Geoacoustic Characteristics of P-Wave Velocity in Donghae City - Ulleung Island Line, East Sea: Preliminary Results

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Abstract

Donghae City - Ulleung Island Line (DC-UI Line) is a representative line for underwater and geoacoustic modeling in the middle western East Sea. In this line, an integrated model of P-wave velocity is proposed for a low-frequency range target (<200 Hz), based on high-resolution seismic profiles (2 - 7 kHz sonar and air-gun), shallow and deep cores (grab, piston, and Portable Remote Operated Drilling), and outcrop geology (Tertiary rocks and the basement on land). The basement comprises 3 geoacoustic layers of P-wave velocity ranging from 3750 to 5550 m/s. The overlying sediments consist of 7 layers of P-wave velocities ranging from 1500 to 1900 m/s. The bottom model shows that the structure is very irregular and the velocity is also variable with both vertical and lateral extension. In this area, seabed and underwater acousticians should consider that low-frequency acoustic modeling is very range-dependent and a detailed geoacoustic model is necessary for better modeling of acoustic propagation such as long-range surveillance of submarines and monitoring of currents.

Keywords: *Geoacoustics, P-wave velocity, Bottom model, East Sea, South Korea Plateau*

I. Introduction

Geoacoustic modeling has been developed to predict sound transmission through submarine layers of sediment and rock [1-4]. It demands a geoacoustic model with measured, extrapolated, and predicted values of geoacoustic parameters controlling acoustic propagation [5-6]. Construction of the geoacoustic model starts with a bottom model reflecting the real sea bottom in terms of lateral and vertical properties of compressional wave velocities in the area of interests.

Bottom model comprises bathymetry, boundary geometry, and true thickness of sediment/rock layers. This bottom model is based on a stratigraphic model to be constructed using data sets of marine geology and geophysics in the study area. For the bottom model, boundaries of each layer in the stratigraphic model can be merged or split and the number of layers is adjusted efficiently according to a target frequencies of acoustic waves. The target frequencies have general ranges of 200 Hz and below, 200 to 1000 Hz, and 1000 Hz to the above for practical purposes [1, 7].

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Donghae City - Ulleung Island Line (DC−UI Line) is a representative line for underwater and geoacoustic modeling in the middle western East Sea (Figs. 1 and 2). In the coastal part of this area, a recent study pointed up more complete understanding of the sea bottom for better modeling of acoustic propagation [8]. The present paper will propose an integrated model of P−wave velocity for a low−frequency range target (<200 Hz), based on high−resolution seismic profiles (2 - 7 kHz sonar and air−gun), shallow and deep cores (grab, piston, and Portable Remote Operated Drilling), and outcrop geology (Tertiary rocks and the basement on land) in the region of the DC−UI Line. For both ocean and seabed acoustians, this model helps fulfill low−frequency acoustic works of underwater and sea bottom in the area such as long−range surveillance of submarines or monitoring of currents.

II. Materials and Methods

Including the DC−UI Line of 137 kilometers, a total of 1,100 line kilometers of high−resolution seismic data (air−gun and 2 - 7 kHz sonar) was gathered in the western shelf and slope margin of the South Korea Plateau [9]. Air−gun profiles use a 96−channel streamer and sources with 635 cubic inches in the R/V Tamhae II. The record length is 6 sec and sampling rate is 1 ms. The shot point interval per shot is 25 meters controlled by the Differential Global Positioning System (DGPS). For Chirp data of the DC−UI Line, we referred to the profiles of Lee [10], Lee and Chough [11], and Lee et al. [12]. The Chirp sonar system (Datasonics CAP−6000W) is a tuned−frequency profiler with a frequency band of 2−7 kHz as a source signal [10].

This study analyzes a total of 51 piston cores and 2 long cores, collected by the R/V Tamhae II in 2000 ~ 2001. Age constraints for the core sediments are based on the K−Ar dating of the tephra layers within two long cores of DH−1 (~ 24 m in length) and DH−2 (~ 28 m in length) [13−14]. The K−Ar datings were conducted by the Static Vacuum Mass Spectrometer (SVMS) VG−5400 in the Korea Basic Science Institute. Geological field surveys for the basement were concerned with Tertiary, Paleozoic, and Precambrian rocks and volcanics in the Bukpyong, Okgye, and Samcheok areas on land. Detailed mapping, sedimentary facies analysis, and sampling of the rocks were fulfilled at 14 sites along the shoreline of the study area.

P−wave velocities of the 51 piston cores and 2 long cores were measured in laboratory at ~ 10 cm intervals. The measurement system for unconsolidated sediments is the pulse transmission method [15]. It is equipped with a set of a pulse generator (Tektronix TM 502A) and a digital oscilloscope (Tektronix TDS 3012) for muddy samples and sediment sound velocimeter (Otronix Model 93−M) for sandy cores [16−17]. Receiver of piezoelectric transducers (PZT 4) is a frequency of 1 MHz in natural resonance.

Temperature compensation for the *in situ* velocity followed the equation of Medwin [18] and Clay and Medwin [19] using mean temperature and salinity of the lowest water database (1961−1999) in the Korea Oceanographic Data Center. For actual modeling, the velocities in Table 1 should be compensated with *in situ* detph below the sea floor of the bottom model according to the Hamilton method [7], and also compensated for the velocities of target−frequency modulation [3]. The basement rock samples on land were saturated with standard sea water during 24 hours, and P−wave velocity was measured by a set of sonic velocity equipment (Sonic Viewer Model−5217A with 500 kHz receiving transducer).

III. Stratigraphic Model

The sedimentary sequence in the western South Korea Plateau consists of nine seismic stratal units, based on reflection character, coastal onlapping, and erosional truncation [13−14]. In the western slope margin of the western South Korea Plateau, the sequence includes nine stratal units, whereas in the partitioned basins of the outer margin, seven stratal units are recognized. Detailed description, interpretation, and methodology of seismic stratigraphy in the western South Korea Plateau are referred to Kwon [13] and Kwon et al. [14]. In the DC−UI Line, nine stratal units are recognized in the western and central parts, whereas acoustic blanking in

Table 1. Seismic and Chronostratigraphy of the western South Korea Plateau [13-14]. Geoacoustic model with measured, extrapolated, and predicted velocity of compressional wave. Note the relation of stratigraphic units and geoacoustic bottom layers.

Age	Stratigraphic Unit			Lithology	Geoacoustic Bottom Layer	P-wave Velocity (m/s)
Quaternary	Unit Set 4	Unit 9	Subunit 9c	Mud	Bottom Layer A	1500
			Subunit 9b	Sand	Bottom Layer B	1650
			Subunit 9a	Sand/Mud		
Tertiary		Unit 8	Subunit 8b	Sand/Mud		
			Subunit 8a	Sand		
	Unit Set 3	Unit 7	Subunit 7b	Mud	Bottom Layer C	1550
			Subunit 7a	Sand/Mud	Bottom Layer D	1650
		Unit 6	Subunit 6b	Sand/Mud		
			Subunit 6a	Sand	Bottom Layer E	1700
		Unit 5		Sand		
	Unit Set 2	Unit 4		Sand/Mud	Bottom Layer F	1800
		Unit 3		Gravel/Sand		
	Unit Set 1	Unit 2		Sand/Mud	Bottom Layer G	1900
		Unit 1		Gravel/Sand		
Early Paleozoic	Joseon Supergroup	Basement-J		Limestone/Shale/Sandstone	Basement-J	5550
Precambrian	Precambrian Metamorphic Rock	Basement-M		Granitic Gneiss	Basement-M	3750

the profiles hindered subdivision of stratal units in the eastern part (Table 1, Fig. 2).

IV. Geoacoustic Model

4.1. Bottom Model

A unit of stratigraphic model is always not compatible to a layer of bottom model. Division of stratigraphic unit is firstly based on chronostratigraphic criteria, whereas a division scheme of bottom model for geoacoustic model is significant geoacoustic properties, especially P-wave velocity. So several stratigraphic units can be merged to a single bottom layer (Table 1: e.g., Subunit 8a to Subunit 9b→Bottom Layer B). The bottom model, geoacoustically reconstructed on the basis of the stratigraphic model, is proposed in Figure 3.

In the DC-UI Line, the range of bottom model is about 137 kilometers from West (37°33'N 129°12'E) to East (37°33'N 130°45'E) (Fig. 1). Water depth ranges from 50 to 1650 meters. The bottom structure represents not only very irregular geometry (Figs. 2 and 3), but also differences of the P-wave velocity between the layers are very significant within 200 meters in a bottom depth (Table 1). It is clear that almost bottom structures of the East Sea as well as those of the DC-UI Line are not simple and not cake-layered as like a test computer model adopted by most acousticians.

4.2. Geoacoustic Model

The construction of a geoacoustic model of the sea floor requires assembly of data from a wide variety of sources in many scientific disciplines including geology, geophysics,

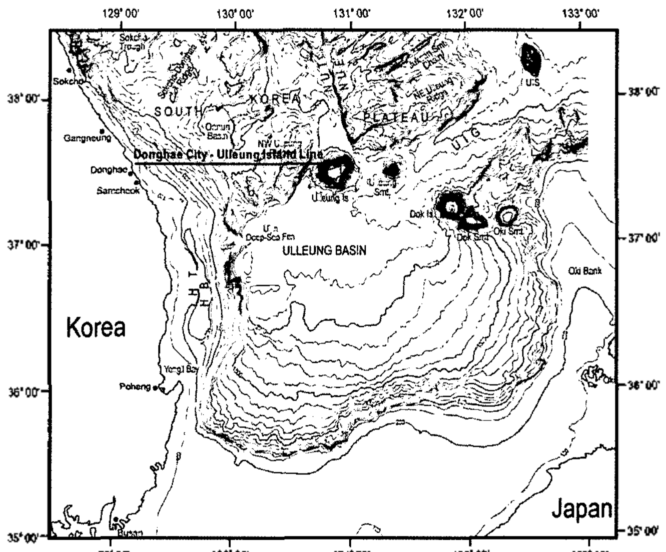

Fig. 1. Physiography of the Ulleung Basin and South Korea Plateau, East Sea (modified after Lee [10]). HB: Hupo Bank, HT: Hupo Trough, NUT: Northern Ulleung Trough, NUE: Northern Ulleung Eascarpment, UIG: Ulleung Interplain Gap, UIS: Ulleung Interplain Seamount. A solid line in the South Korea Plateau indicates the Donghae City-Ulleung Island Line.

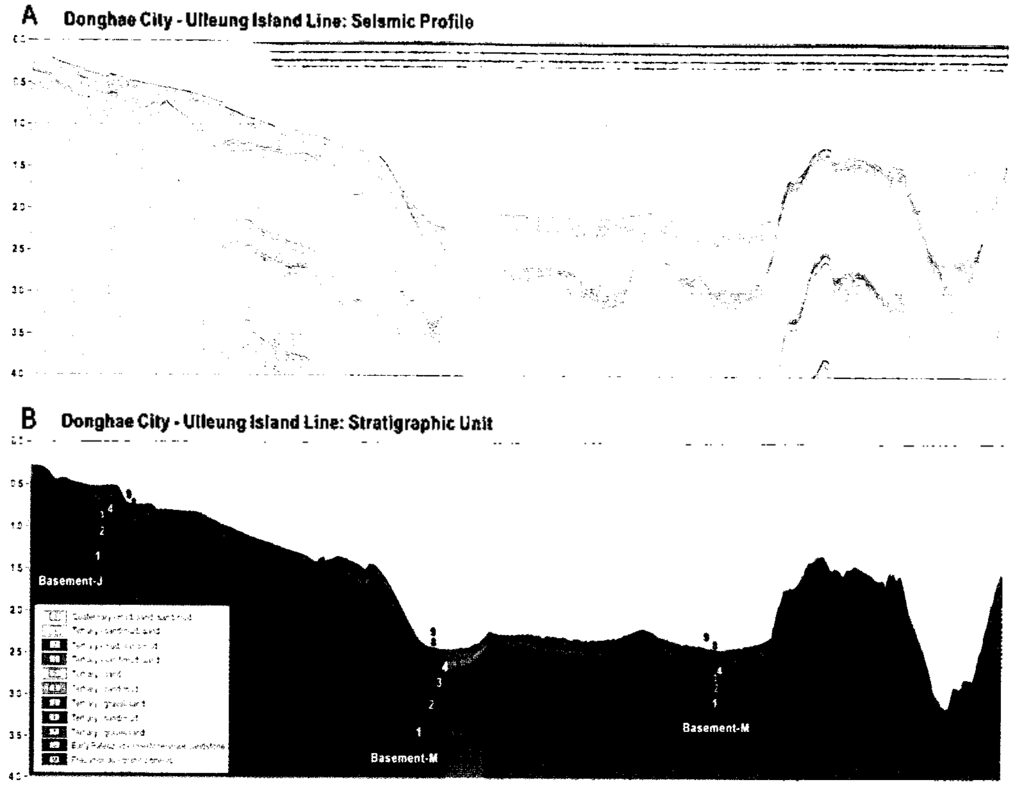

Fig. 2. (A) Seismic profile and (B) its stratigraphic interpretation of the Donghae City-Ulleung Island Line. Legend indicates the number of stratigraphic units and age/lithology of each unit in Table 1.

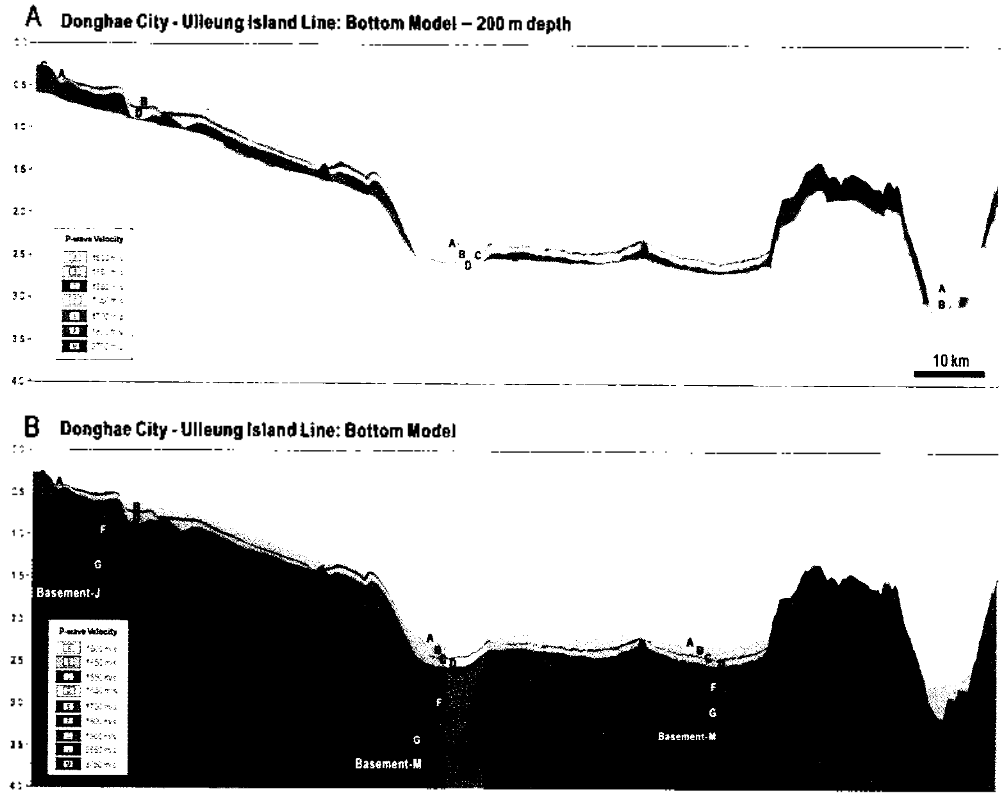

Fig. 3. P-wave bottom models of 200 meters depth (A) and whole depth (B) in the Donghae City-Ulleung Island Line. The models are for a target of low-frequency ranges (<200 Hz). Legend indicates the geoacoustic bottom layers and P-wave velocity of each layer in Table 1.

and acoustics [7, 20]. Numerous P−wave velocities for the geoacoustic model were measured, extrapolated, and predicted to detail the real sea bottom in the DC−UI Line. The data were analyzed in terms of significant true thickness of a layer. According to acoustic division of the layers, stratigraphic units are converted to the geoacoustic layers of bottom model (Fig. 3). The P−wave velocities in the geoacoustic bottom layer were averaged for a representative value of bottom layer velocity (Table 1).

Geoacoustic Bottom Layer A is characterized by well stratified seismic facies with high amplitude and continuous reflection, showing sheet drape deposition. A long core (DH−1) and many piston cores were recovered in this layer, so direct measurement of P−wave velocity was made in the laboratory. The P−wave velocity of this layer A is about 1500 m/s.

Layer B is represented by well stratified seismic facies with intermediate amplitude and continuous reflection, and the upper part occasionally includes stratified internal reflectors. DH−2 and several piston cores of this layer were acquired in the older deposits, not covered by younger starata. The P−wave velocity of this layer B is about 1650 m/s.

Layer C is represented by well stratified seismic facies with high amplitude and continuous reflection. The internal stratified reflectors are parallel with the seafloor. A few piston cores were recovered. The P−wave velocity of this layer C is about 1550 m/s.

Layer D is characterized by transparent and chaotic seismic facies in the upper part and crude stratification in the lower part. A few piston cores were acquired. The P−wave velocity of this layer D is about 1650 m/s.

Layer E commonly includes a single or a couple of strong internal reflectors in the upper part and transparent reflectors in the lower part. There are a few piston cores. The P−wave velocity of this layer E is about 1700 m/s.

Layer F consists of two or three crudely stratified internal reflectors. The upper part is characterized by well stratified and disrupted seismic facies with high amplitude and intermediate frequency. The middle part is represented by transparent or crudely stratified seismic facies. The lower part consists of an upper well stratified subunit and a lower transparent subunit. There are a few piston cores. The P−wave velocity of this layer F is about 1800 m/s.

Layer G rests on the basement rocks of the Precambrian granitic gneiss and Paleozoic sedimentary rocks, and mainly occurs in the topographic lows with abundant volcanic intrusions. The unit is characterized by high amplitude and sigmoid to oblique prograding reflection patterns. There is not a core in this layer, so the P−wave velocity of 1900 m/s was assumed on the velocity values of in other cores of similar lithology, predicted on the seismic facies.

Based on data of the basin analysis [13−14], the basement is probably of limestone origin (5550 m/s) in the western part of the DC−UI Line and Precambrian granitic gneiss (3750 m/s) in the eastern part. However, the boundary between the two rocks is not clear.

V. Summary

In the DC−UI Line, geoacoustic and bottom model of P−wave velocity is proposed on the basis of detailed stratigraphic model (Table 1; Fig. 3). The basement comprises 3 geoacoustic layers of P−wave velocity ranging from 3750 to 5550 m/s. The overlying sediments consist of 7 layers of P−wave velocities ranging from 1500 to 1900 m/s. The bottom model shows that the structure is very irregular and the velocity is also variable with both vertical and lateral extension.

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