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Constraints on Free gas and Gas hydrate bearing sediments from multi-channel seismic data, offshore Southwestern Taiwan.

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Abstract.

Bottom-parallel or Bottom-simulating seismic reflector (BSR) have widely been observed in various continental margin environements. The BSR is commonly interpreted as marking the base of the stability field for gas hydrate (e.g. Miller et al., 1991; Hyndman and Spence, 1992; Hyndman and Davis, 1992; Bangs et al., 1993; Dillon et al., 1996). Gas hydrates are christalline solid formed of a cage of water molecules surrounding a natural gas molecule, commonly of methane, under specific conditions of relative high pressure and low temperature. Thus, experimental results of methane hydrate synthesis indicate that hydrates occur in water depth greater than 280 m, when the temperature at sea-level is 0*. Offshore southern Taiwan, Reed et al. (1992) first recognized the occurance of a BSR. In 1998, Chi et al. published a comprehensive map of the distribution of BSR in southern Taiwan. These authors examined more than 8,000 km of seismic data and concluded that at least 20,000 km2 of the Taiwan accretionary prism, in water depths ranging from 500 to 2000 m, is covered by BSRs. The highest concentration of BSR is located in the northwestern part of the studied area, where rapid deposited terrigenous sediments may have relatively high amounts of organic carbon, thereby providing a source for the methane. In this study, we present two unpublished multi-channel seismic profiles, and examine means to estimate the amounts of gas hydrate and free gas contents in this area (figure 1).

During the ODP Leg 164 (e.g. Paull et al., 1996 ; Dickens, et al., 1997; Guerin et al., 1999), on the continental margin off southeastern North America, a study of natural gas hydrates in marine sediments has been conducted. From 200 to 450m bellow sea floor, gas hydrates have been drilled and recovered. During coring, several direct and indirect estimates of the hydrate saturation where conducted. Paull et al. (1996) concluded that, at the three drill sites, the gas hydrates occupy more than 1% of the bulk sediment volume, resulting in 5 to 15 % saturation of the pore space depending on the porosity. Further more, it has established that the hydrated layer is underlain by an even thicker strata bearing large quantities of free methane gas. Finally, the chemical and isotopic composition of the gases recovered from the core samples all indicate that the gas is primarily microbially produced via CO2 reduction (Egeberg and Barth, 1998; Egeberg and Dickens, 1999). Finally, traces of ethane and methane, as well as changes in pore water chemistry and isotopic composition of recovered gas, suggest that the majority of methane and dissolved carbon dioxide where not locally produced and migrated from bellow into the system.

Laboratory measurements of pure methane hydrate density and acoustic velocity range respectively from 1.024 to 1.045 g/cm3 and 3.3 to 3.8 km/s. The combination yield a moderate acoustic impedence contrast from that of surrounding sediments, suggesting a small reflection coefficient at normal insidence, although a large compressional velocity contrast produces a larger reflection at larger angles of insidence (Singh et al., 1993; Singh and Minschull, 1994; Wood et al., 1994). Further more, small quantities of gas in the pore space of marine sediments cause a dramatic decrease in compressional velocity, while further increase cause little change. Shear wave velocity slightly increase with increasing gas saturation, with it's maximum variation near full saturation (Minshull et al., 1994). Therefore, the BSR is mainly caused by the reflection across the interface between hydrate bearing and gas saturated sediments. Thus, the same amount of gas hydrates was proposed at the sites 994, 995, and 997 (ODP Leg 164, e.g Paull et al., 1996) although no BSR is imaged at the vicinity of site 994. Furthermore, the results of methane hydrates synthesis from pure water and methane show that a lower temperature and higher pressure are necessary for hydrate formation compared to dissociation. The intermediate zone can be regarded as meta-stable, where both phases can be present.

In order to providing an assessment of the amount and distribution of free gas and gas hydrates in southwestern Taiwan, we conduct a careful analysis of two multi-channel seismic profiles presenting large sections where a strong BSR is imaged (figure 2). The seismic data was acquired by the Institute of Oceanography, National Taiwan University, on board the Ocean Researcher I, along two NE-SW parallel profiles lying slightly north of the area compromised in Chi et al.'s comprehensive map. Detailed velocity analysis, in time-space and tau-p domains, as well as amplitude versus offset analysis are conducted in the sections bearing gas hydrates and free gas. The results are compared to theoretical elastic properties for the 3-phase matrix of gas hydrates and free gas saturated sediments (Lee et al., 1996). Then, reflection coefficient analysis and acoustic forward modeling further constrain our estimates. Furthermore, offshore southwestern Taiwan, the BSR is most commonly found in the crest of anticlines, mud volcanoes, and the vicinity of thrusts. Finally, we discuss the importance of structural controls, such as high angle faults, for the vertical transport of the pore water and gas in the concentration of methane hydrates.

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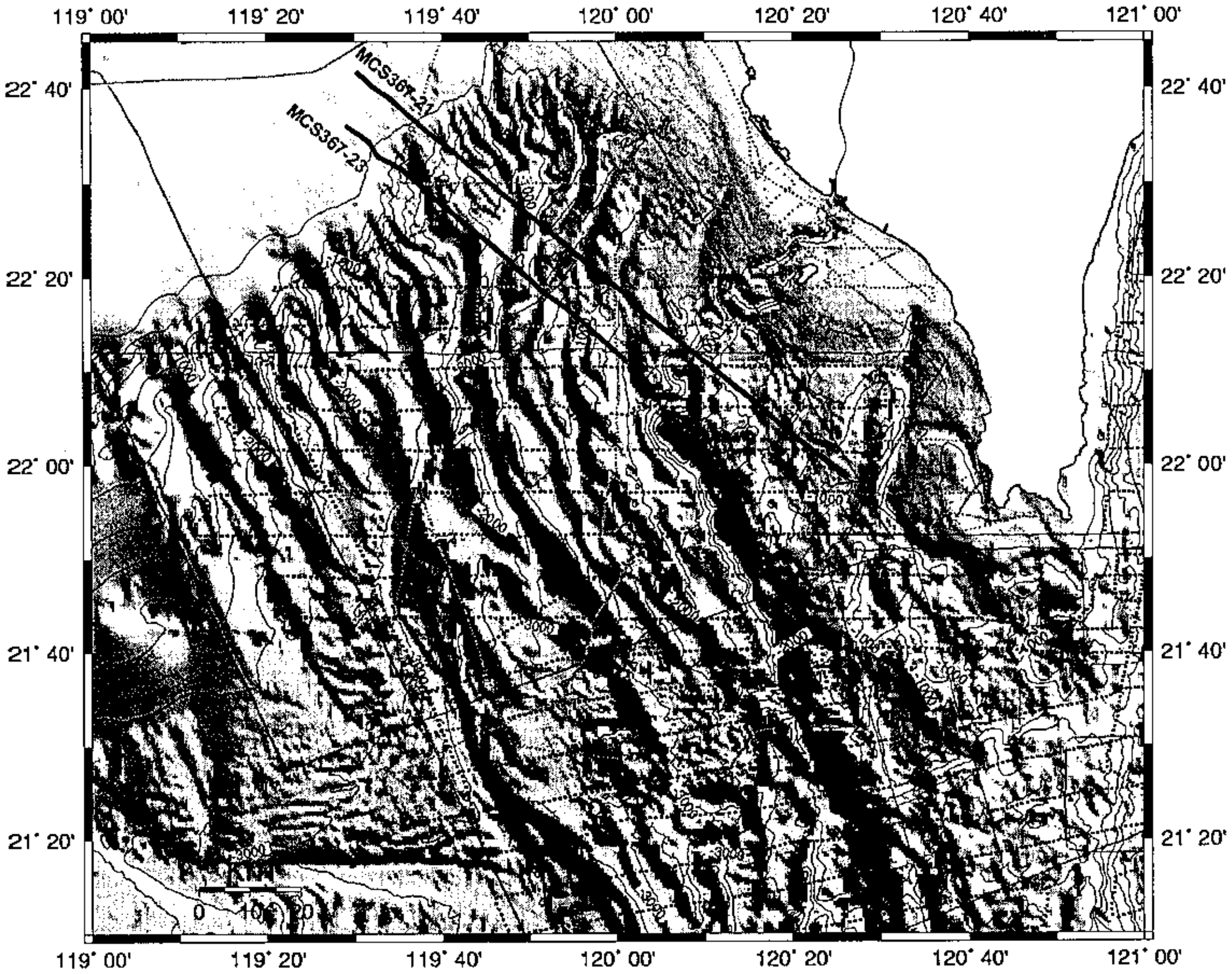
Figure caption.

Fig 1.: Location map of the multi-channel seismic profiles (MCS367-21 and MCS367-23) presented in this study. Other seismic reflection profiles available in this area are shown (EW9509 with gray lines, Moore et al., in press, MW9006 with black dots, Chi et al., 1998, and QCS320 with light gray dots). The bathymetric data is shaded from the east.

Fig 2.: Seismic reflection profile MCS367-23. A proheminent BSR is imaged in this portion of the seismic data. High amplitude reflectors underneath the BSR may indicate the presence of free gas trapped underneath the hydrates. Vertical exaggeration at sea floor is 3,75.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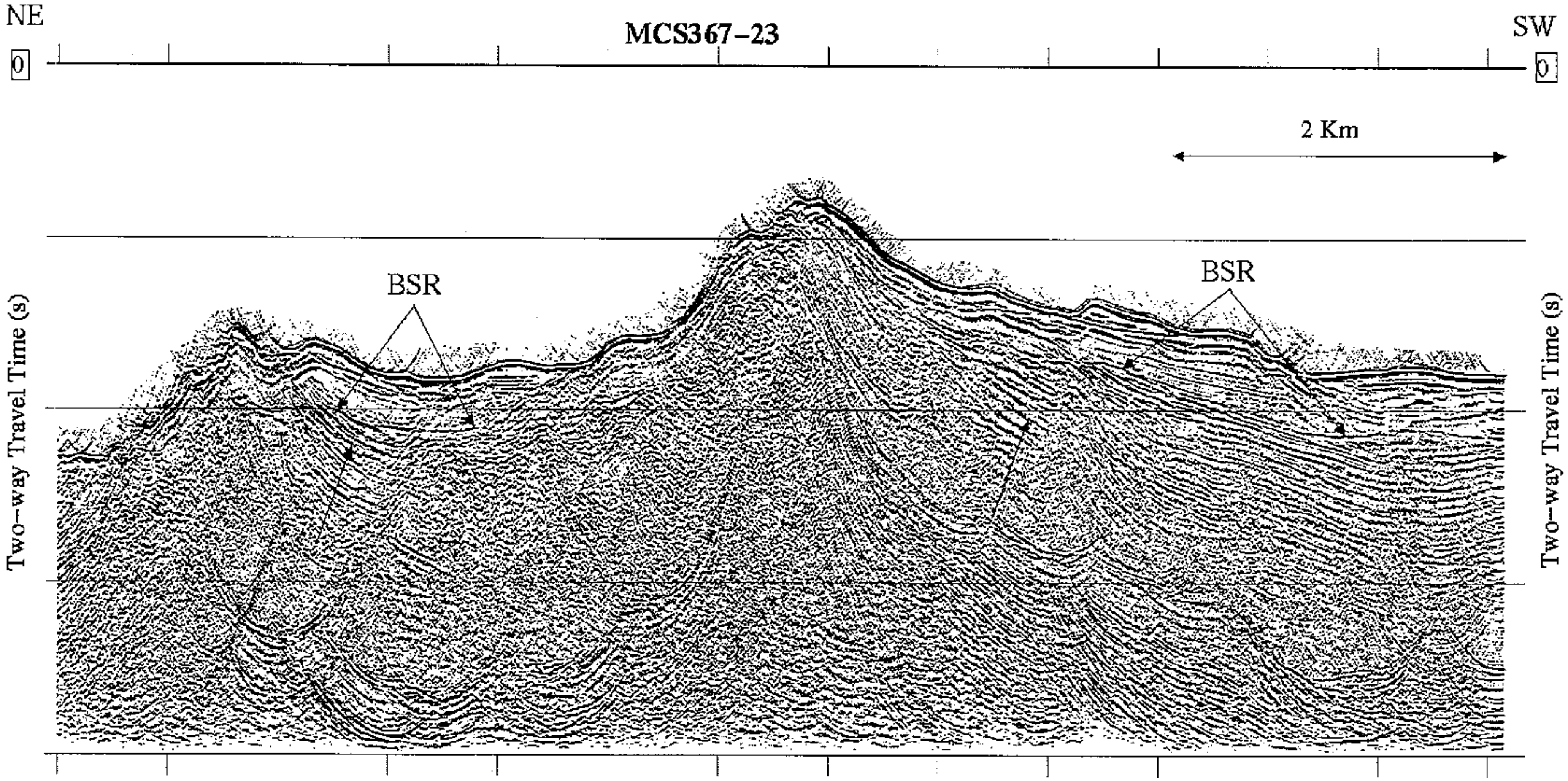
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