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Geoacoustic Characterization of Boundary 2001 Experimental Locations

by

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Abstract – DREA has collected geoacoustic data to characterize the experimental areas for the Boundary 2001 sea-trial, in particular Sable Island Bank on the Scotian Shelf. Measurements include bathymetry, vertical incidence seismic reflection, sidescan sonar, wide angle reflection and bottom loss (WARBLE), grab samples, and geotechnical data using a cone penetrometer The Scotian Shelf has numerous surficial seabed features that could create false targets, or "geoclutter", for tactical and low frequency active sonars. It has also been observed that the seabed at experimental location NS-1 is dynamic, bed forms have rotated or been destroyed in a six month interval between sidescan measurements.

I. Introduction

The surficial sediment distribution of the Scotian Shelf (Fig. 1) is closely related to the processes that transpired during and since the last glaciation In general, the shallow water bank areas tend to have sand or gravel overlying glacial till and then a consolidated rock layer (sedimentary offshore and metamorphic inshore). Meanwhile, the deep basins tend to have clays and silts that are washed away from the bank areas and deposited on top of the deeper till and rock layers Osler [1] provides a summary of the geological history, geoacoustic properties of surficial sediments, and general oceanography. Table 1 includes a brief description of the different seismic units

Table 1: Summary of Surficial Sediment Units

Name	Description	Seismic Character	Compressional Sound Speed (km/s)
Scotian Shelf Drift	Glacial Till	Incoherent seismic reflectors	1.75 to 1 92
Emerald Silt	Glaciomarine sediment	Continuous reflectors	1.48 to 1.59
Sable Island Sand and Gravel	Well sorted sand and gravel	Highly reflective	1.6 to 1.8 (sand) 1.8 to 1 9 (gravel)
LaHave Clay	Silty clay confined to basins	Seismically transparent	1.46 to 1.49 km/s
Sambro Sand	Silty sand grading to gravelly/well sorted sand.	Highly reflective	~1.65 km/s

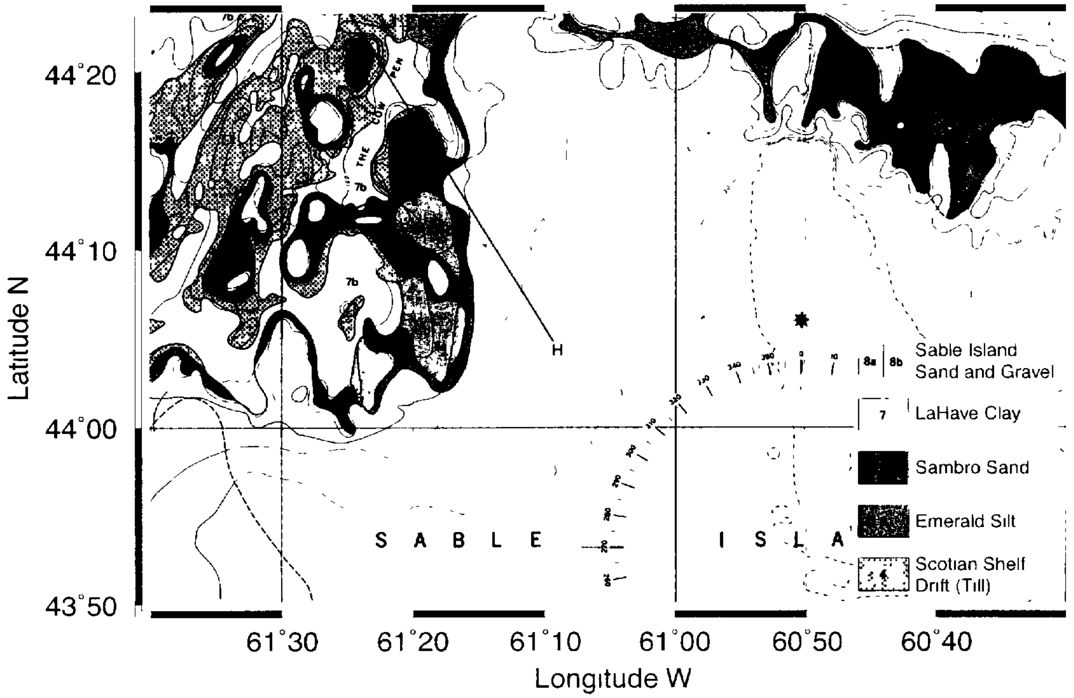

Figure 1 · Surficial geology of the area surrounding experimental site NS-1 from King [2]

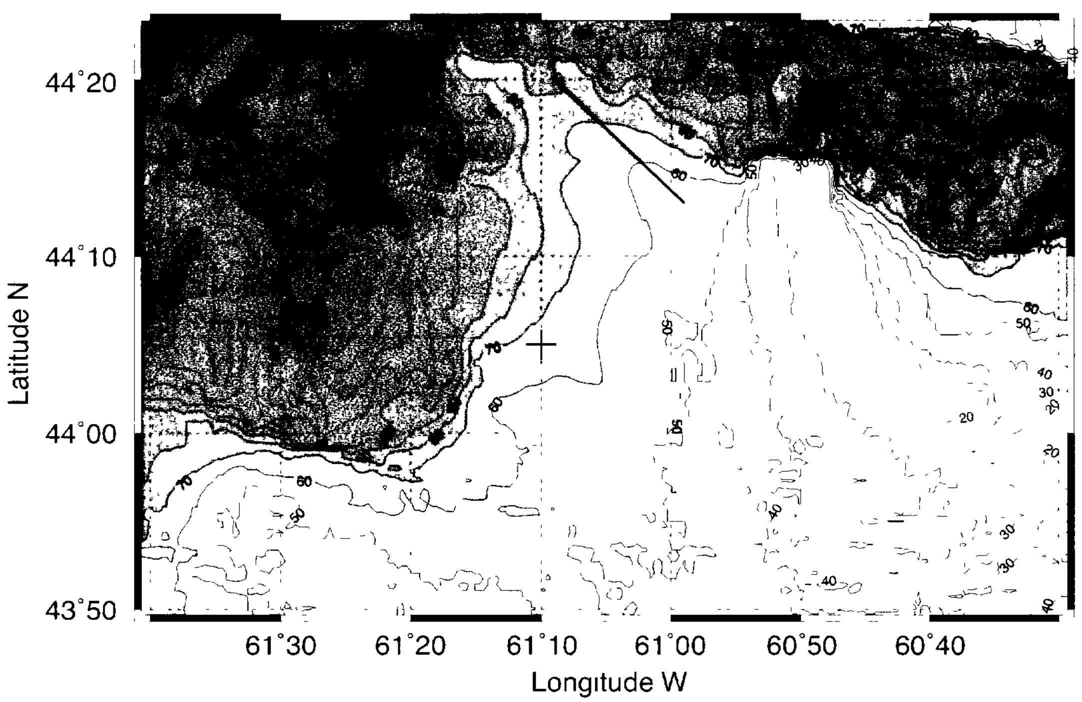

Figure 2: Bathymetry contours of the area surrounding experimental site NS-1 derived from the Canadian Hydrographic Service digital compilation. Approximate location of exposed portion of gas pipeline is in red

Surficial seabed features abound on the Scotian Shelf including: glacial till ridges, gas escape craters, or pock marks (usually in the basins), gravel berms, iceberg keel scours, buried channels, bedrock outcrops, sand waves and ridges, shell beds, and pipelines. Several criteria guided the selection of the experimental site. It is a considerable distance, approximately 45 n mi., from the shelf edge to avoid internal wave activity and strong sound speed gradients It is also away from oil and gas production platforms (the nearest is Alma at 43°35.7N 60°40.9W) and the seismic exploration presently concentrated along the shelf edge to avoid interfering sources of noise It has a predominately sand seabed with a diversity of other seabed types and features nearby And, it has a water depth that is suitable for deploying DREA wide band sonar (WBS) and underwater acoustic target (UAT) research equipment (approximately 60 to 120 m)

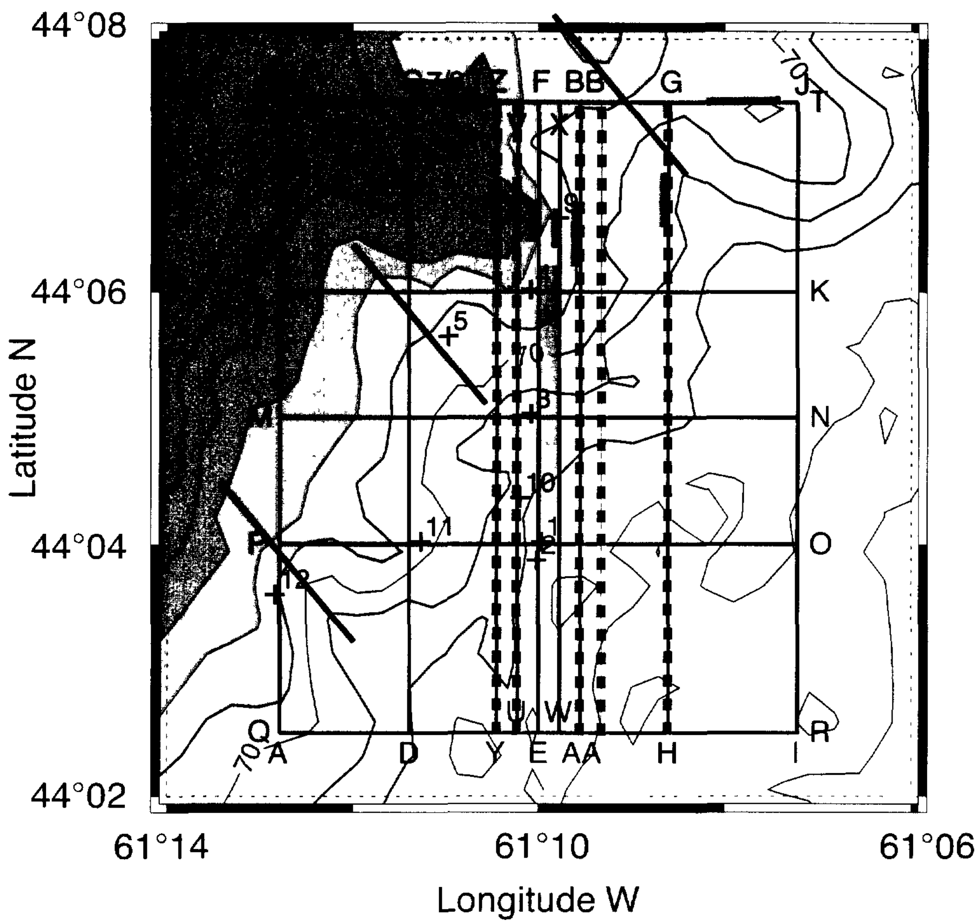

Figure 3. Summary of geophysical observations at NS-1. Bathymetry contours are from a compilation of single channel echo sounder measurements from CFAV Quest. Klein 5500 sidescan and EdgeTech X-star chirp sub-bottom profiler lines collected in October 2000 are marked by the black lines with red letters at end points. Tracks repeated in May 2001 are dashed green lines. Brown + symbols indicate the locations of grab samples and pink lines indicate the extent of a burial channel. Solid red lines mark sand ridge crests

II. Characterization of Surficial Geology

To characterize the surficial geology at NS-1 (44°05N, 61°10W), a series of sidescan and sub-bottom profiler survey lines were collected (Figure 3). Two interesting features were noted in the seismic reflection data. an infilled channel that is at least 5 to 10 m deep and approximately 400 m wide, situated in a swale to the north of NS-1; and an extensive series of depressions, approximately 1 m deep, that have more scatter and higher reflection loss than the surrounding seabed. Some of the depressions appear to be related, or rooted, to an irregular near surface reflector that tends to be from 0 to 3 m below the surface.

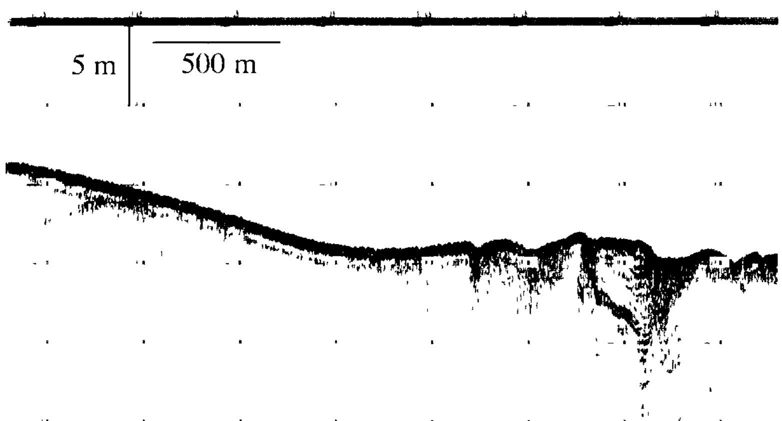

Figure 4. Hull mounted EdgeTech X-star, 5 ms 2 to 8 kHz chirp, sub-bottom profile along W-X. Note the filled channel on the right and the near surface reflector on the left.

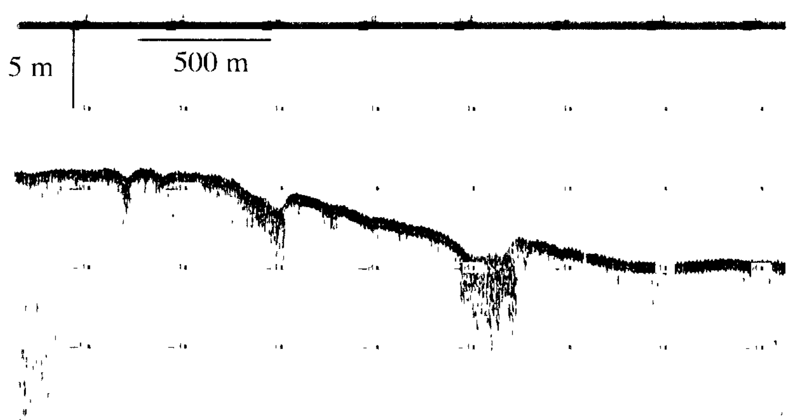

Figure 5: Hull mounted EdgeTech X-star, 5 ms 2 to 8 kHz chirp, sub-bottom profile along T-S Note the depressions with higher scatter and reflection loss and the near surface reflector on the left and right sides that may the base of the depressions.

The sidescan data (Fig 6) reveal an extensive series of quasi- parallel ribbons that are approximately 30 m apart and roughly parallel to bathymetry contours. They are likely parallel to the mean flow direction of the current, forming as the helical particle motion of the near seabed current deposits material in ribbons In October 2000, mega-ripples with wavelengths of 3 to 4 m and heights of ~0.2 m were superimposed on the ribbons (Fig 7a). The asymmetric shape of the mega-ripples is also indicative of a mean flow to the northeast. For the mean grain sizes in the areas where ripples are found (well sorted medium sand, 0.25 to 0.5 mm, ϕ=1.0 to 2.0), currents in the range of 0.4 to 0.6 m/s would have been required to create the mega-ripples On an Acoustic Doppler Current Profiler moored nearby from 15 to 25 October 2000, the largest near seabed currents were observed during the passage of Hurricane Michael on 19 October 2000. As the magnitude of these currents is in the required range for bed form development, and the sidescan data were collected days following the Hurricane, it is speculated that the mega-ripples were formed by the Hurricane and have since decayed (Fig 7b) The ribbons seem to be a more persistent feature as they were observed in archival data in 1982 (*C.S.S. Hudson* cruise 82-040) and during the repeat survey in May 2001 (Fig. 7b).

The sidescan data (Fig. 6) also reveal higher reflectivity patches that are quasi-orthogonal to the ribbons in the southern part of the survey area and more randomnly oriented in the north These patches are the depressed areas observed in the sub-bottom profiles (Fig 5) They contain material with a larger grain size (medium to very coarse sand, 0 5 mm to 2 mm, ϕ=-1.0 to 1.0) than the surrounding areas. In the October 2000 data (Fig. 8a), they contained symmetric ripples with a wavelength of ~2.5 m and height of ~0 3 m. In the May 2001 data (Fig. 8b), their wavelength is roughly half and they have rotated by ~30° towards a more east-west orientation. The symmetric nature of the ripples suggests that they were probably formed by wave motion.

Very few rocks, or similar obstacles, were observed in the survey area, though boulder fields were seen to the south of the survey area during turns An example of a rock can be seen in Figure 8 and it appears to be have been partially buried in the time interval from October 2000 to May 2001. All of the aforementioned observations, clearly indicate that the seabed at this location is dynamic. If a characterization of the bed forms is necessary to understand the roughness parameters for seabed scattering, then this characterization must be done coincident with the scattering measurements. Further, these observations have implications for marine engineering as the seabed may have been assumed to be quiescent at this depth.

III. Geo-acoustic and Geo-technical Properties

Geoacoustic properties of the seabed are required for modeling the reverberation and propagation data collected during the Boundary 2001 sea-trial. DREA is pursuing two methods for obtaining this information The first is using the wide angle seismic reflection and bottom loss (WARBLE) technique of Holland and Osler [3] using a towed source (GeoAcoustics boomer plate) and moored receiver (UAT). The second method is direct *in-situ* measurements using a free fall cone penetrometer (FFCPT) that is under development and will eventually carry optional geoacoustic modules (*e.g.* resistivity).

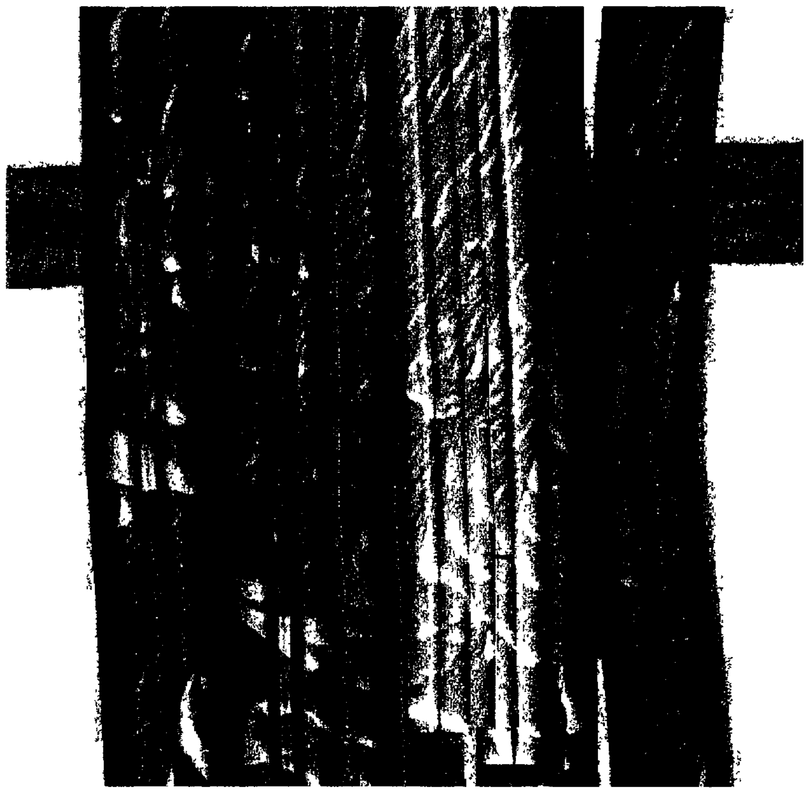

Figure 6: Mosaic of Klein 5500 sidescan data in the central corridor (lines Y-Z, U-V, E-F, W-X, AA-BB, and yellow box in Fig. 3). There is an extensive series of parallel ribbons oriented northeast to southwest and quasi-orthogonal patches with higher scatter (the seabed depressions) Width of the image is 2300 m.

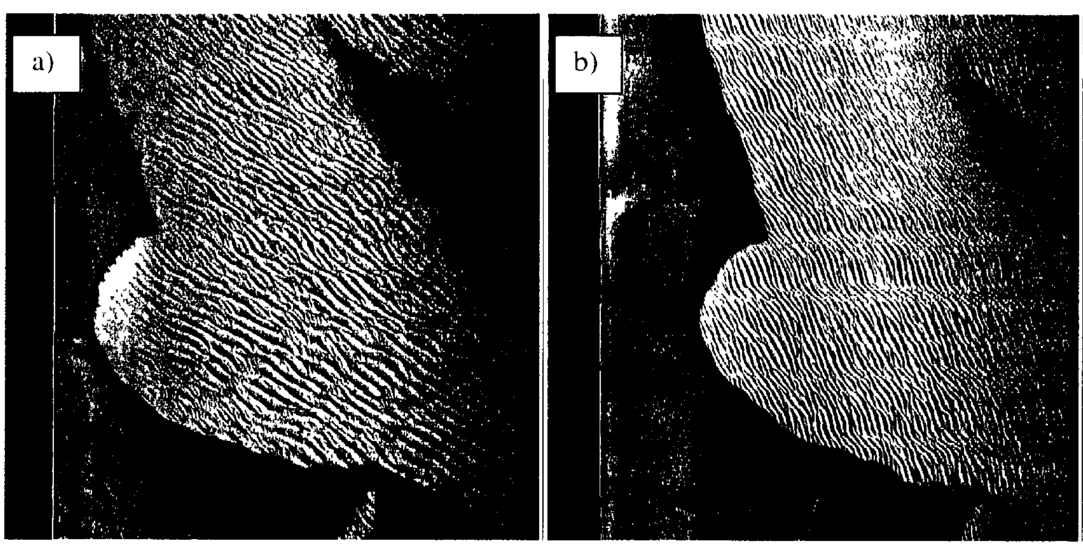

Figure 7: Klein 5500 sidescan images on line G-H from a) October 2000 and b) May 2001. The wavelength and orientation of ripples has changed Width of images is 150 m

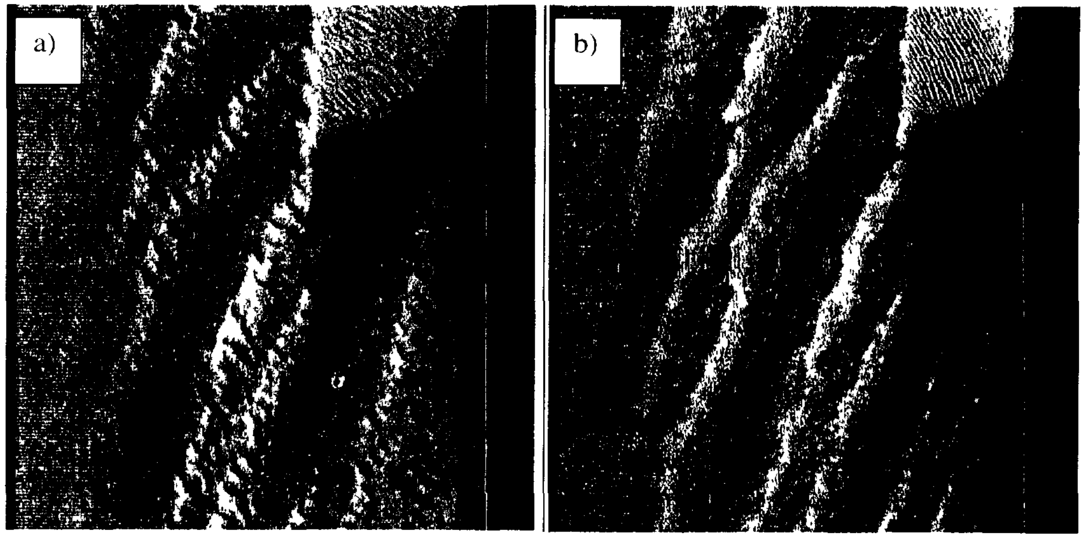

Figure 8: Klein 5500 sidescan images on line G-H from a) October 2000 and b) May 2001 The mega-ripples superimposed on the ribbons have decayed and the rock has been more deeply buried. Width of images is 150 m.

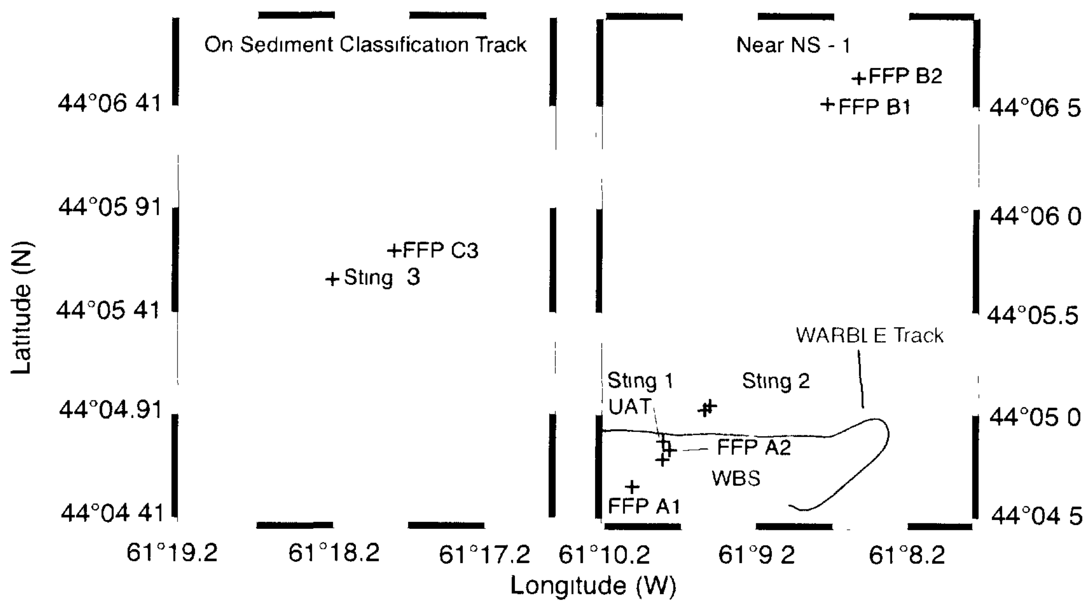

Figure 9: Location map of the WARBLE run and penetrometer (FFCPT and STING) drops near NS-1.

The location of the WARBLE run, FFCPT drops and seabed terminal impact naval gauge (STING) drops near NS-1 are displayed in Figure 9. FFCPT and STING drop locations were selected to include: the depressions with high scatter, the area where WBS mono-static and bi-static experiments were conducted, and an area where NRV Alliance conducted some direct path scattering measurements. Results from the WARBLE run are not yet available.

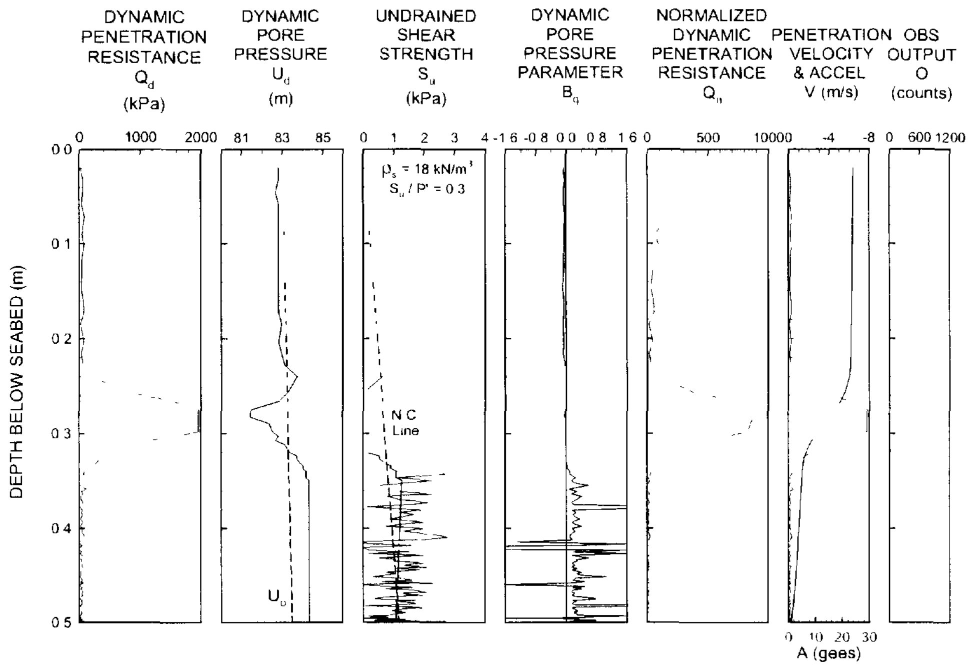

Figure 10: FFCPT material parameters versus depth for a deployment near NJ-1 on the ONR Strataform. Analysis provided by Christian Situ Geoscience Inc.

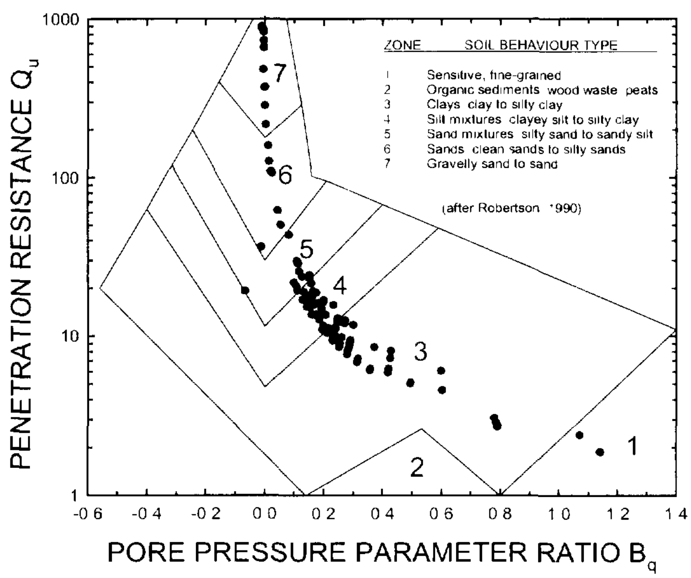

Figure 11: Sediment classification chart using penetration resistance and pore pressure parameter data displayed in Figure 11. Marine sediment types range from clays (3), through silts(4) to sand (5) and gravels (7). Dots are color coded from violet at the surface to red at depth `Analysis provided by Christian Situ Geoscience Inc.

The FFCPT is a free fall probe that has been developed to measure geotechnical and geoacoustic properties of the seabed [4]. Its combination of geotechnical sensors, acceleration, pore pressure, hydrostatic pressure, and optical backscatter, represents a significant advance over acceleration-based penetrometers, such as the expendable bottom penetrometer (XBP), and permits the direct application of geotechnical analysis methods and parametric-based correlations already long established in engineering practice. It provides two independent means of calculating the undrained shear strength [4] and utilizes a standard CPT-based sediment classification chart as part of the interpretation algorithm [5]. Near NJ-1 (39°14.949N, 72°51.798W) on the ONR Strataform area, the FFCPT has detected and measured the geotechnical properties of a pervasive near surface sand layer that is in between clay and silt layers (Figs. 10 and 11) Similar analyses will be conducted near NS-1 on the Scotian Shelf, though the depth of penetration is limited by the diameter of the prototype FFCPT and the hardness of the sand seabed.

IV. Conclusions

DREA has collected geoacoustic data to characterize the experimental areas for the Boundary 2001 sea-trial, with particular emphasis on Site NS-1 on Sable Island Bank, Scotian Shelf, Nova Scotia. Measurements include bathymetry, vertical incidence seismic reflection, sidescan sonar, geoacoustic properties from WARBLE inversions, grab samples, and *in-situ* data using a prototype cone penetrometer that is being modified to carry geoacoustic sensor modules. At NS-1, there is an extensive series of flow parallel ribbons intersected by quasi-orthogonal depressions. The depressions are erosional patches that are composed of coarser grained material, contain wave formed ripples, and manifest themselves as having higher scatter at vertical incidence and at shallow grazing angle. The seabed at NS-1 is dynamic as bed forms observed in October 2000 have rotated or been destroyed in the time interval until the repeat survey in May 2001. This may have implications for acoustic scattering experiments that rely on quantitative roughness parameters of the seabed and marine engineering projects that may have been assumed that the seabed is quiescent at this depth.

V. Acknowledgements

The author would like to acknowledge the contributions from the following groups and individuals: the Mine Counter Measures group at DREA for assistance in collecting the sidescan data; the Canadian Forces Route Survey office for assistance in sea-trials and preparing a mosaic of the sidescan data, the Canadian Hydrographic Service and Geological Survey of Canada-Atlantic for permission to use their bathymetric compilation; Dr. Ned King and Dr. Michael Lee of the GSC-Atlantic for assistance in interpreting the sidescan data and sediment dynamics; and Brooke Ocean Technology and Christian Situ Geosciences for material concerning the free falling cone penetrometer.

VI. References

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