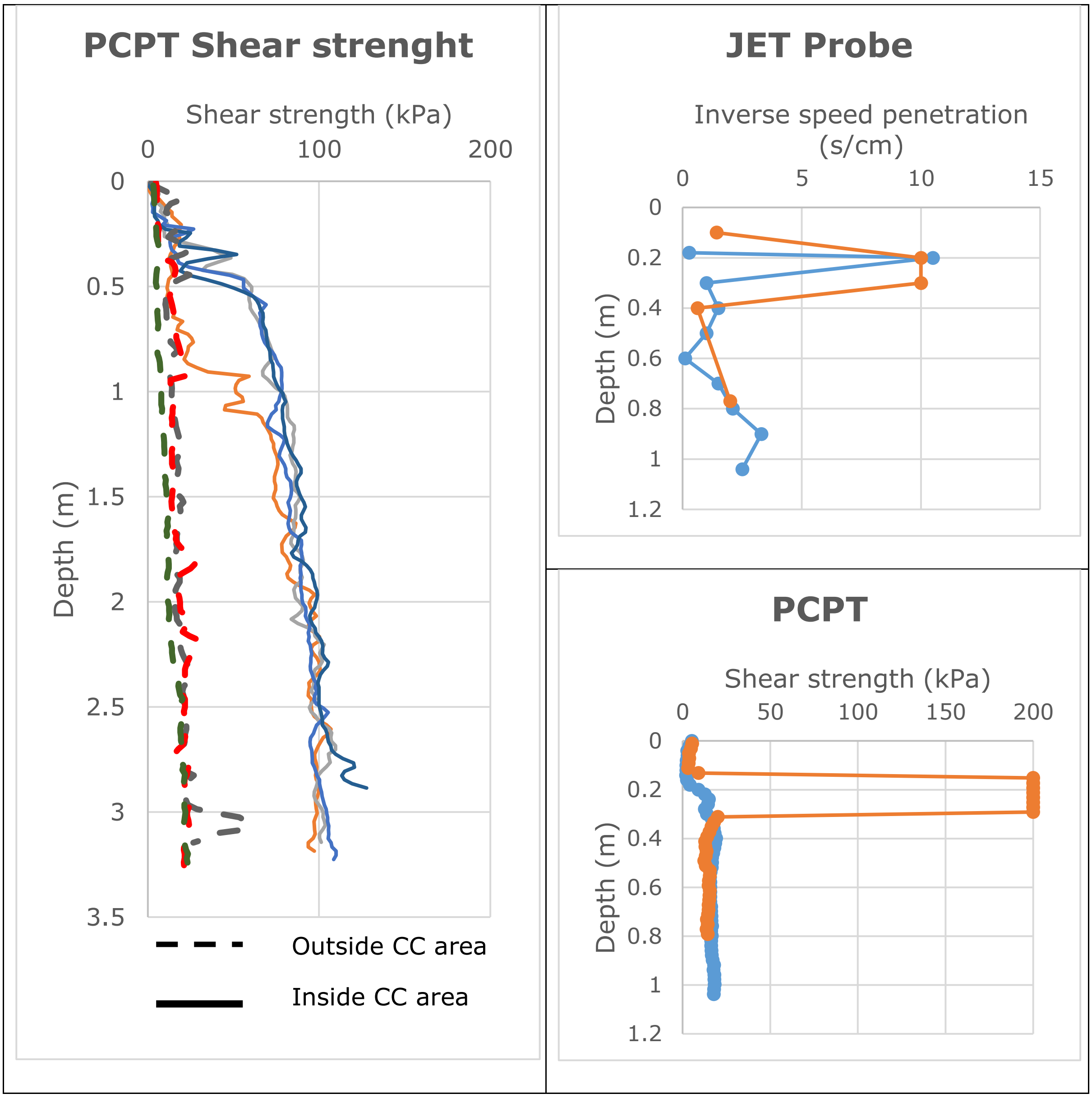

Fig. 3 – Results from PCPT shear strength analysis and jet probes inside and outside the CC outcrops.

Conclusion

Within an offshore project, the desktop study is one of the most critical phases of pre-engineering. Sometimes its importance is underestimated, thus increasing risk of unexpected scenarios observed during survey phases that may require severe project re-designing. With the example presented herein, the occurrence of unpredicted soils (CC) lead to a substantial review of the initial burial assessment. An anomalous increase of the undrained shear strength within the clay embedding CC's is possibly associated with the same process (seepage) that generated carbonate precipitation. The jet-probe technique has highlighted a direct correlation between the efficiency of this burial method and the shear strength recorded by the PCPT's.

References

Aloisi, G., Pierre, C., Rouchy, J-M, Foucer, J-P and Woodside, J., 2000. Methane-related authigenic carbonates of eastern Mediterranean Sea mud volcanoes and their possible relation to gas hydrate destabilisation. *Earth Planet. Sci. Lett*. 184, 321-338.

Falace, A., Kaleb, S., Curiel, D., Miotti, C., Galli, G., Querin, S., Ballesteros, E., Solidoro, C and Bandelj, V., 2015. Calcareous Bio-Concretions in the Northern Adriatic Sea: Habitat Types, Environmental Factors that Influence Habitat Distributions, and Predictive Modeling. *PLoS ONE* 10 (11): e0140931. doi:10.1371/journal.pone.0140931

Hovland, M. & Risk, M., 2003. Do Norwegian deep-water coral reefs rely on seeping fluids? *Marine Geology* 198, 83-96.

Hovland, M. & Judd, A.G., 1988. Seabed pockmarks and seepages – impact on geology, biology and the marine environment. Graham & Trotman Ltd, London, pp 293.

Taviani, M., Franchi, F., Angeletti, L., Correggiari, A., Correa, M.L., Maselli, V,Mazzoli, C., Peckmann, J., 2015. Biodetrital carbonates on the Adriatic continental shelf imprinted by oxidation of seeping hydrocarbons, *Marine and Petroleum Geology*, doi: 10.1016/j.marpetgeo.2015.03.015.