REGIONAL BATHYMETRY AND SUBSEA SHALLOW GEOLOGY WITHIN THE GULF REGION AND THE CHALLENGES IT PRESENTS TO THE WORK IN OUR INDUSTRY

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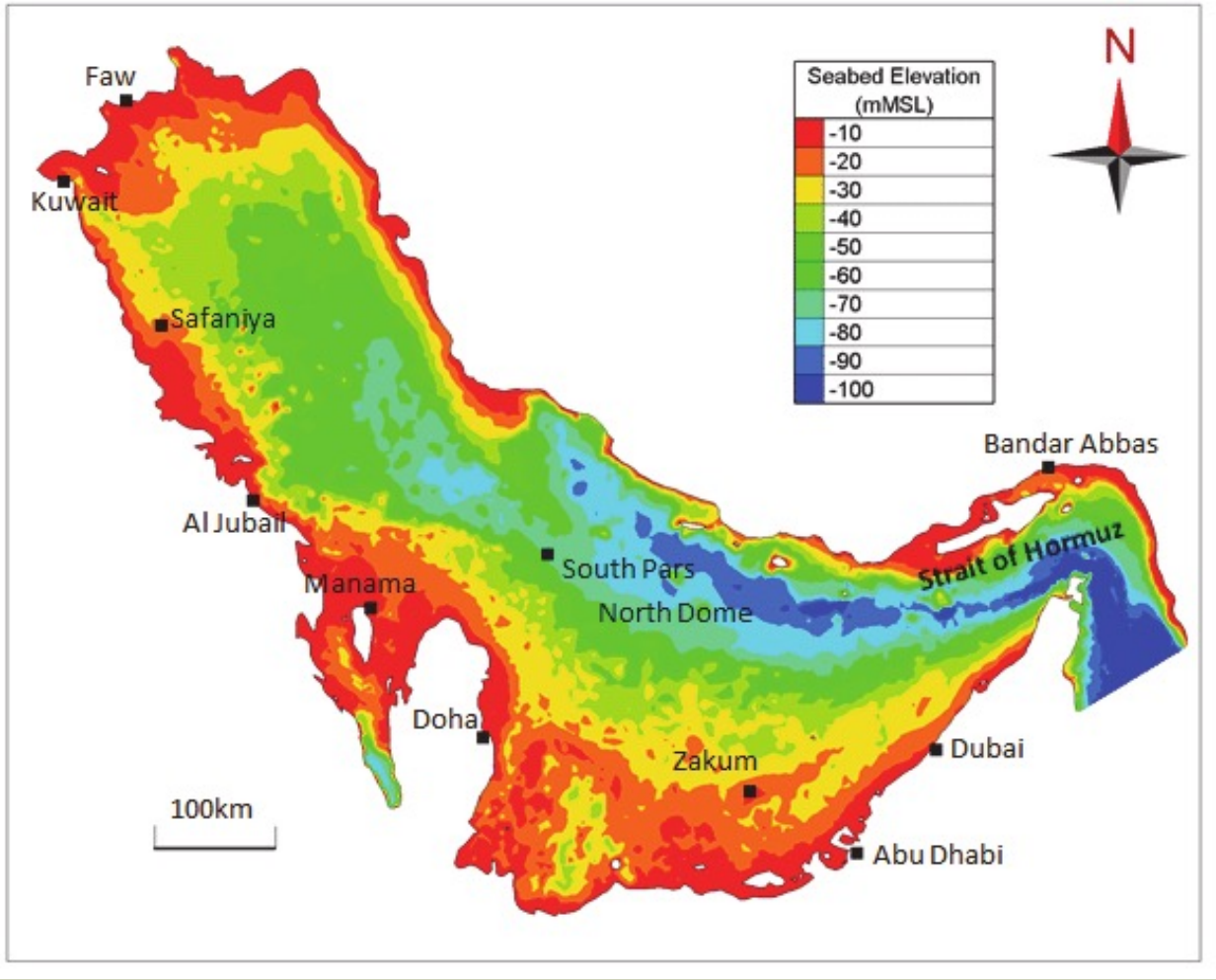
INTRODUCTION

- The geology of the Gulf Area has been significantly influenced by the deposition of marine sediments associated with numerous sea level changes during relatively recent geological time. The Gulf is surrounded by Oman, Saudi Arabia, UAE, Qatar, Bahrain, Kuwait, Iraq and Iran.

FIGURE 1: MAP OF ARABIAN PENINSULA

BATHYMETRY



- The Gulf is a semi enclosed water body centered in the Middle East. In the east central regions of the Gulf, water depths exceed 100 meters, but for the most part, these are less than 50 meters. (Figure 1A). The Gulf is approximately 800km long, 200km wide and reduces to a width of 39km at the entrance (Strait of Hormuz).

FIGURE 1A: GULF SEABED ELEVATIONS (RELATIVE TO MEAN SEA LEVEL, MSL).

PHYSIOGRAPHY

FIGURE 2: SATELLITE IMAGERY GULF.

- The Iranian shore is mountainous, and there often are cliffs; elsewhere a narrow coastal plain with beaches, intertidal flats, and small estuaries borders the gulf.
- Cliffs are rare on the Arabian shore of the gulf, except around the base of the Qatar Peninsula and in the extreme southeast around the Strait of Hormuz, where they form the spectacular coast of the Musandam Peninsula.
- Most of the Arabian shore is bordered by sandy beaches, with many small islands enclosing small lagoons.

TOPOGRAPHY

Illustrative 3D Elevation Model

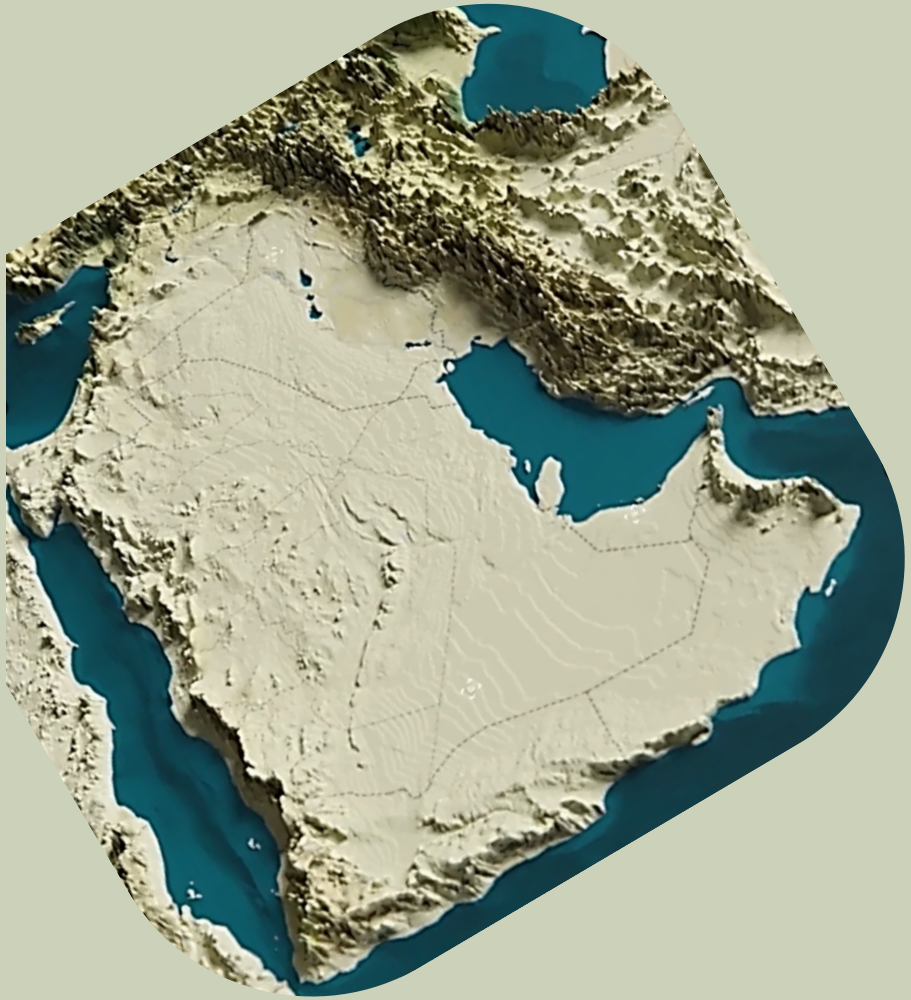
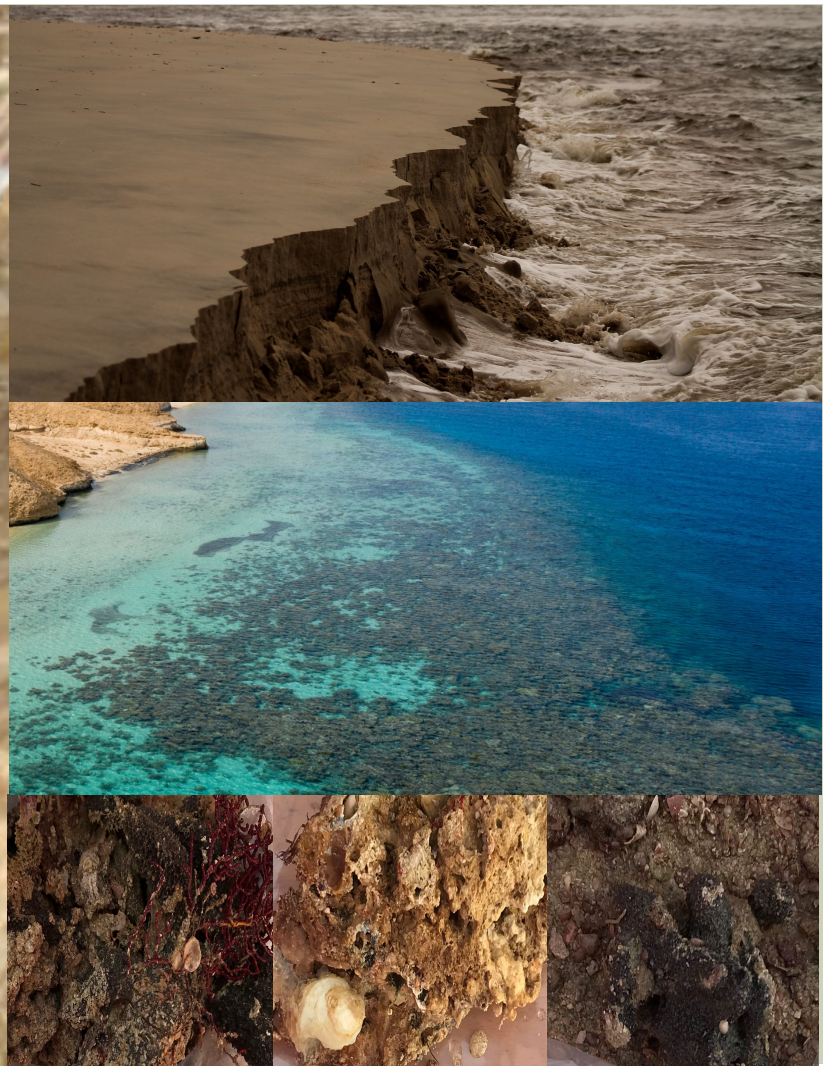


FIGURE 2A: ILLUSTRATIVE 3D ELEVATION MODEL.

- The Iranian shore is mountainous, and there often are cliffs; elsewhere a narrow coastal plain with beaches, intertidal flats, and small estuaries borders the gulf.
- Cliffs are rare on the Arabian shore of the gulf, except around the base of the Qatar Peninsula and in the extreme southeast around the Strait of Hormuz, where they form the spectacular coast of the Musandam Peninsula.
- Most of the Arabian shore is bordered by sandy beaches, with many small islands enclosing small lagoons.

SHALLOW GEOLOGY

- The main shallowest sedimentary units generally occurring in the gulf region includes land based sediments formed by the weathering/erosion process (SAND, CLAY, SILT, and Muddy sediment combinations), remains of living organisms (shells , corals and other microscopic organisms), oceanic inorganic minerals that precipitate directly from the seawater (eg.Gypsum) and weak rock formations of various compositions (Calcarenite, Calcisiltite etc).



HOW IT OCCURS? GEOHAZARDS

- Major marine geohazards includes submarine landslides/slope failures, subsidence, fluid flows/seepage, shallow gas/gas migration, scour events & migrating bedforms, soft/weak layer, seismicity (earthquake), volcanism, positive reliefs, negative reliefs, diapirs and faulting.

- Among the most notable after-effects of geohazards occurring are blowouts, loss of the flanking soil to wells, platform settlements, uncontrollable gas or water flows, leaks from the well-bore casing, damage to the well-bore casing, loss of wells, loss of platform foundations, rupture, excessive deformation and differential settlement. Development of unsupported spans, scouring, and backfill erosion are also potential effects considered for pipelines. Intermediate weak layers, inconsistent sedimentary layers, shallow gas, erosion and truncation sub-seabed surfaces, buried paleo channels and buried boulders/obstructions which poses risk to the rig emplacement and drilling.

HOW TO IDENTIFY? GEOHAZARDS

- The increasing amount of offshore Oil & GAS / Energy developments including offshore installations, drilling, wind farms and dredging has made accurate seabed mapping essential.

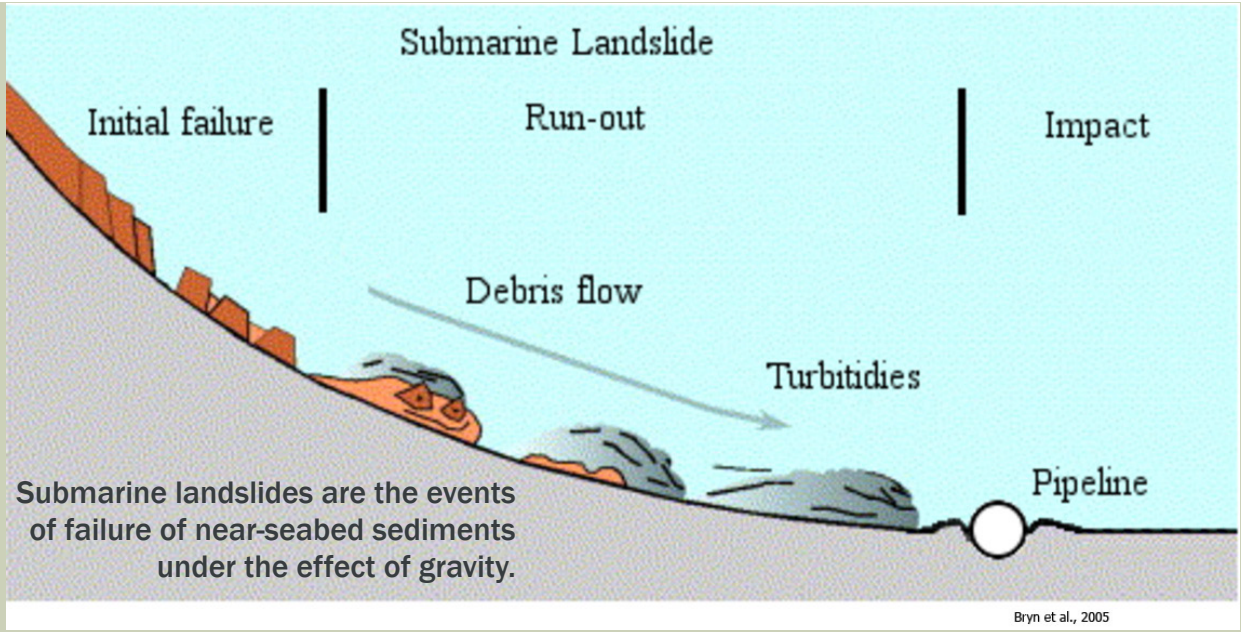
- For these applications to be used, a thorough understanding of the topography of the seafloor as well as the composition of the sediment at both the surface and deeper levels is necessary. A conventional approach to acquiring information about the seafloor's composition entails taking real sediment samples and acoustic remote sensing.

- The geophysical survey techniques that uses single beam, multibeam, Sub-bottom profiler and side scan sonars to classify seabed surfaces and sub-surfaces has been successful in identifying the shallow geohazards and provide mitigating resolutions.

GEOHAZARDS EXAMPLES

- **Submarine landslides/slope failures:** Submarine landslides are sediment movements down a slope on the seabed. Gas and gas hydrates, fast-moving sedimentation rates, groundwater seepage, tectonic action, volcanic activity, fluid migration, overpressure build-up and human activity are the main causes of submarine landslides.

- Faults act as conduits of seepage. Shallow gas within the sediments creates acoustic scattering and attenuation and reduces the penetration. High amplitude, acoustic turbidity/masking or blanking Gas chimneys/pathways are also reported to be created by gas and fluid seepage and migration in shallow marine sediments (Figure 3,4 & 6).



ACOUSTIC MASKING & SEABED SLOPES

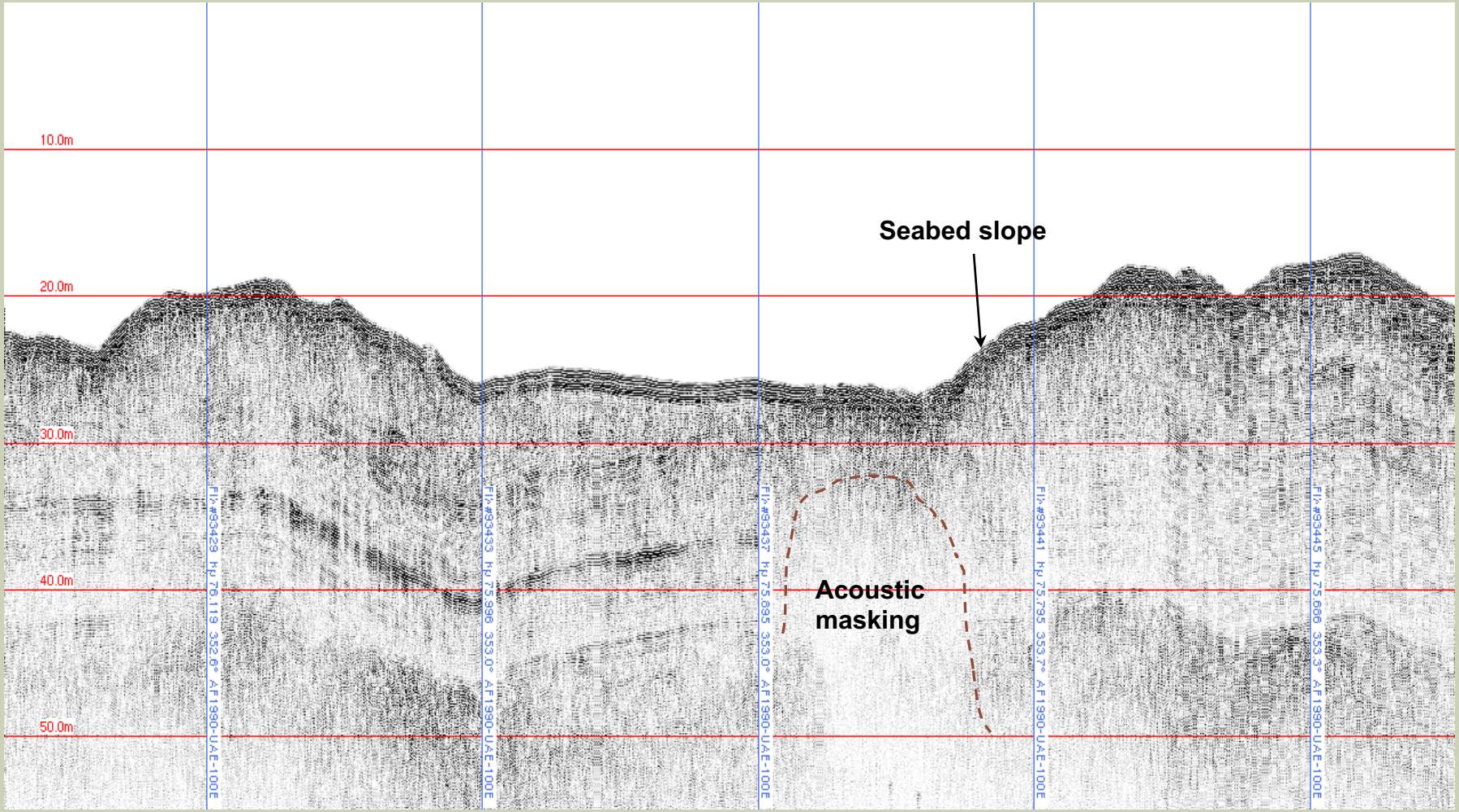


FIGURE 3: SUB-BOTTOM PROFILER DATA EXTRACT SHOWING ACOUSTIC MASKING & SEABED SLOPES

ACOUSTIC BLANKING & FAULTS

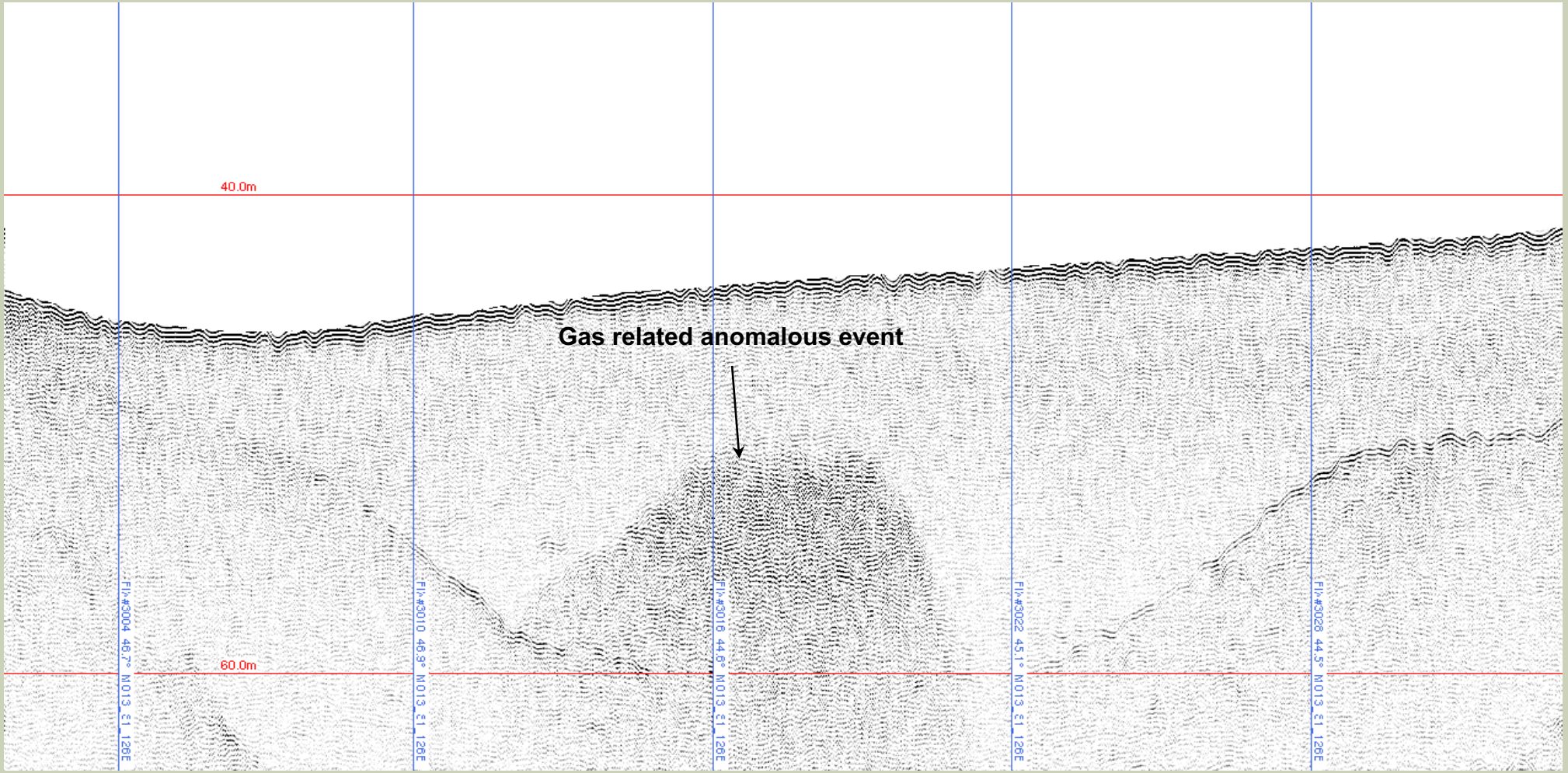


FIGURE 4: SUB-BOTTOM PROFILER DATA EXTRACT SHOWING GAS RELATED ANOMALOUS EVENT

FAULTS/FRACTURES

- Tectonic forces deform rocks and consolidated sediments to form folds and faults. Faults are formed by the displacement slip of the rocks/sedimentary unit along a plane.

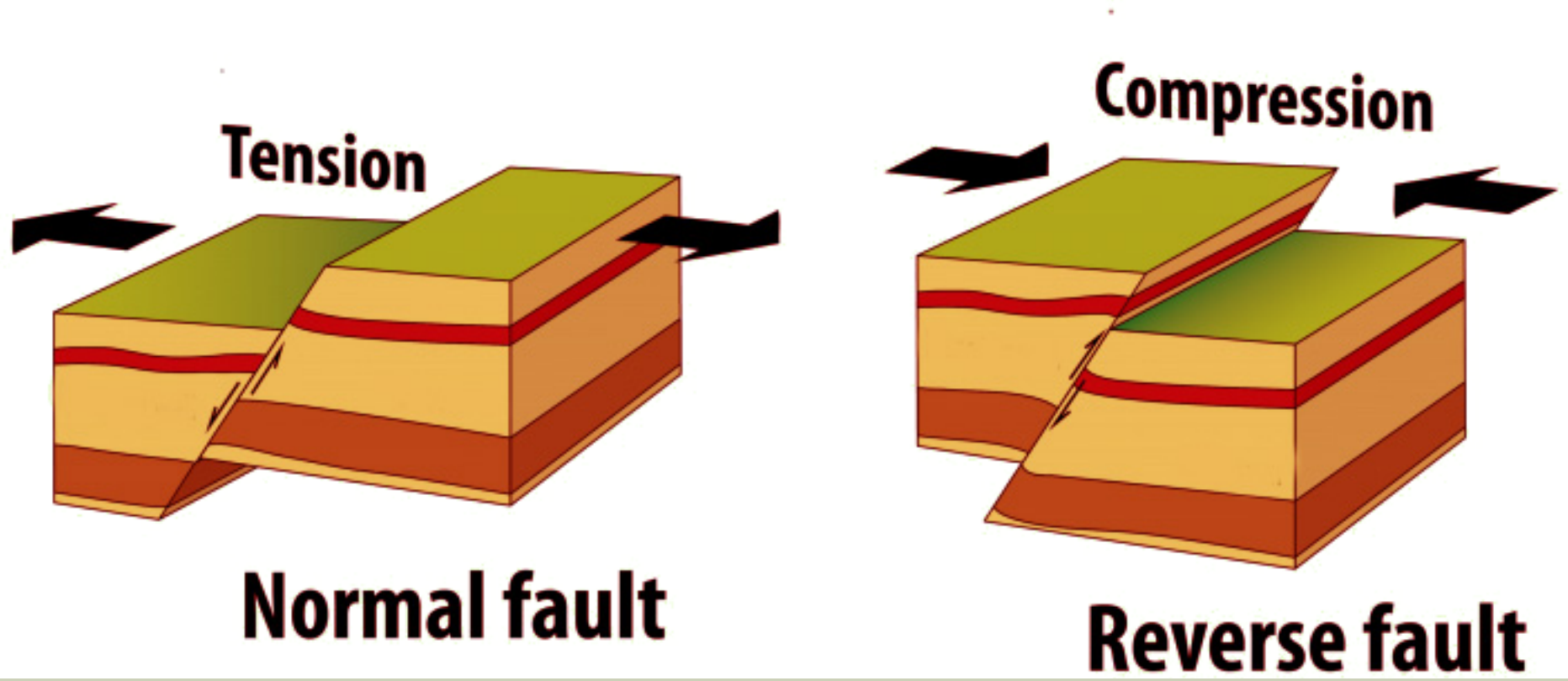


FIGURE 5: SCHEMATIC DIAGRAM OF TYPICAL FAULTS

ACOUSTIC BLANKING & FAULTS/FRACTURES

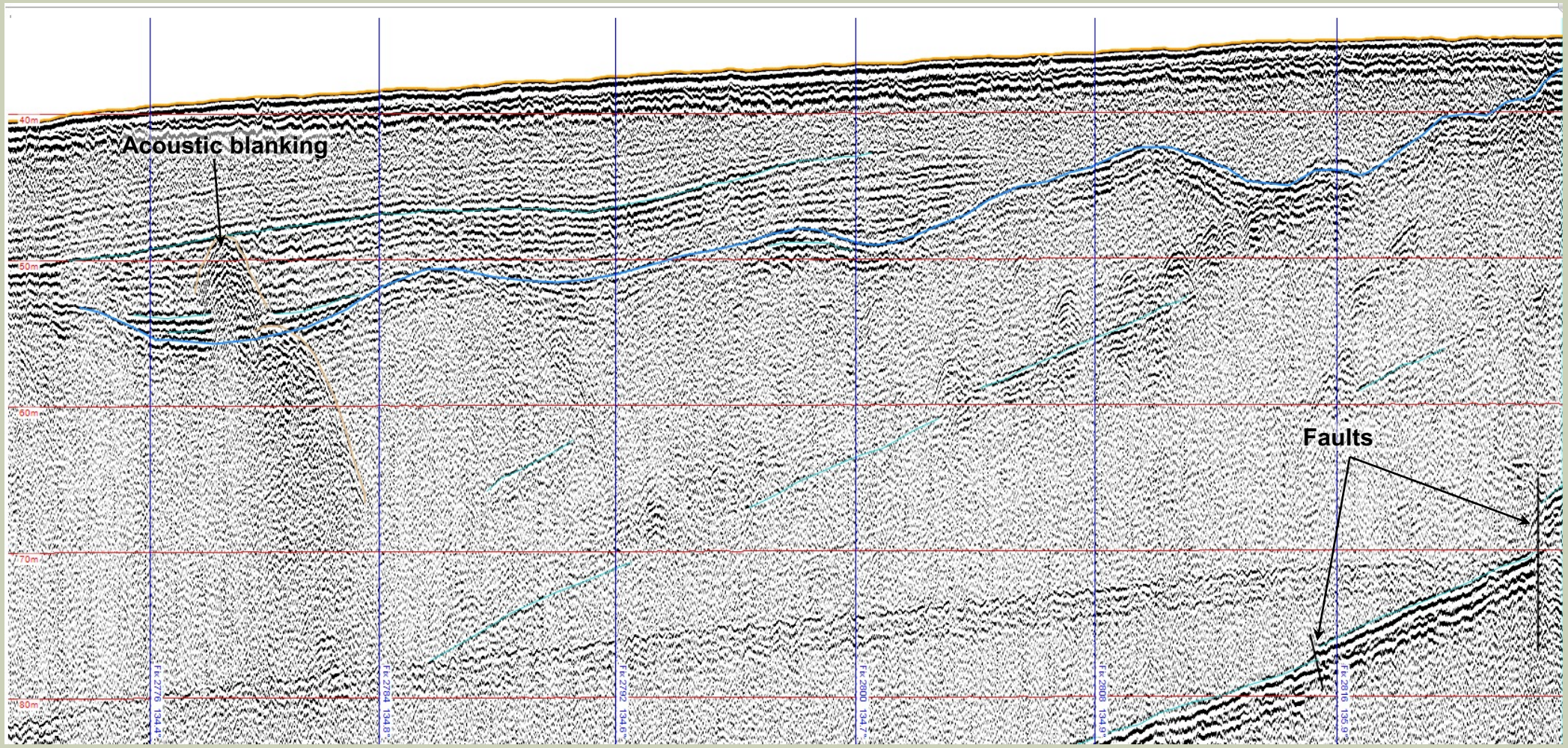


FIGURE 6: SUB-BOTTOM PROFILER DATA EXTRACT SHOWING ACOUSTIC BLANKING & FAULTS/FRACTURES

FAULTS

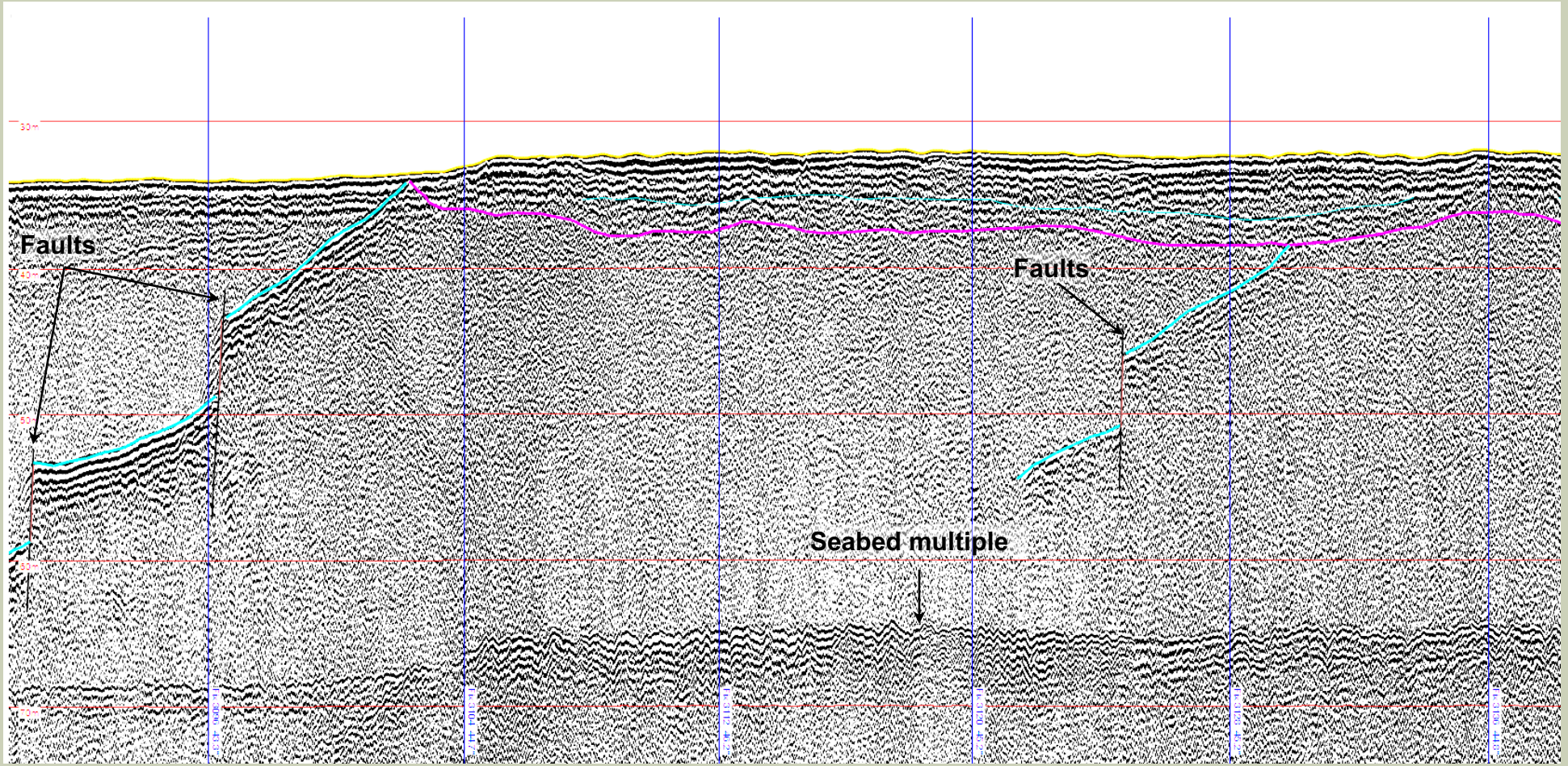


FIGURE 7: SUB-BOTTOM PROFILER DATA EXTRACT SHOWING FAULTS

GEOHAZARDS EXAMPLES

- **Fluid flows/seepage :** When there is rapid sedimentation, the fluid becomes trapped in the sediments. Porous sediments store fluids and when the overburden pressure of the overlying sediment create stress, the pore fluid/biogeochemical processes generated gas and fluids expel through weak soils, pores, chimneys or fractures/faults. Pockmarks (Figures 8, 9 & 10) are seabed depressions or crater shapes formed by seepage of fluids upwards through the unconsolidated sediments on the seafloor from below. The diameter of these pockmarks can vary by several meters , while their depth can range from decimeters to a few tens of meters.

NASCENT POCKMARK/SEABED DOMES

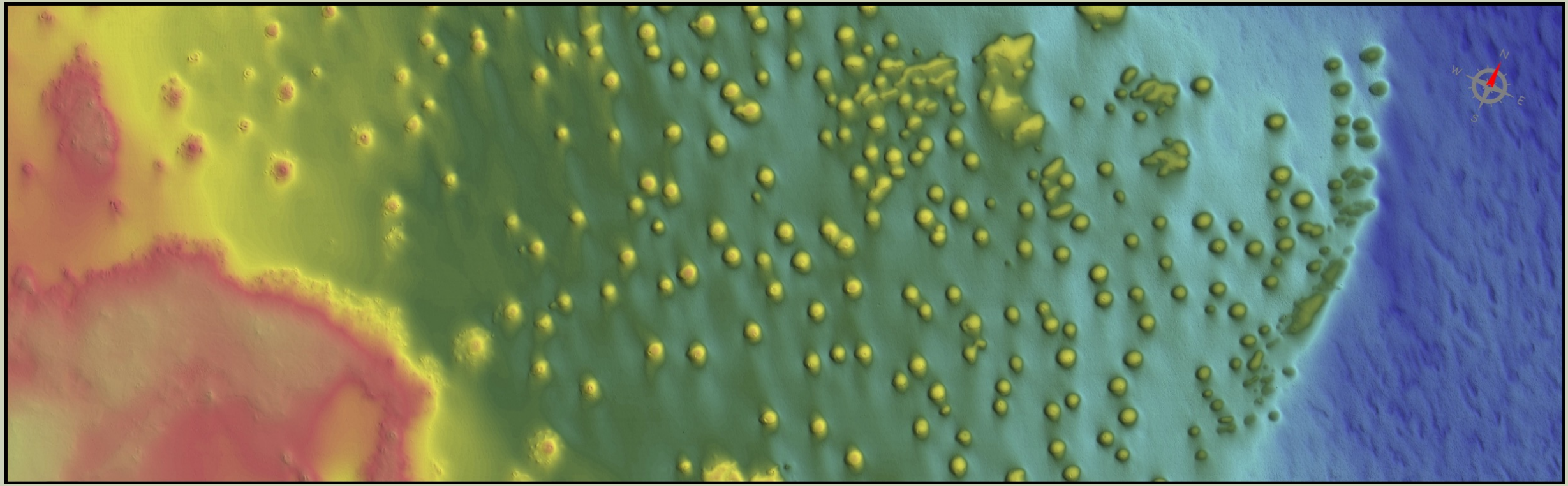


FIGURE 8: MBES DATA EXTRACT SHOWING CLUSTER OF MOUNDS / SEABED DOMES - PRECURSOR OF POCKMARKS

ACTIVE POCKMARKS

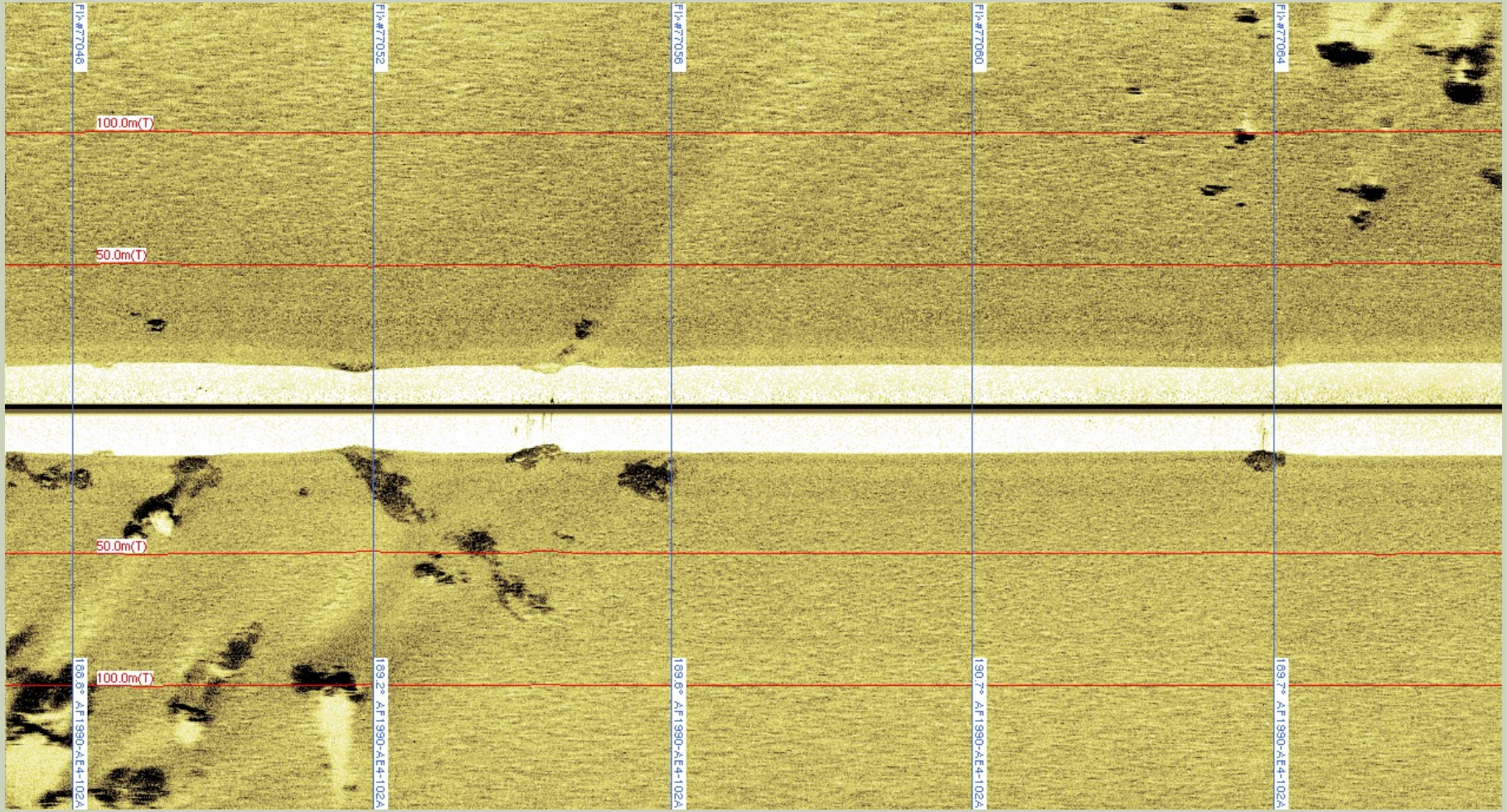


FIGURE 9: SIDE SCAN SONAR DATA EXTRACT SHOWING ACTIVE POCKMARKS

INACTIVE POCKMARKS

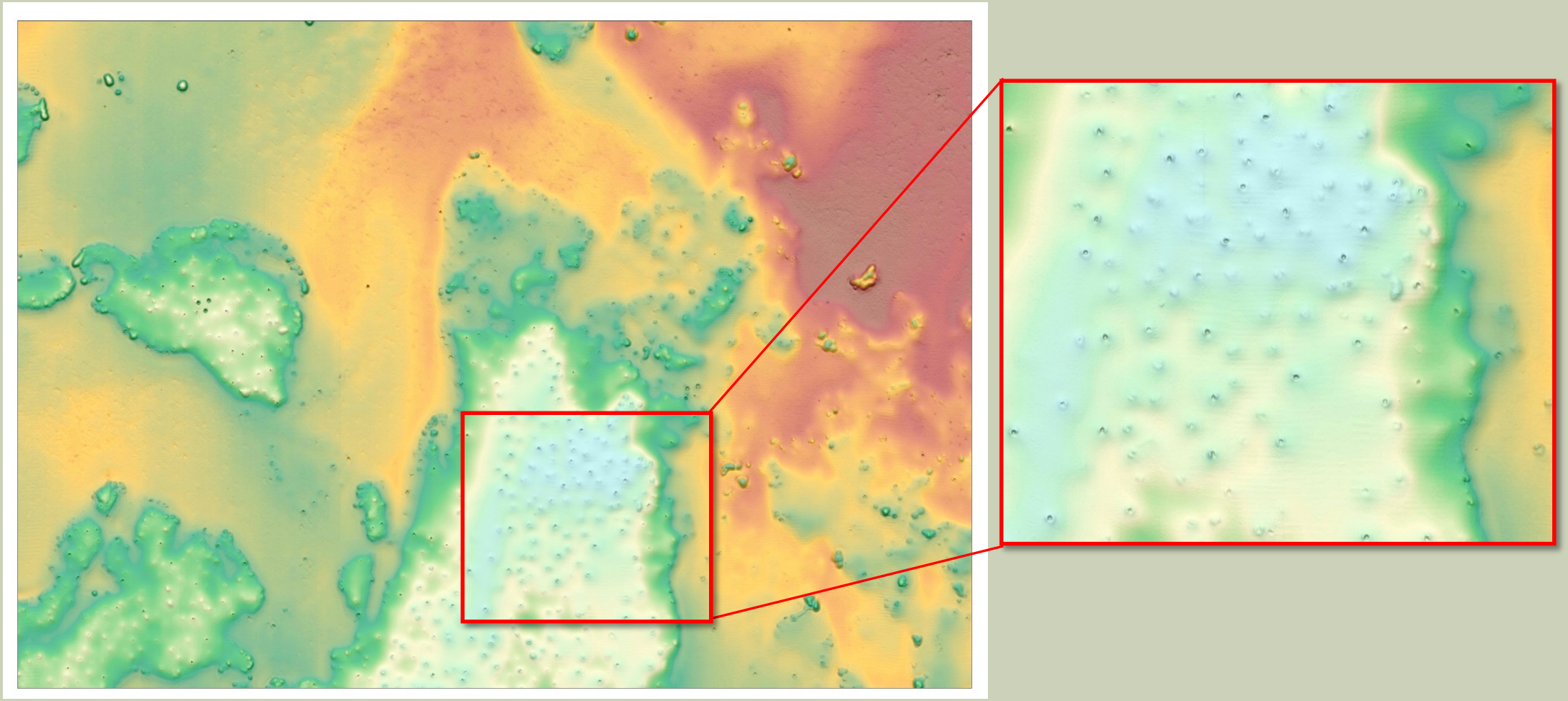


FIGURE 10: MBES DATA EXTRACT SHOWING POCKMARKS

COLLAPSED RIG - INCONSISTENT SEDIMENTARY LAYERS

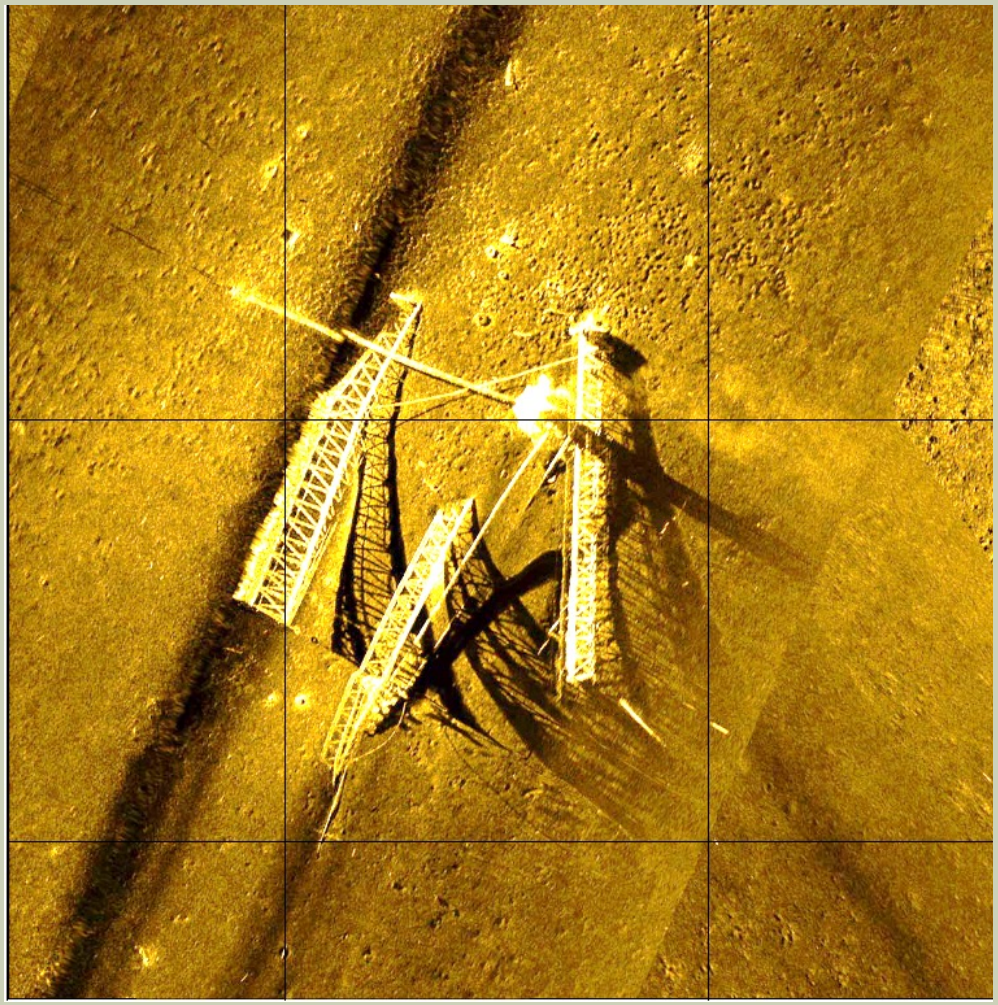


FIGURE 11: SIDE SCAN SONAR DATA EXTRACT SHOWING A COLLAPSED RIG

- Seabed instability due to varying thickness, soil properties and bearing capacity, between emplaced legs may cause variable leg penetration and affect stability of the rig.

BLOWOUT

- Blow out: Blowouts occur when an uncontrolled oil or gas release from the well take place due to the failure of pressure control systems. This happens mostly when the drilling fluid creates over pressure in addition to the overburden pore pressure or drilling through excessive pressure zones. In some of the marine environments shallow abnormal pressured gas formation/accumulation can be present at very shallow depth where conventional blowout prevention equipment will not be able to prevent (Figure 12).

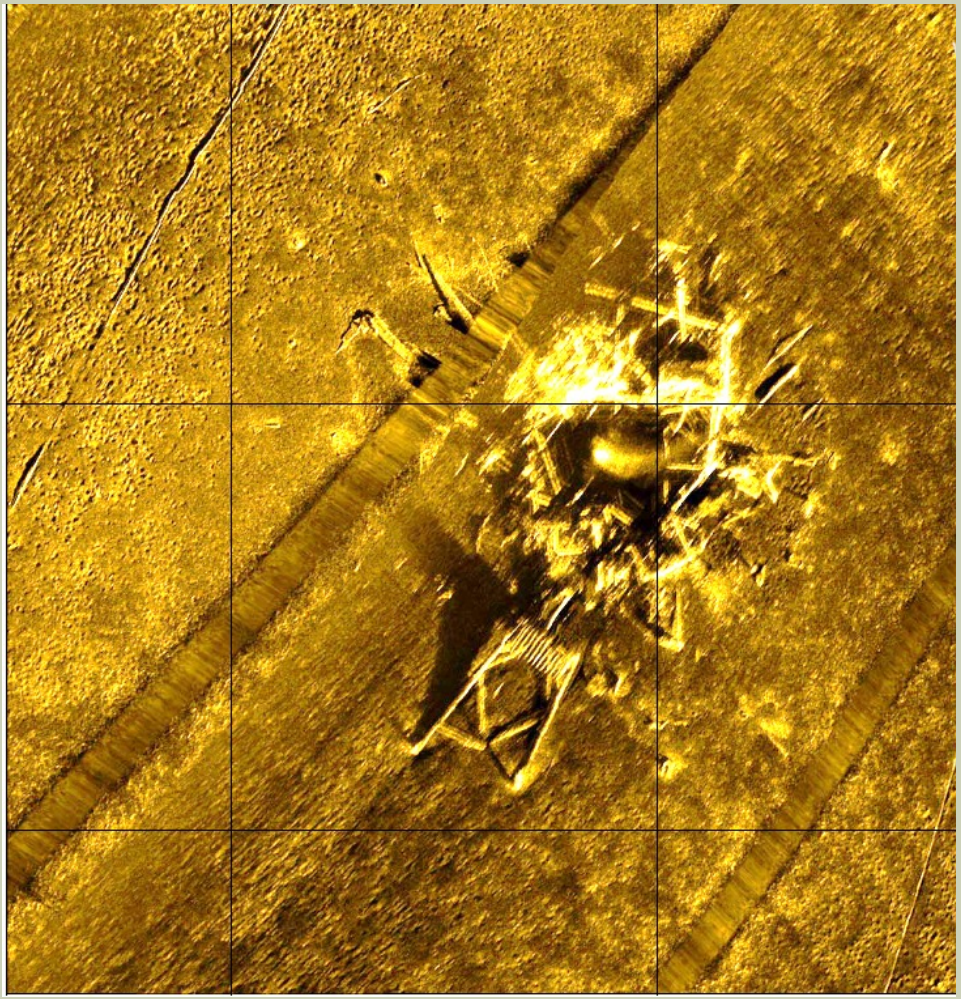


FIGURE 12: SIDE SCAN SONAR DATA EXTRACT SHOWING COLLAPSED RIG AND PLATFORM

PUNCH TROUGH

- **Soft/weak layers:** Punch-through failure of jack-up spudcan foundations occurs in active oil and gas drilling exploration regions, where relatively stiff/dense soil layer with insufficient bearing capacity overlies a soft marine layer. Therefore, installation of spudcan foundations in such seabed formations threatens the stability of the jack-up rig (Figure 13).

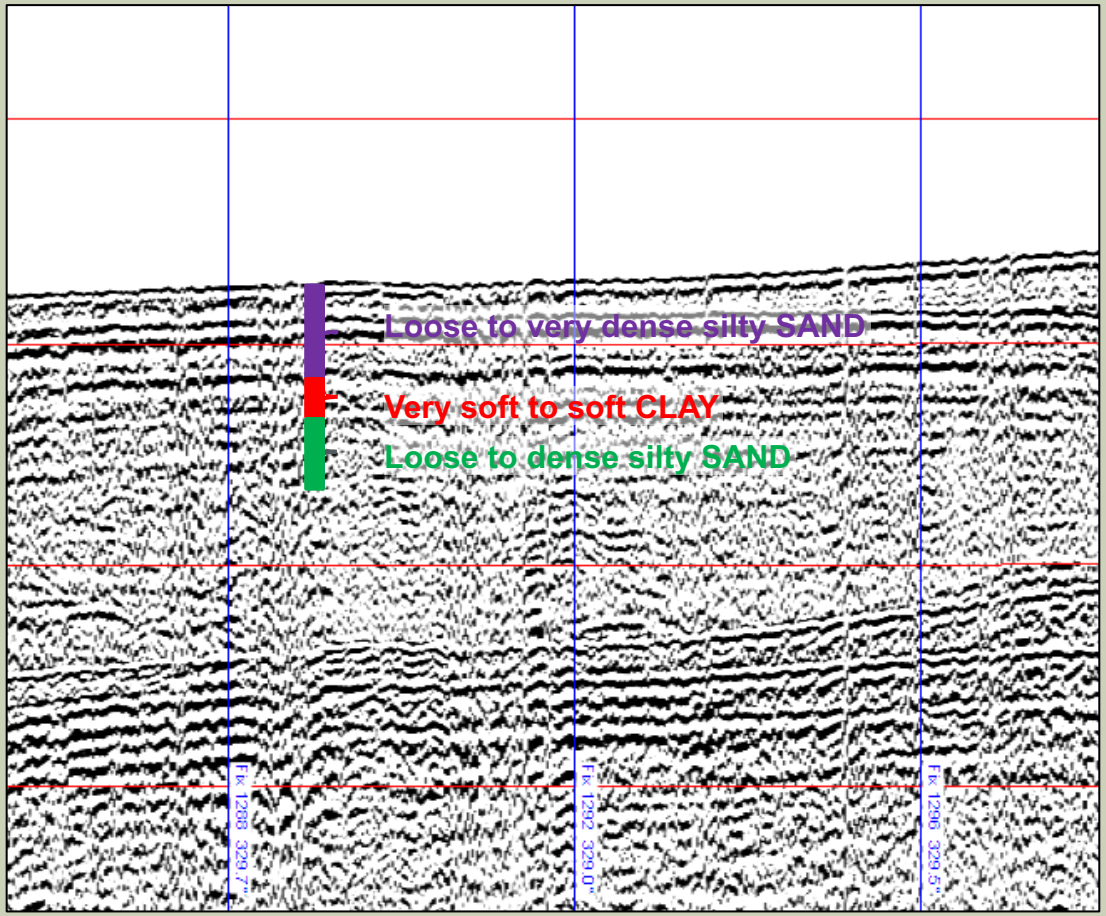


FIGURE 13: SUB-BOTTOM PROFILER DATA EXTRACT SHOWING POSSIBLE PUNCH TROUGH HAZARD

SOFT SILT SEDIMENTARY UNIT

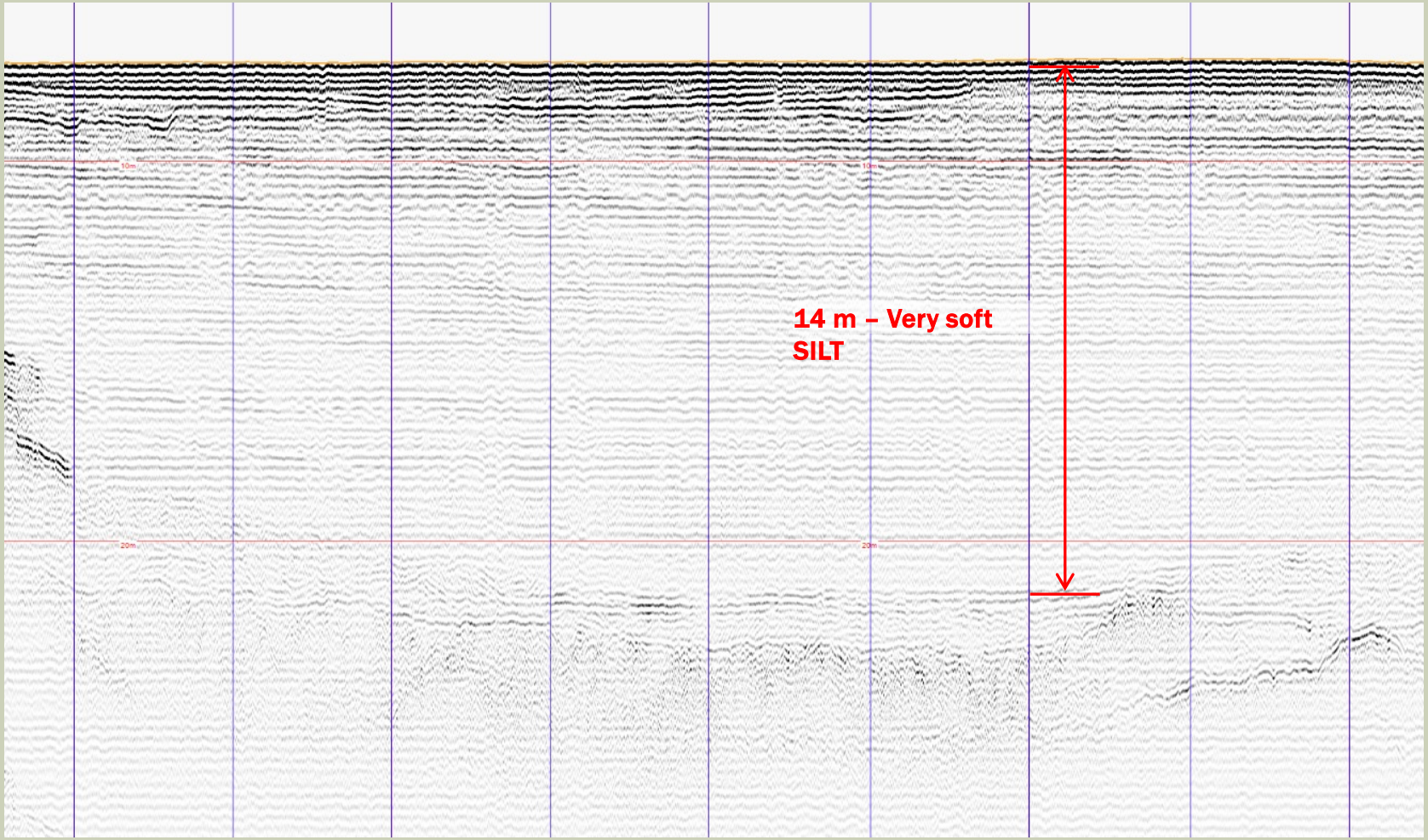


FIGURE 14: SUB-BOTTOM PROFILER DATA EXTRACT SHOWING THICK VERY SOFT TOP SEDIMENTARY UNIT

- Thicker surficial layer of soft unconsolidated sediments may result in the burial of pipelines and cables (Figure 14,15 & 16).

BURIED PIPELINES

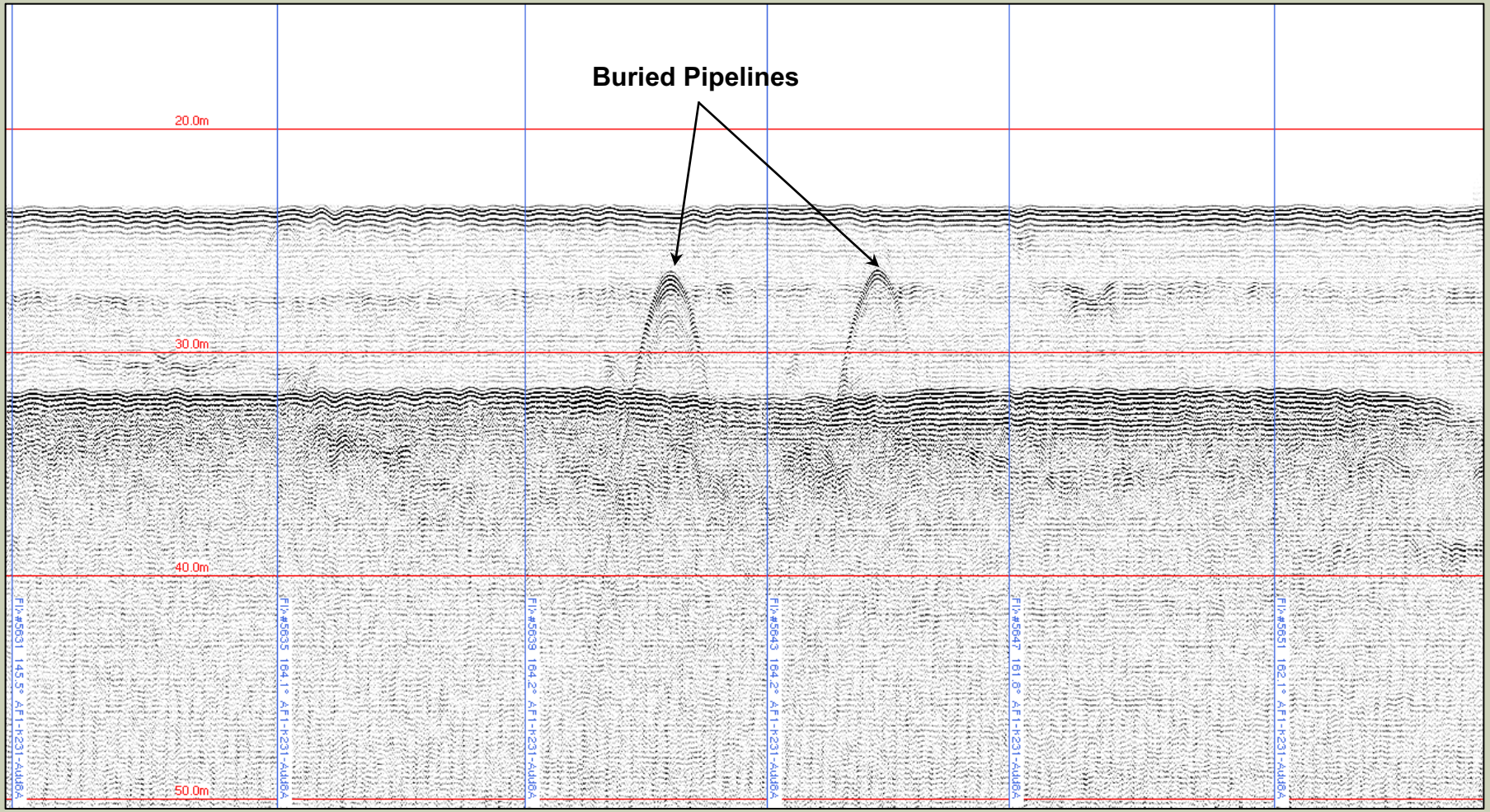


FIGURE 15: SUB-BOTTOM PROFILER DATA EXTRACT SHOWING BURIED PIPELINES

BURIED CABLE

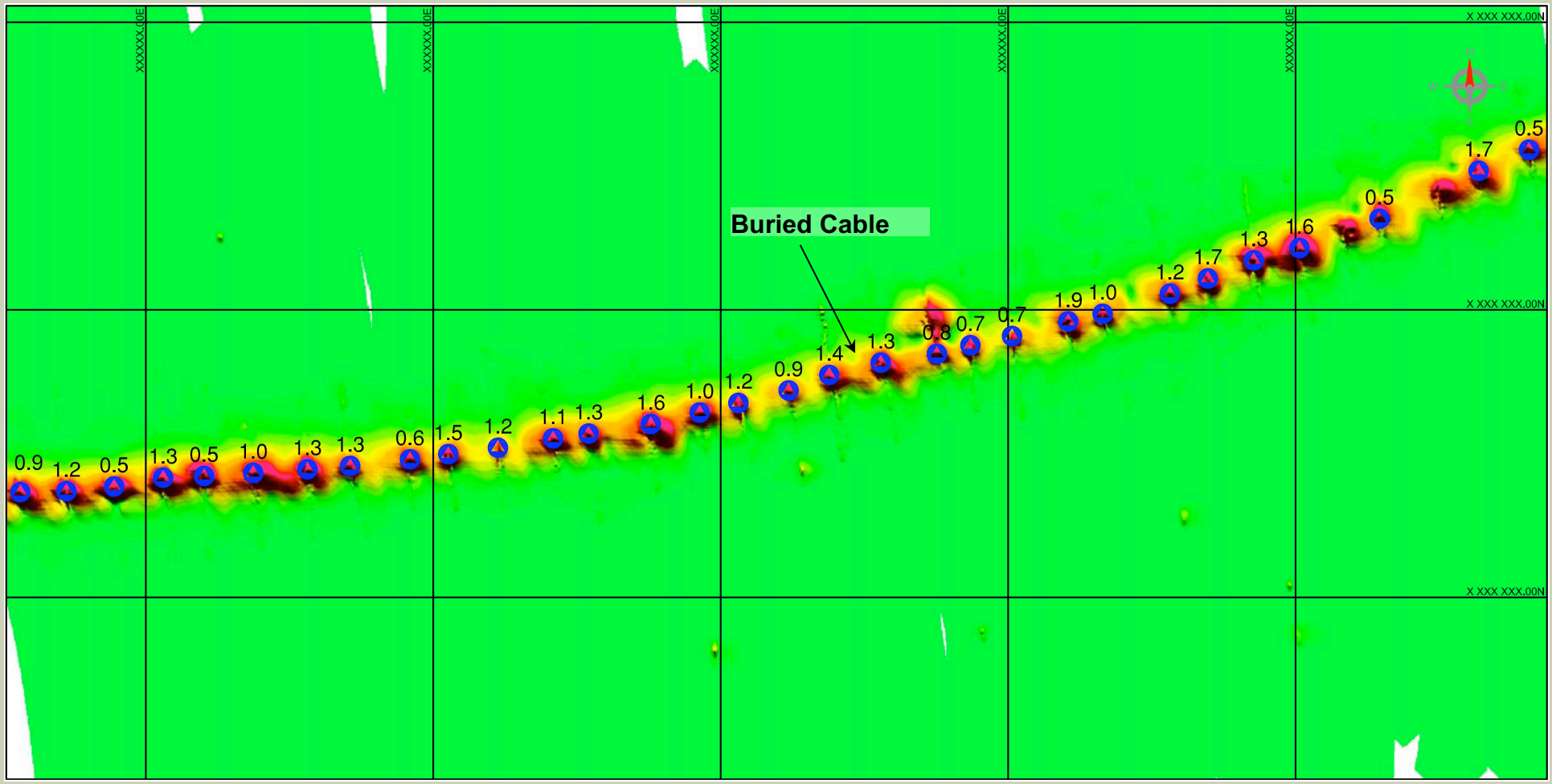


FIGURE 16: GRADIOMETER DATA EXTRACT SHOWING BURIED CABLE WITH CALCULATED BURIAL DEPTHS

BURIED OBSTRUCTIONS

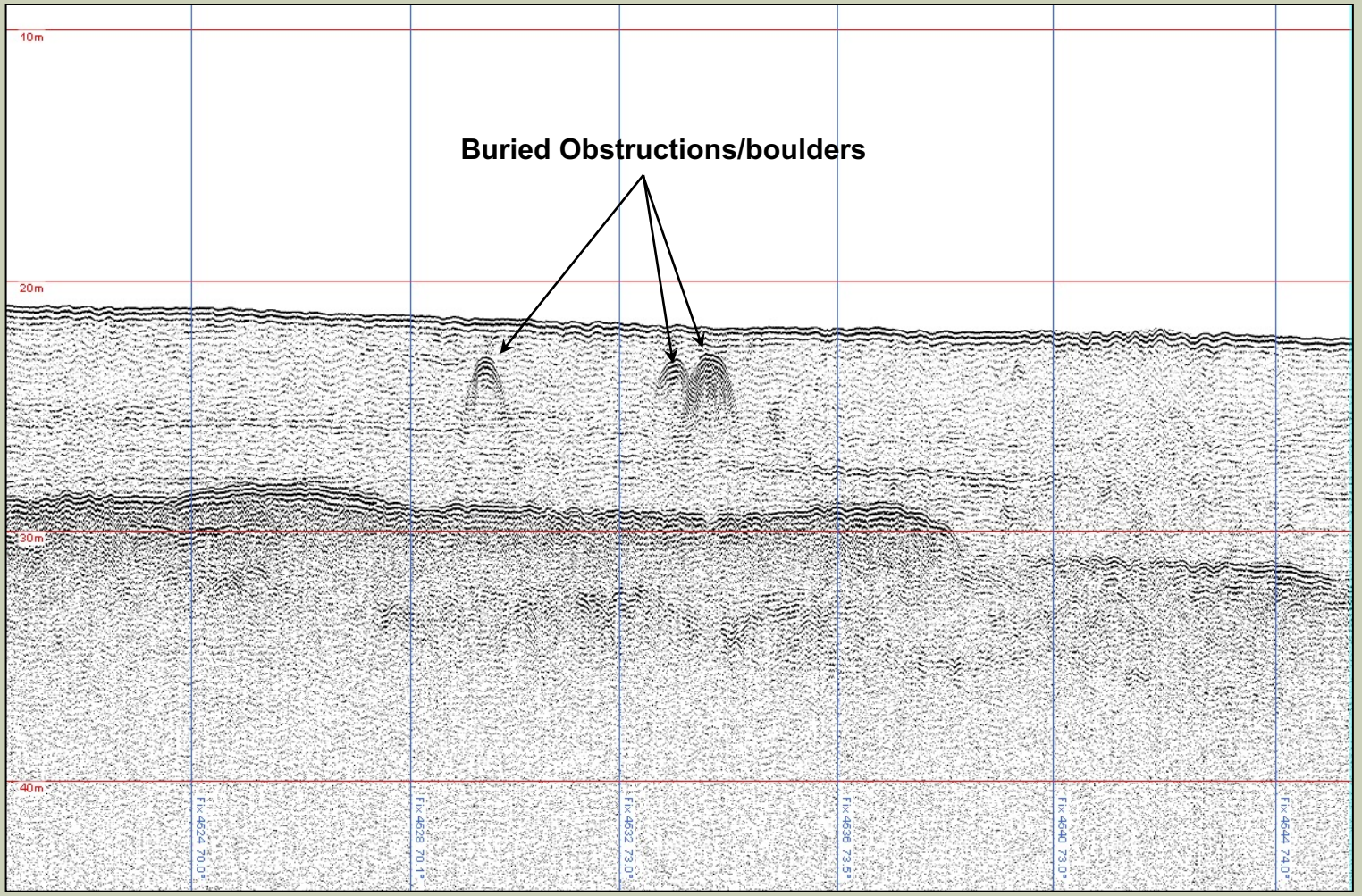


FIGURE 17: SUB-BOTTOM PROFILER DATA EXTRACT SHOWING BURIED OBSTRUCTIONS IN SOFT SEDIMENTS

SEABED SCOUR

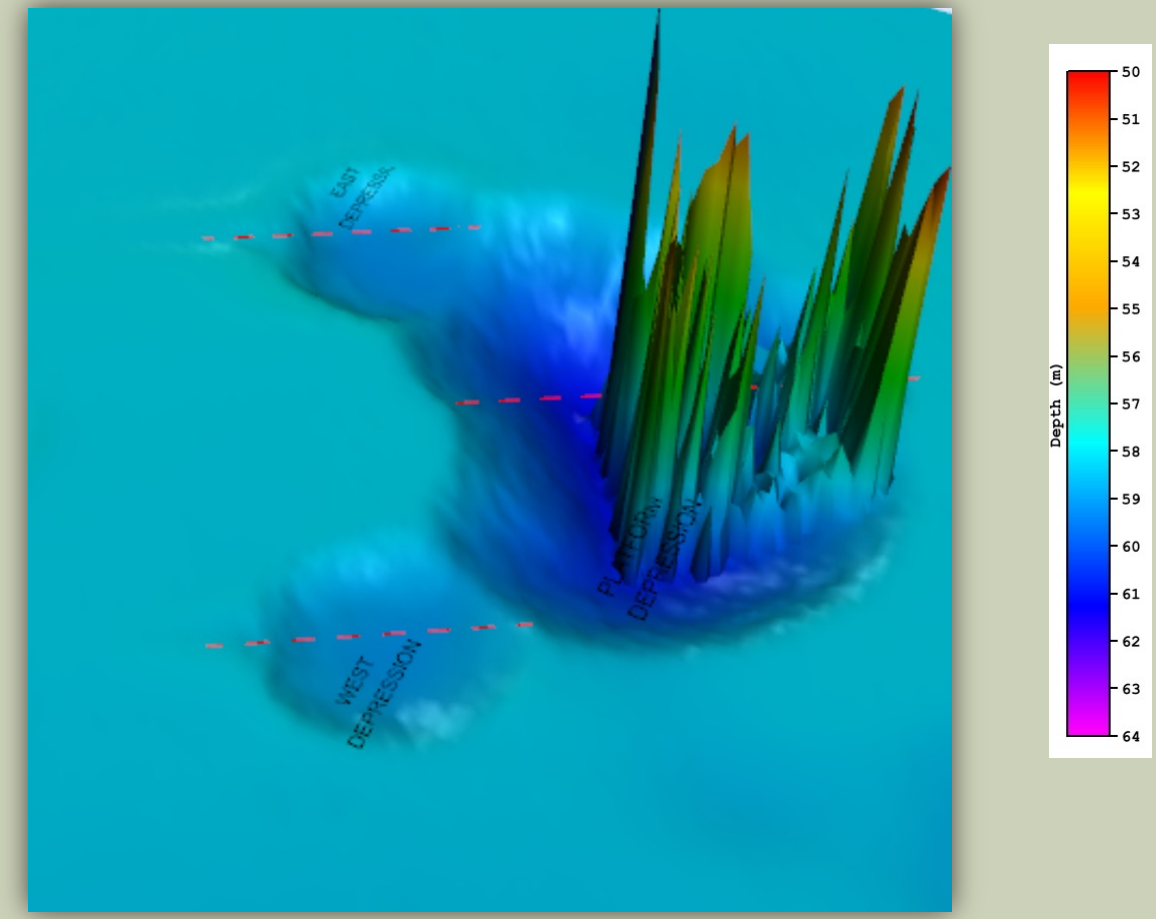


FIGURE 18: MULTIBEAM DATA EXTRACT SHOWING SEABED SCOUR EVENT AROUND THE PLATFORM

- **Scour events & Migrating bedforms:** This category of geohazards includes the scouring or removal of sediment surrounding a marine structure and the related phenomenon of sediment mobility such as sand waves. Sand waves or migratory bedforms with dimensions and shapes similar to desert dunes, are produced by bottom currents in regions with a strong tidal regime and loose sedimentation. They can also happen in waterways and straits when the force of the stream causes it to quicken.

SAND RIPPLE BED FORMS

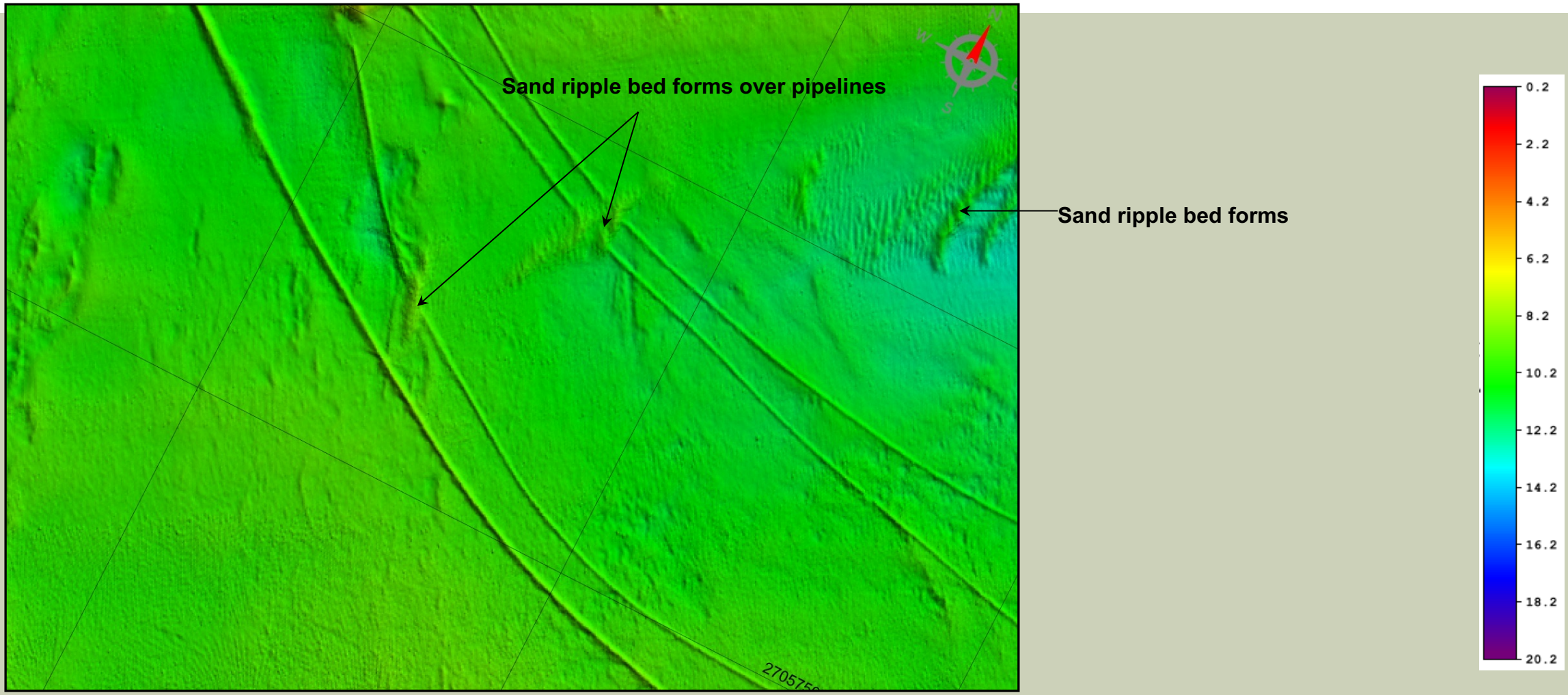


FIGURE 19: MBES DATA SHOWING PIPELINES BURIED WITH SAND RIPPLE BED FORMS

CALCARENITE OUTCROPS & SAND RIPPLES

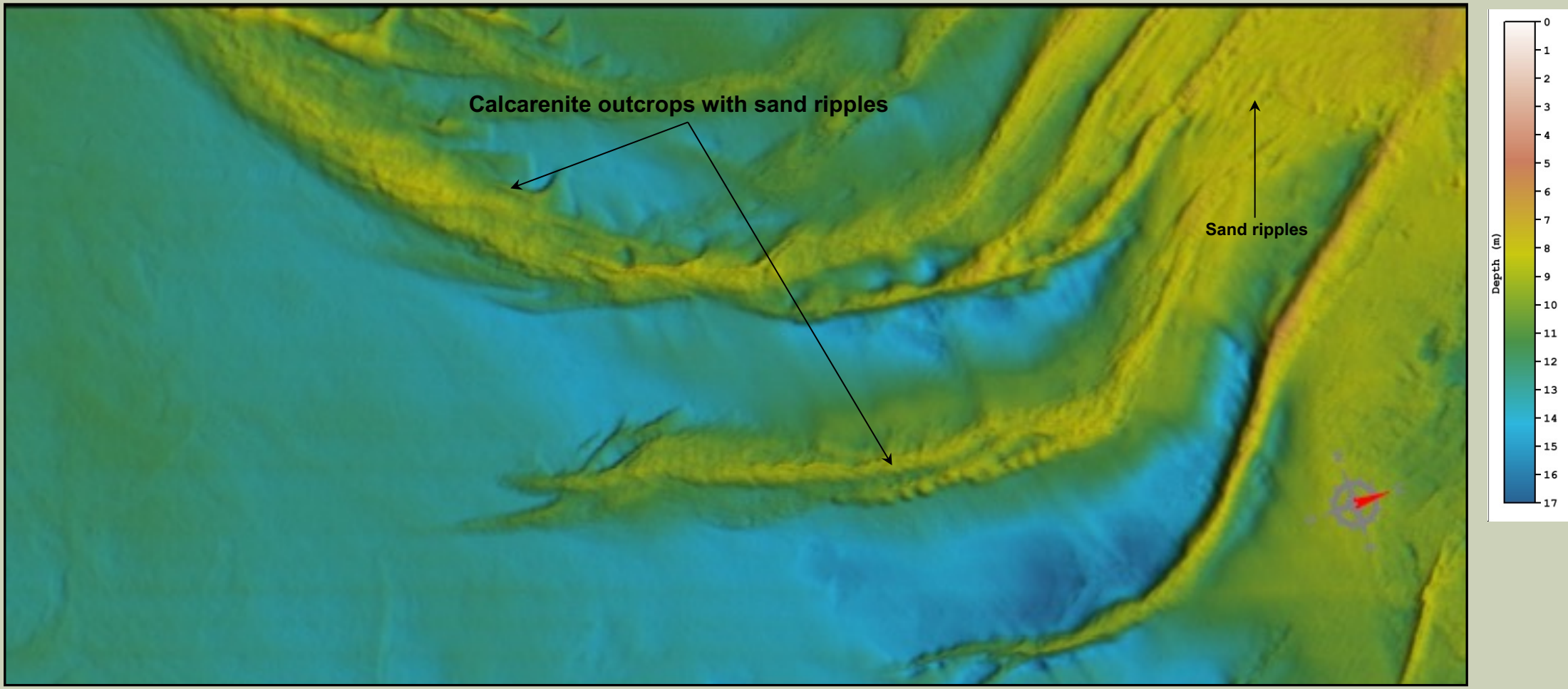


FIGURE 20: MULTIBEAM DATA SHOWING CALCARENITE OUTCROPS OVERLAID WITH SAND RIPPLE BED FORMS

CALCARENITE & SAND RIPPLES

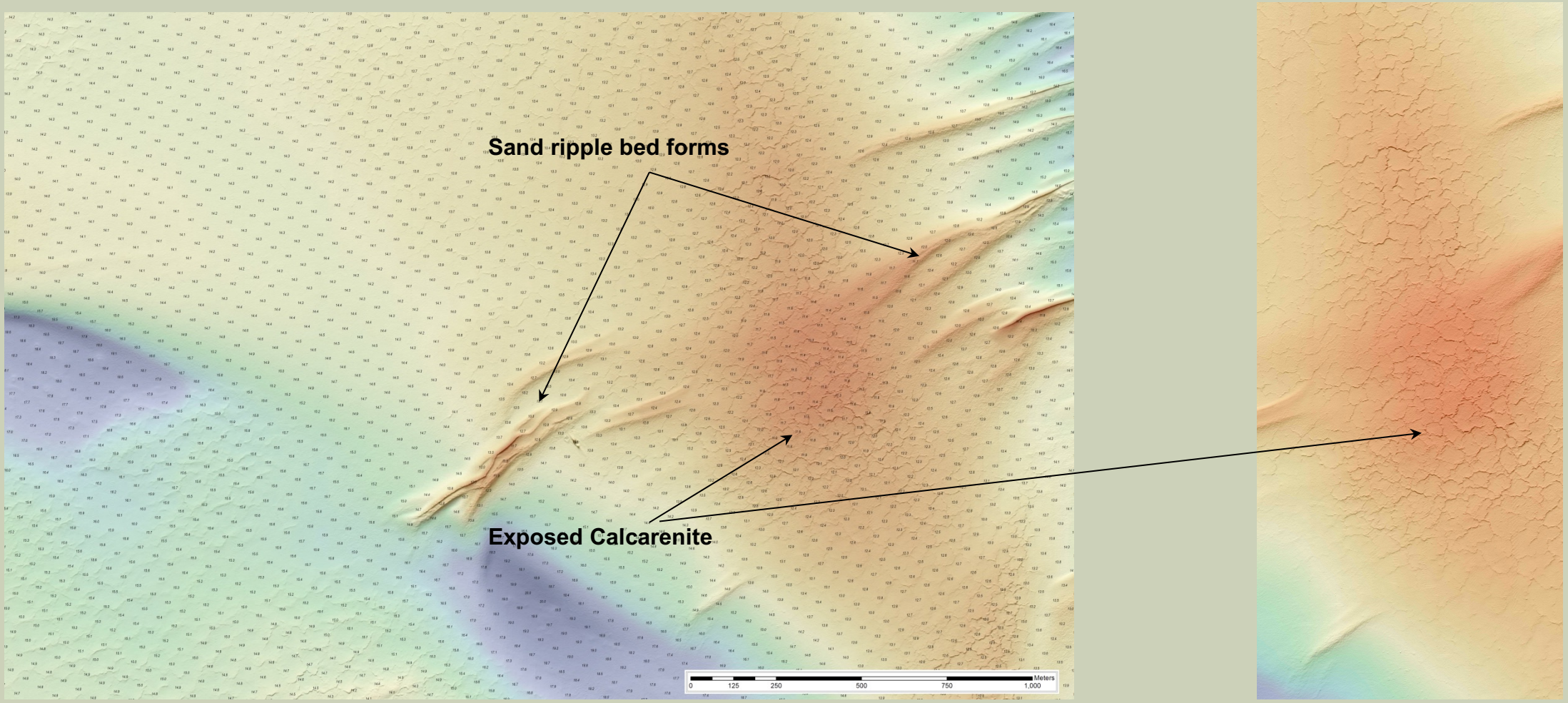


FIGURE 21: MULTIBEAM DATA EXTRACT SHOWING SAND RIPPLES & EXPOSED CALCARENITE

POSITIVE RELIEF CORAL OUTCROP

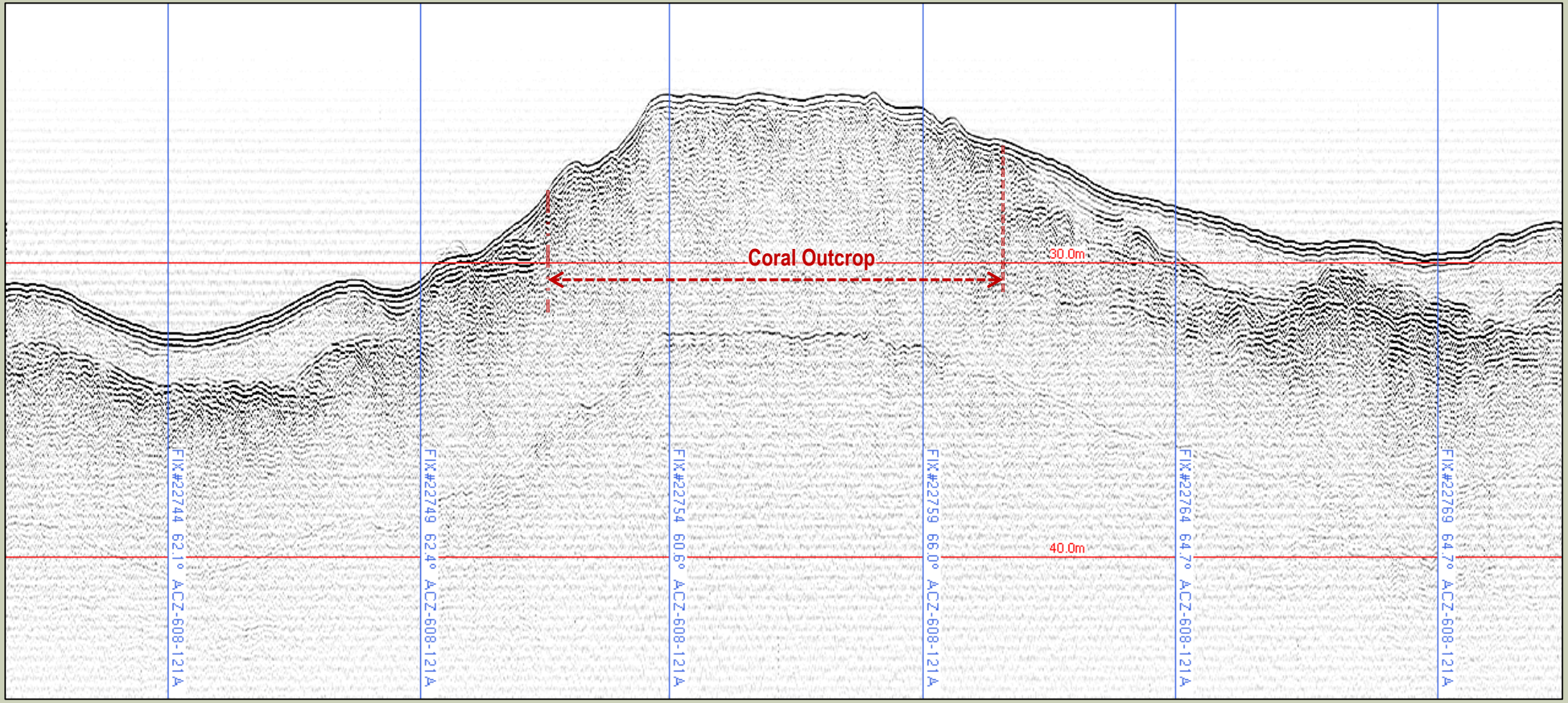


FIGURE 22: SUB-BOTTOM PROFILER DATA EXTRACT SHOWING CORAL OUTCROP

POSITIVE RELIEF CALCARNITE OUTCROP

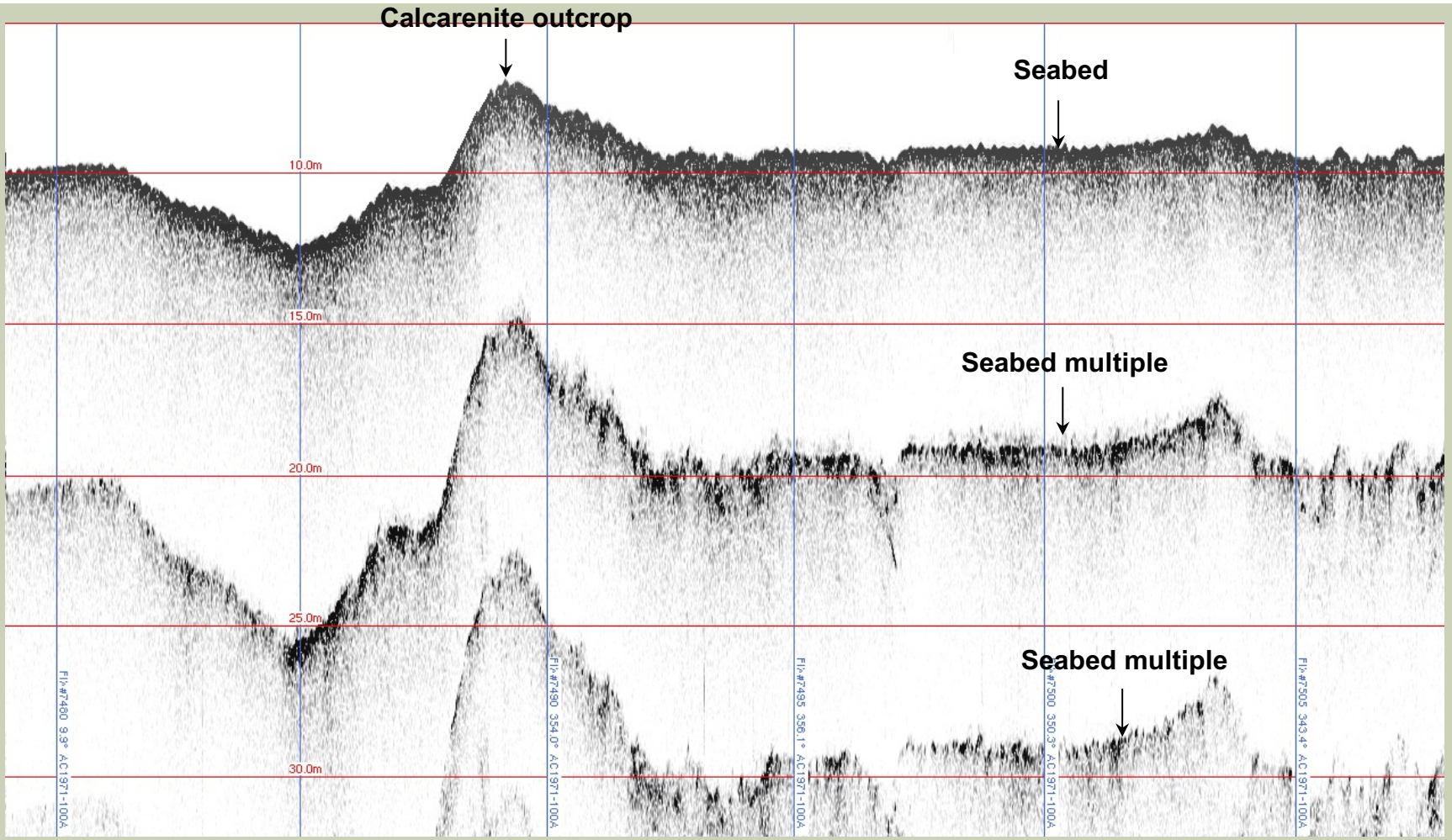


FIGURE 23: CHIRP SUB-BOTTOM PROFILER DATA EXTRACT SHOWING CALCARENITE OUTCROP

OUTCROP/SHALLOW PATCH

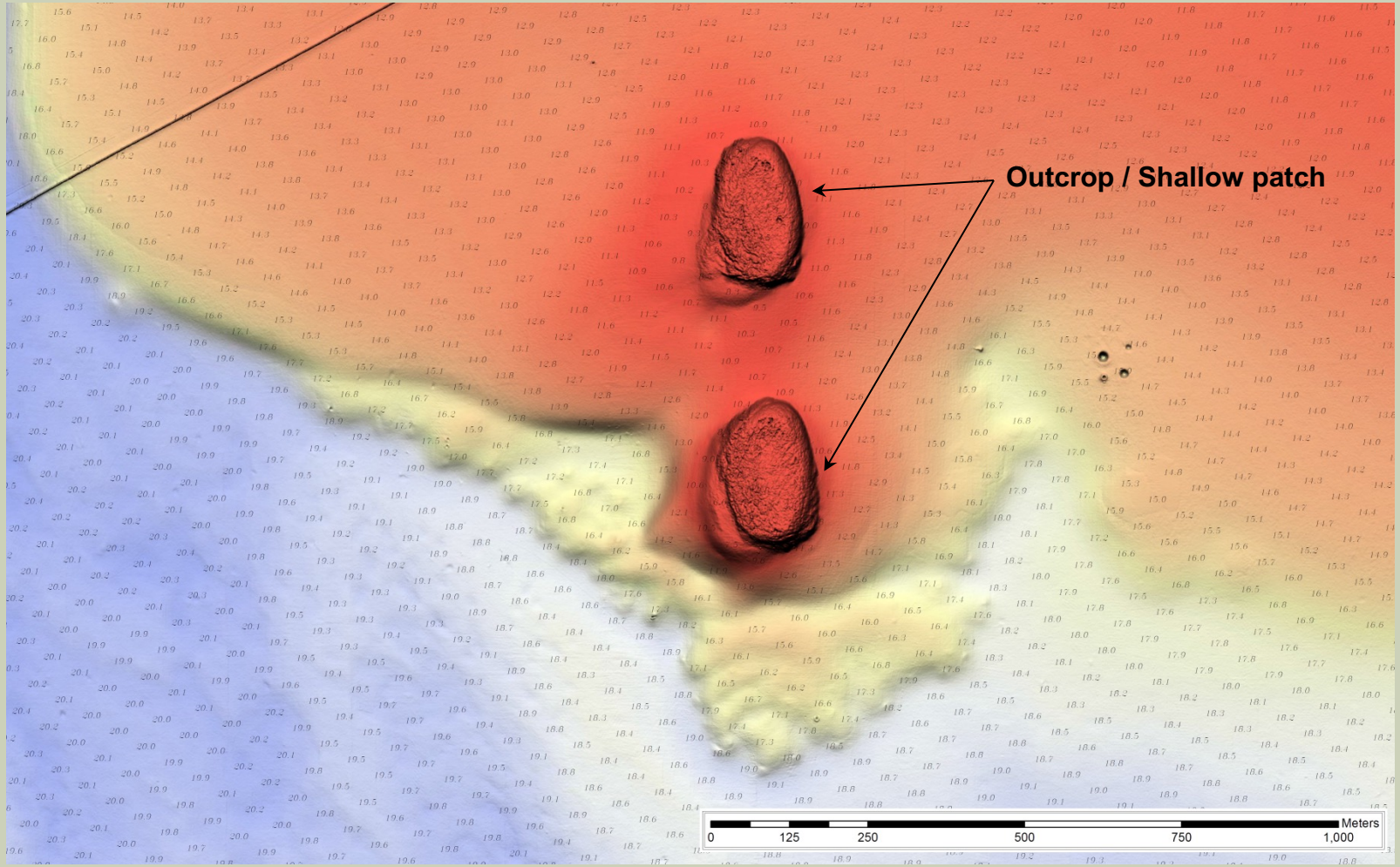


FIGURE 24: MBES DATA EXTRACT OF OUTCROP/SHALLOW PATCH

- Very shallow water depths (<10 m) and sudden depth variations / positive reliefs are some of the major constraints to the surveys and installations as most of the Gulf region oil field developments are extending to very shallow water.

NEGATIVE RELIEF
SEABED TROUGHS & ESCARPMENTS

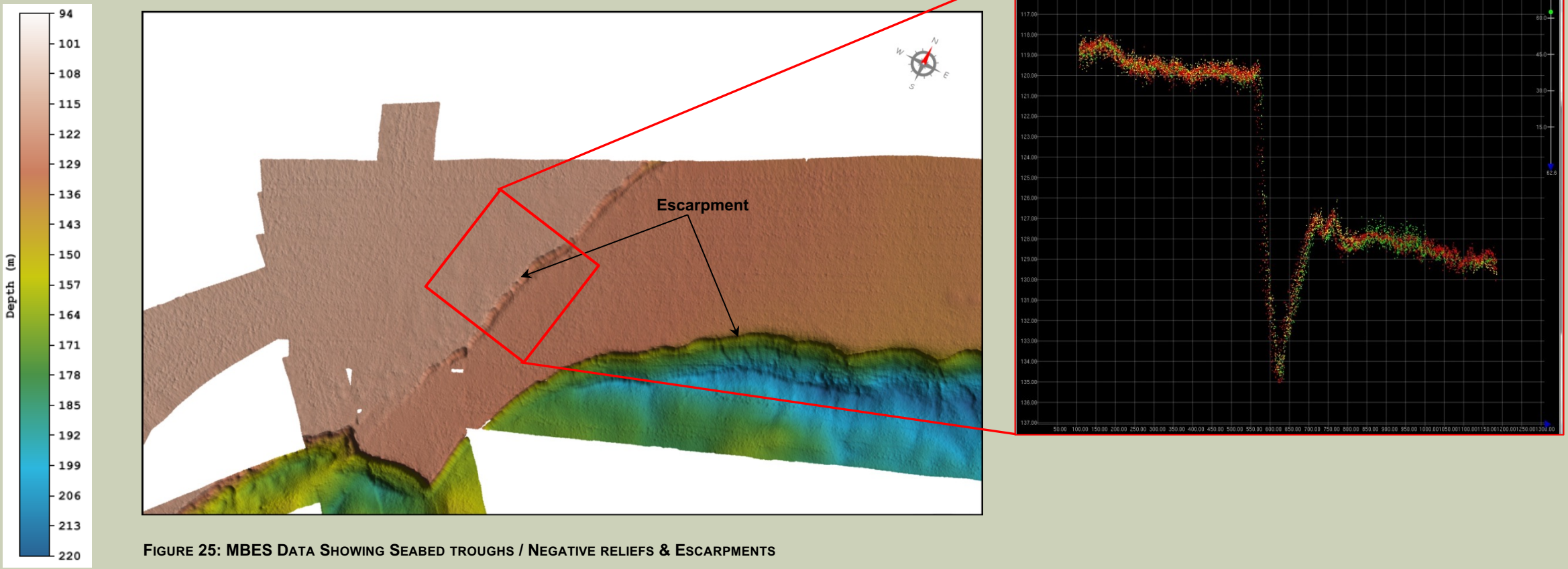
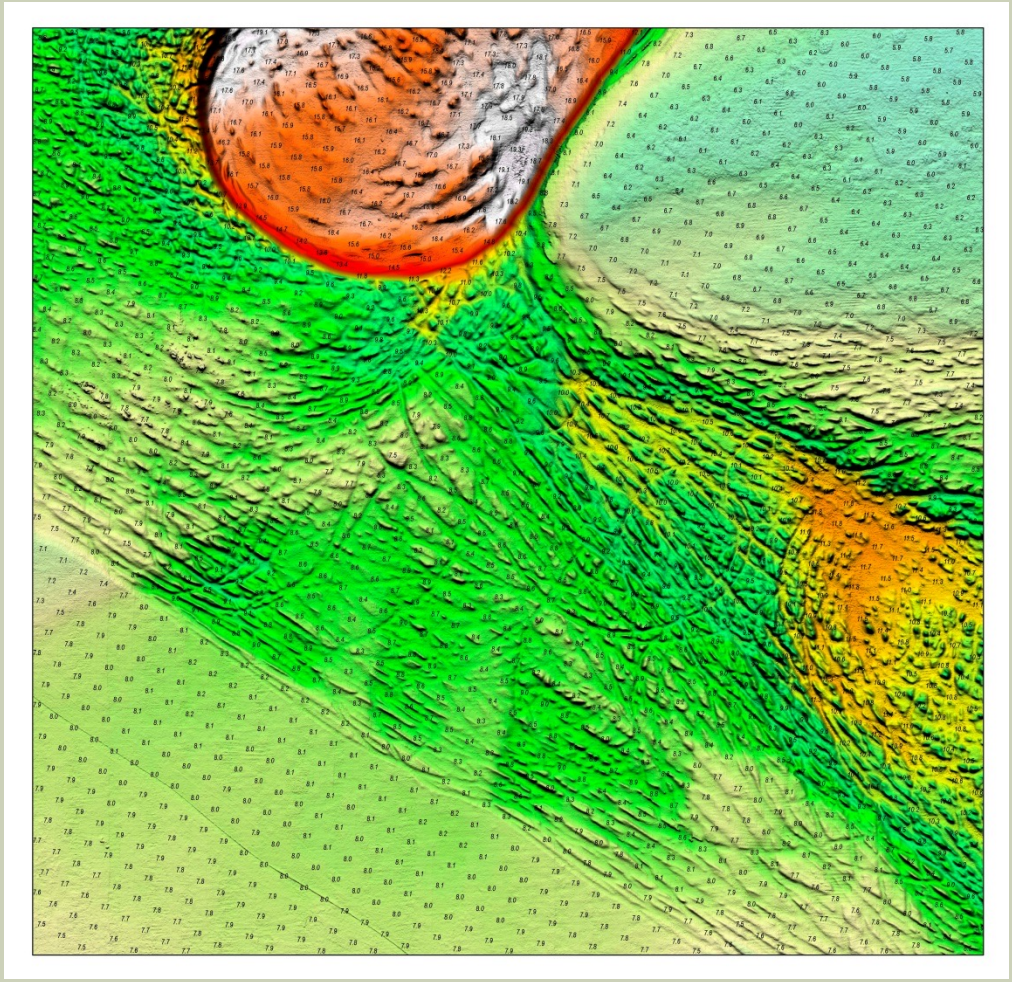


FIGURE 25: MBES DATA SHOWING SEABED TROUGHS / NEGATIVE RELIEFS & ESCARPMENTS

NEGATIVE RELIEF
SEABED TROUGHS & ESCARPMENTS

FIGURE 26: MBES DATA SHOWING SEABED TROUGH / NEGATIVE RELIEF & ESCARPMENT

NEGATIVE RELIEF DUE TO DREDGING



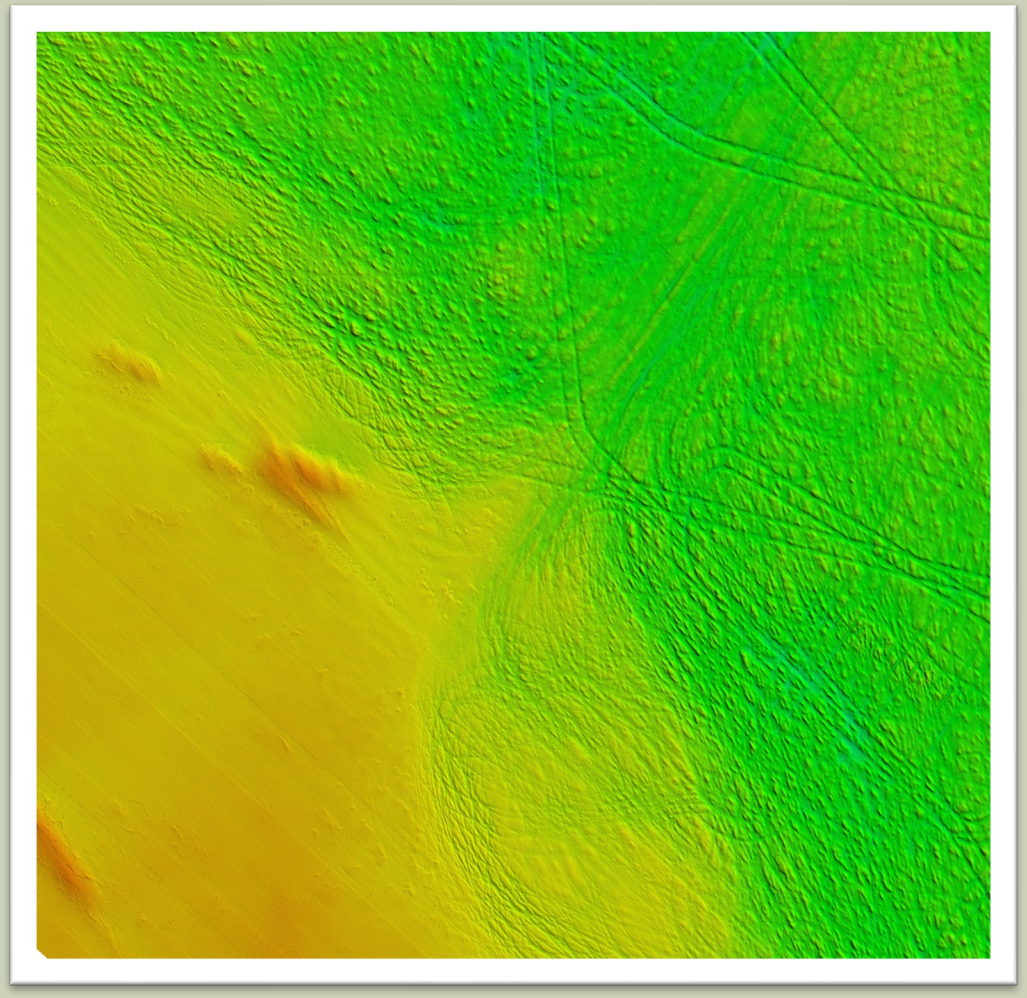


FIGURE 27: MBES DATA EXTRACT OF DREDGED SEABED - MANMADE RUGGED SEABED & NEGATIVE RELIEF

CORALS

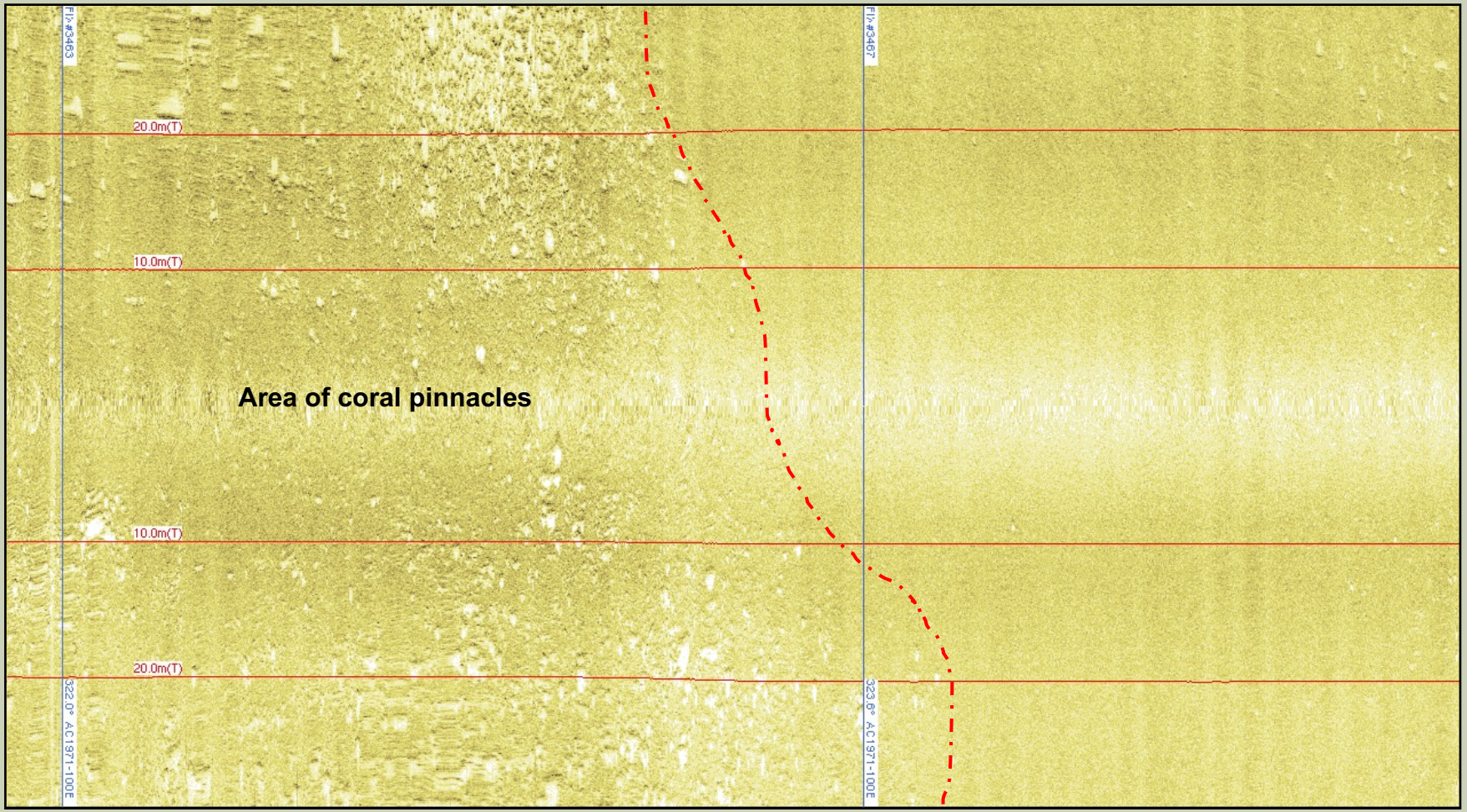


FIGURE 28: SIDE SCAN SONAR DATA SHOWING CORALS

MARINE GROWTHS

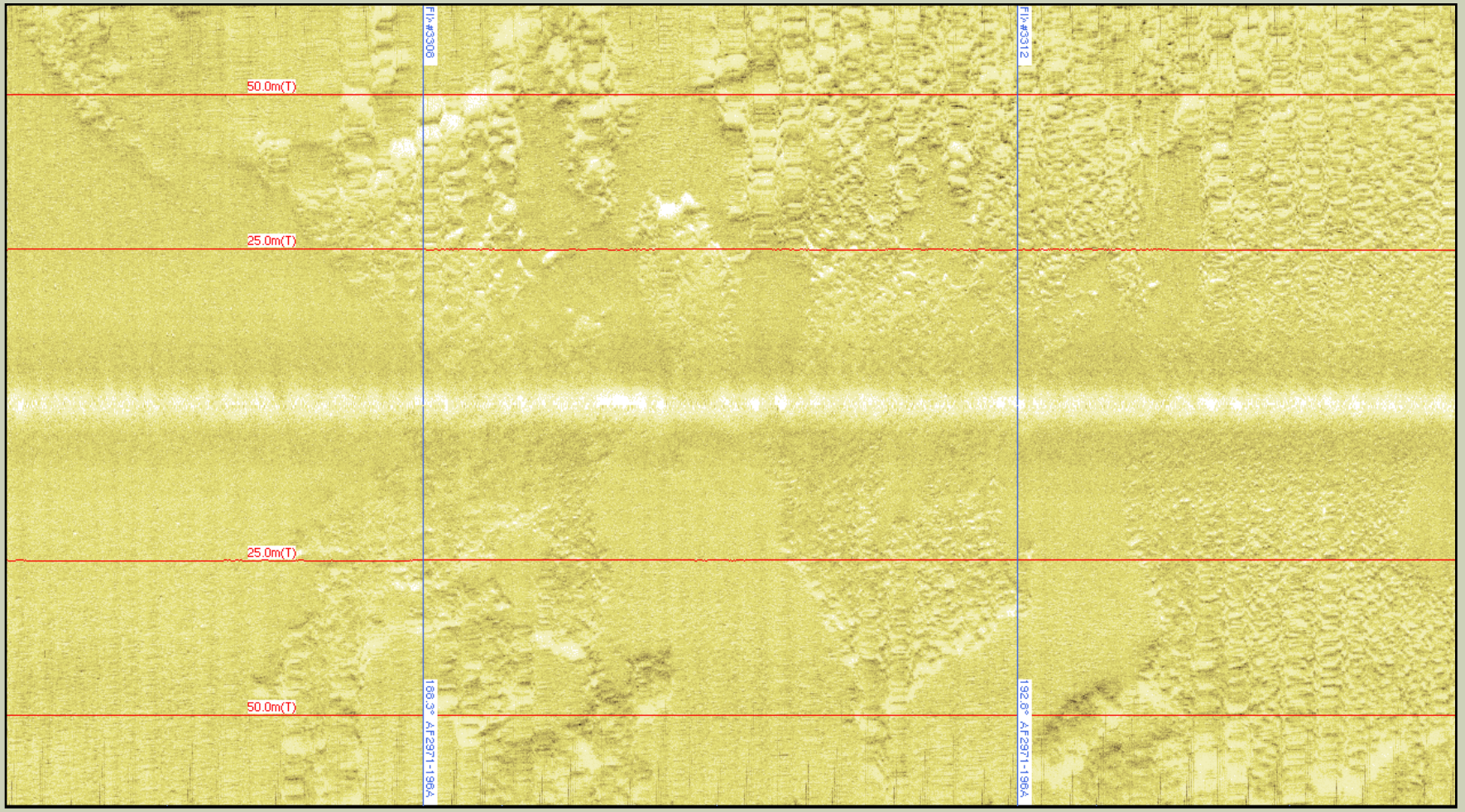


FIGURE 29: SIDE SCAN SONAR DATA SHOWING MARINE GROWTHS

BURIED PALEO CHANNEL

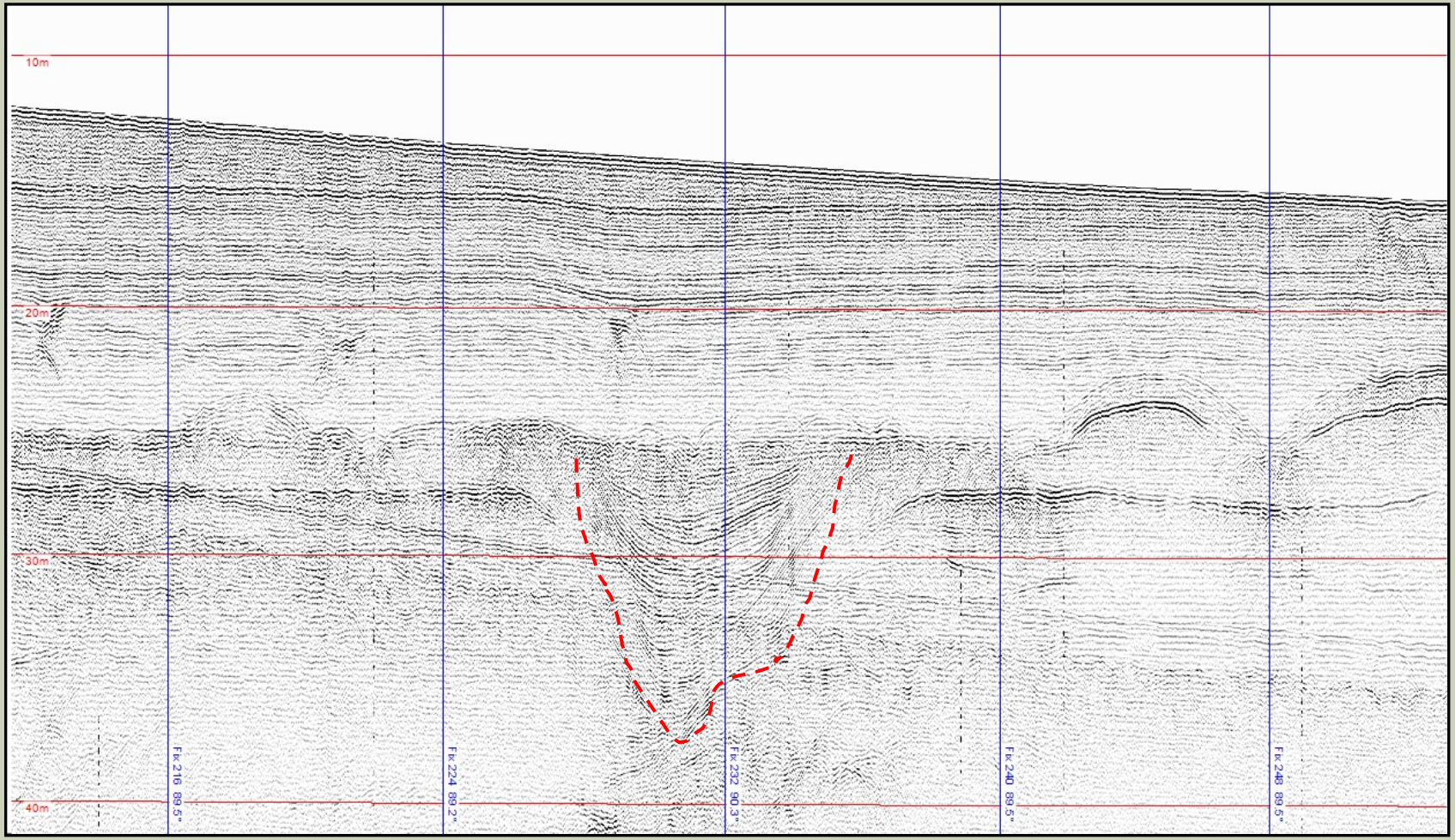


FIGURE 30: SUB-BOTTOM PROFILER DATA EXTRACT SHOWING BURIED PALEO CHANNEL

- Buried channel – Channel/fluvial sediments are highly variable in soil properties and grain sizes vertically and horizontally. Slope of the buried channel sidewalls also pose risk to installations.

CONCLUSION

- An assessment of any seafloor, subsurface geologic, man-made features and conditions that may have an adverse effect on the proposed drilling /installation operations is essential for oil & gas / wind farm industry. Geophysical surveys with side scan sonar, Sub-bottom profiler, multi-beam echo sounder & magnetometer and geotechnical soil analysis are necessary to mitigate any pre-installation and drilling risks and constraints.
- Climate change and the rise in increasingly intense natural events enforce that historical experience is not sufficient to determine safety. It increases the need of multi-disciplinary surveys, complementing with expert teams when evaluating the hazard and risk with cost-effective measures.

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