A PRELIMINARY STUDY OF THE GEOACOUSTIC PARAMETERS OF GASSY SEDIMENT IN ST. MARGARET'S BAY, NOVA SCOTIA.

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1. INTRODUCTION

In recent years, St. Margaret's Bay, Nova Scotia, has become an important experimental site for Defence R&D Canada. It is well sheltered, has low maritime traffic, and is relatively close to the city of Halifax. Consequently, there is a growing need for oceanographic models for the bay, including geoacoustic models to predict sound propagation. The deep central basin of St. Margaret's Bay is an interesting region for geoacoustic studies because of the gas bubbles embedded in the surficial layer of sediment. This gas can be seen on sub-bottom profiles as a reflection horizon at depths of 2 to 4 m below the seafloor.

The geoacoustic parameters of gassy sediment are complicated to measure since they vary with frequency. The sound speed and attenuation of a surficial gassy layer have been measured by some, like Gardner [1], for frequencies between 3 and 100 kHz. However, very few have documented the values of these parameters for frequencies below 1 kHz. This work aims at estimating the values of these parameters at frequencies below 500 Hz.

2. METHOD

In this paper, measured and modeled Transmission Loss (TL) as a function of range were compared to estimate the values of geoacoustic parameters in gassy sediment. The method consists of modeling the acoustic propagation of a simulated signal for different seabed models to calculate the TL *vs.* range. These curves are then compared to the measured TL from real underwater sources. A good match of the peaks, troughs and the general slope between the measured and modeled TL *vs.* range should correspond to a good estimate of the seabed parameters. The preliminary results presented here were obtained by visually matching the measured and modeled TL of low-frequency sources in the deep central basin of St. Margaret's Bay.

2.1 Experimental and Simulated Data

Data from two similar experiments were used to measure *in situ* TL as a function of range. In each case, a low-frequency underwater source was towed along a straight transit and recorded on a vertical line array of hydrophones at ranges varying between 40 m and 800 m. Each of the two sources emitted a narrowband signal of four frequencies ranging between 72 Hz and 451 Hz. TL as a function of range was measured for all eight frequencies and for each hydrophone of the vertical array. A similar set of curves was then produced for simulated signals propagated over several seabed models using a parabolic equation model [2].

2.2 Seabed models

Two seabed models were generated as a starting point for the analysis. The compressional sound speed and attenuation estimates of the first model followed the theory developed by Anderson and Hampton [3, 4]. According to this theory, at frequencies below the resonance frequency of the gas bubbles embedded in the sediment, the sound speed of the compressional sound wave can be over ten times slower than in gas-free sediment. The theory describes how a small quantity of gas can significantly increase the attenuation of the compressional sound wave, while it has little effect on the sound speed.

Properties of the sediment and the embedded gas have to be known with great accuracy to evaluate compressional sound speed (c_p) and attenuation (α_p) using the Anderson and Hampton formulas, however, little is known about the gas found in St Margaret's Bay. Consequently, our first seabed model used values of sound speed and attenuation that were calculated by comparing the characteristic of St Margaret's Bay to the similar and well studied environment of Eckernförde Bay, in the Baltic Sea [5]. These calculations led to a very low sound speed of 75 m/s, and an attenuation of 1.0 dB/λ, for frequencies between 72 and 451 Hz.

The second seabed model was developed by following a study published in 1977 by Kepkay [6]. In his thesis, Kepkay reported *in situ* measurements of sound speed in the deep central basin of St. Margaret's Bay. According to these measurements, the average sound speed was 1364 m/s in the top 2 m of sediment, for frequencies presumed lower than the resonance frequency of the gas bubbles. This number is lower than the estimated sound speed in saturated gas-free sediment, 1440 m/s [6], but much higher than predicted by the Anderson and Hampton formula. Since Kepkay did not measure the attenuation in the sediment, this second model included the same attenuation value as in the previous model.

In both seabed models, the geoacoustic parameters other than the c_p and α_p of the gassy sediment layer, including the shear sound speed (c_s), attenuation (α_s), and density (ρ), were estimated from Piper and Keen [7], and Osler [8].

After comparing the TL produced using the two seabed models with the measured TL *vs.* range, each parameter characterizing the gassy layer was modified individually to analyze its influence on the TL of the signal. A range of seabed models were then produced and preliminary results of geoacoustic parameters for the deep central basin were obtained by retaining the seabed model producing the best visual match of measured and modeled TL *vs.* range.

3. RESULTS

Table 1 presents the geoacoustic parameters corresponding to the seabed models presented in the previous section. Models are produced by using one of the three Gassy Lahave clay layers overlying the other sediment layers. These gassy layers correspond to: (a) the Anderson and Hampton theory, (b) the measurements from Kepkay, and (c) the final model producing the best TL match.

Table 1. Geoacoustic parameters used to construct three seabed models, corresponding to (a) the Anderson and Hampton theory, (b) the measurements from Kepkay, and (c) the final model producing the best TL match.

Sediment		Thickness [m]	ρ [g/cm^3]	C_p [m/s]	α_p [dB/λ]	c_s [m/s]	α_s [dB/λ]
Gassy Lahave clay	a	2	1.25	75	1.00	0	1.6
	b	2	1.14	1364	1.00	50	0.5
	c	3	1.14	1100	15.00	50	0.0
Saturated Lahave clay		2	1.27	1440	0.05	75	0.0
Lahave clay		10	1.56	1480	0.03	125	1.0
Till, Gravel		∞	2.00	1900	0.48	450	3.0

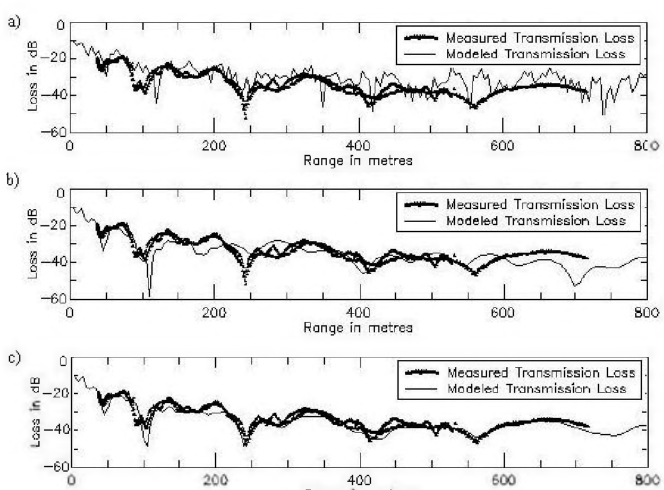

Fig. 1. Comparison of TL vs. range for simulated and measured signal at 117 Hz, seabed from a) Anderson & Hampton theory, b) Kepkay's measurements, and c) best visual match of data.

Figure 1 presents the comparison between the real and modeled TL *vs.* range using the three seabed models presented in Table 1. Here, the black dots represent the measured TL *vs.* range, and the black lines represent the modeled TL *vs.* range at a frequency of 117 Hz and a hydrophone depth of 29 m. The double line formed by the black dots is caused by the duplication of ranges from the symmetrical source transiting towards and past the array.

4. DISCUSSION

The preliminary results presented here introduce a geoacoustic model for St Margaret's Bay that produce reasonable TL match at frequencies below 500 Hz. In future work an inversion algorithm will be used to refine our model and evaluate the changes in compressional sound speed and attenuation with frequency. A better comprehension of the very-low frequency acoustic response in gassy sediment will help localize more accurately targets in coastal environments like bays and harbours. This inversion analysis will allow calculations of uncertainties associated with the different geoacoustic parameters, which will provide valuable insight for further improvements to target localization algorithms.

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