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# Acoustic characteristics of seafloor sediments in the abyssal areas of the South China Sea

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ABSTRACT

Deep-sea sediment cores were obtained from abyssal areas (water depth > 4000 m) in the South China Sea (SCS) to derive acoustic characteristics by using a WSD-3 digital acoustic instrument at a frequency of 100 kHz. The compressional wave velocity (*Vp*) of the seafloor sediments in the central basin is differentiated into 3 provinces on the basis of the sediment properties (esp. mean grain size and velocity). Provinces H1 and H2 have a high compressional wave velocity and coarse particles, while the middle province L has a low compressional wave velocity and fine particles. The results show that the distribution of *Vp* is related to the sediment physical properties, sediment sources and ocean current. Vertical variations in the *Vp* indicate that it increases with burial depth in the high-velocity province, but is complicated in the low-velocity province, reflecting that the more active or complicated sedimentary environment in province L may be affected by the topography. We proposed a laboratory sound velocity measurement method based on Hamilton sound velocity ratio method. In addition, the measurement values from this method are close to the in situ sound velocity determined by adjusting the temperature of the sediment samples.

## 1. Introduction

Acoustic characteristics of seafloor sediments are closely related to geological environment, they can help to understand sedimentary stratigraphic structure, reflect a lithological and geotechnical description of the sediments, study the past and modern sedimentary environment and deposition process (Hamilton, 1970, 1980; Kim et al., 2011; Liu et al., 2013; Hou et al., 2015; 2018; Ballentine et al., 2017).

Sediment acoustics have been explored for at least 60 yrs by oceanographers and have been of great interest in various fields such as marine geophysics, seafloor engineering, paleoceanography, and hydroacoustics (Hamilton, 1970, 1980; Kim et al., 2017). Since the 1950s there have been several important papers on the subject of sediment acoustics starting with the early measurements by Edwin L Hamilton (1956, 1956), representing a steady progress in the understanding of sediment acoustics (Chotiros and Isakson, 2013). Hamilton has published numerous papers dealing with the acoustic characteristics of seafloor sediments (Hamilton et al., 1955; 1956, 1970, 1980). Many other researchers have studied the empirical and theoretical relationships between acoustic and physical properties (Briggs and Richardson, 1997; Buckingham and Richardson, 2002; Robb et al., 2006; Liu et al., 2013; Hou et al., 2015; Ballard et al., 2015; Kim et al., 2017). In addition, most of these efforts come from the Naval Research Laboratory, such as the Sediment Acoustic Experiment 1999 (SAX99) (e.g. Thorsos, 2000), the Coastal Bottom Boundary Layer (CBBL) Program (e.g. Richardson et al., 1997) and the Joint High-Frequency Backscatter Experiment (JOBEX), and the most fruitful program so far is SAX99 (Endler et al., 2016). In addition to experimental studies, there is a considerable body of work in the literature on the theory of acoustic propagation in marine sediments. Biot developed the most prominent poroelastic theory, the "Theory of Propagation of Elastic Waves in a Fluid-Saturated Porous Solid" (1956a, 1956b). Later, the theory was extended, discussed and tested by many other researchers (Stoll, 1974; Dvorkin and Nur, 1993; Leurer, 1997; Chotiros and Isakson, 2004; Endler et al., 2015; Tong et al., 2016).

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In this study, sediment cores were obtained in the abyssal areas (water depth > 4000 m) of the South China Sea (SCS) to derive acoustic characteristics (compressional wave velocity, acoustic impedance and reflection coefficient) and physical parameters (including porosity, particle size, sorting coefficient, sand content, clay content, wet and dry bulk densities, and water content) of sediment to study the distribution and determinants of compressional wave velocity (*Vp*).

## 2. Materials and methods

### 2.1. Physical setting

The SCS is the largest marginal sea in the western Pacific; it corresponds to an area of Cenozoic crustal extension, flanked by the Asian continent, the Philippines, and the Sundaland continent. Three of the world's biggest rivers feed the SCS: The Mekong, Red and Pearl Rivers respectively supply 160, 130 and 70–80 million tons of sediments annually to the SCS (Liu et al., 2010). The modern SCS is impacted by the East Asian monsoon system (Wang et al., 2005). A strong northeast monsoon blows along the coasts of China and Vietnam in winter, and a weak southwest monsoon blows from the Indian Ocean in summer (Webster, 1994; Fernando et al., 2007).

This study area is in the central basin of the SCS (Fig. 1). The central SCS basin is floored primarily by oceanic crust, and is confined by the continent-ocean boundary and is comprised of three major sub basins, namely, the East, Southwest, and Northwest Sub basins. In the SCS, the sediment transport and deposition is determined by the flow strength and direction, and different sediment types have distinct provinces with boundaries that roughly parallel the topography. The bioclastic component determines the sediment classification in bathyal-abyssal areas. Volcanic material is predominantly distributed in deep-sea basins (Liu et al., 2013).

### 2.2. Sediment coring

Six seafloor sediment core samples (0.2–4 m length) were collected in the abyssal areas of the SCS with a gravity corer during the SCS Open Cruise by R/V Shiyan 1. The R/V was from the South China Sea Institute of Oceanology (SCSIO), Chinese Academy of Sciences (CAS). A polyethylene core liner was inserted in the gravity corer barrel to reduce the disturbance to the sediments. Upon retrieval of the gravity corer, we removed the core liner and the sediment core sample it contained, and then placed them in a laboratory at a constant temperature and constant pressure (23 °C, atmospheric pressure). Among the sediment sample locations, station S1 was in the East Sub-basin of the SCS (water depth > 4000 m), near Luzon island. Stations S2, S3 and S4 were in the Northwest Sub-basin (water depth > 4100 m); these three stations were surrounded by seamounts and/or abyssal hills. Stations S4 and S5 were in the Southwest Sub-basin of the SCS (water depth > 4300 m).

### 2.3. Sample analysis

The sound velocity (*Vp*) was measured in a standard laboratory (23 °C, atmospheric pressure) using a portable WSD-3 digital sonic instrument and the coaxial differential distance measurement method (Fig. 2). The measurement parameters were as follows: the sediment core initial length was L1 (average of 50 cm); the sediment measurement interval was L2 (average of 25 cm); and the full waveforms were digitized at frequencies of 100 kHz, a single channel sampling length of 4096 points and a sampling interval of 0.1 μs. The acoustic transducers were in direct contact with the top of the sediment core and were coupled to the liner on the bottom by using Vaseline. At first, all of the cores were cut into 50 cm fragments to measure the acoustic characteristics (except for the core from station S1, which was measured directly due to an insufficient length). Then a 25 cm sample was cut from the top of the core.

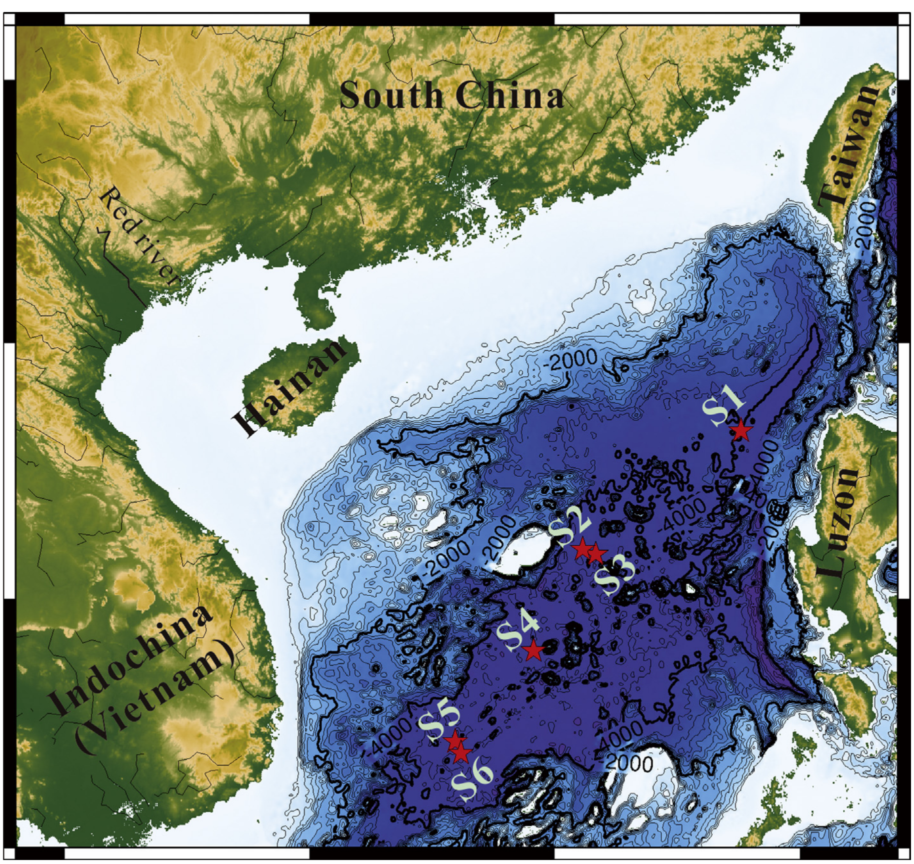


**Fig. 1.** Locations of seafloor sediment samples in the South China Sea (SCS).