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Seismic quality factors across a bottom simulating reflector in the Makran Accretionary Prism, Arabian Sea

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ABSTRACT

The hydrate-bearing sediments above the bottom simulating reflector (BSR) are associated with low attenuation or high quality factor (Q), whereas underlying gas-bearing sediments exhibit high attenuation. Hence, estimation of Q can be important for qualifying whether a BSR is related to gas hydrates and free-gas. This property is also useful for identifying gas hydrates where detection of BSR is dubious. Here, we calculate the interval Q for three submarine sedimentary layers bounded by seafloor, BSR, one reflector above and another reflector below the BSR at three locations with moderate, strong and no BSR along a seismic line in the Makran accretionary prism, Arabian Sea for studying attenuation (Q^{-1}) characteristics of sediments. Interval Q for hydrate-bearing sediments (layer B) above the BSR are estimated as 191 ± 11, 223 ± 12, and 117 ± 5, whereas interval Q for the underlying gas-bearing sediments (layer C) are calculated as 112 ± 7, 107 ± 8 and 124 ± 11 at moderate, strong and no BSR locations, respectively. The large variation in Q is observed at strong BSR. Thus Q can be used for ascertaining whether the observed BSR is due to gas hydrates, and for identifying gas hydrates at places where detection of BSR is rather doubtful. Interval Q of 98 ± 4, 108 ± 5, and 102 ± 5, respectively, at moderate, strong and no BSR locations for the layer immediately beneath the seafloor (layer A) show almost uniform attenuation.

1. Introduction

Gas hydrates are crystalline form of methane and water, and are found in shallow sediments of outer continental margins where temperature is low; pressure is high and methane concentration exceeds the solubility limit (Kvenvolden, 1998; Sloan, 1998). They have attracted the scientific attention due to their natural occurrences; their role in climate change (methane being a green house gas) and submarine hazard that may cause slope failure; and most importantly their potential as future major energy resource (Booth et al., 1996; Klauda and Sandler, 2005; Sain and Gupta, 2008; Sain and Ojha, 2008). Hence, detection and quantitative assessment of gas hydrates are essential for evaluating the energy potential and assessing the environment-hazard. The commonly used proxy for gas hydrates is the bottom simulating reflector (BSR) that can be identified based on its characteristic features (Sain and Gupta, 2008) in seismic data. The BSR is an interface between gas hydrate-bearing sediments above and free-gas-saturated sediments below, which can be characterized by high seismic velocity for hydrate- and low seismic velocity for gas-bearing sediments; high resistivity for both hydrate- and gas-bearing sediments; seismic blanking due to gas hydrates; high reflection strength and frequency shadow for the presence of gas (Ojha and Sain, 2009; Satyavani et al., 2008). Another important property to characterize the hydrate- and gas-bearing sediments is the seismic quality factor (Q) or attenuation (Sain et al., 2009). Estimation of Q is also required for compensating the effects of attenuation in the quest to improve the subsurface seismic images (Bellefleur et al., 2007); to better interpret the effects of amplitude variation with offset (AVO); and to invert seismic data for deriving material properties.

Gei and Carcione (2003) show in their model study that attenuation decreases or Q increases with increasing concentration of gas hydrates due to stiffening of sediments. In certain environments, fluids may be present within the gas hydrates stability zone, which show an increase in attenuation (Q^{-1}) for hydrate-bearing sediments (Guerin and Goldberg, 2002; Chand and Minshull, 2004; Priest et al., 2006). Matsushima (2006) demonstrated that hydrate-bearing sediments cause attenuation in the sonic frequency range (10–20 kHz), but not in the seismic frequency range (30–110 Hz). This leads to a scientific debate on the attenuation of gas hydrates. By employing the logarithmic spectral ratio (LSR) method to the surface seismic reflection data, Sain et al.

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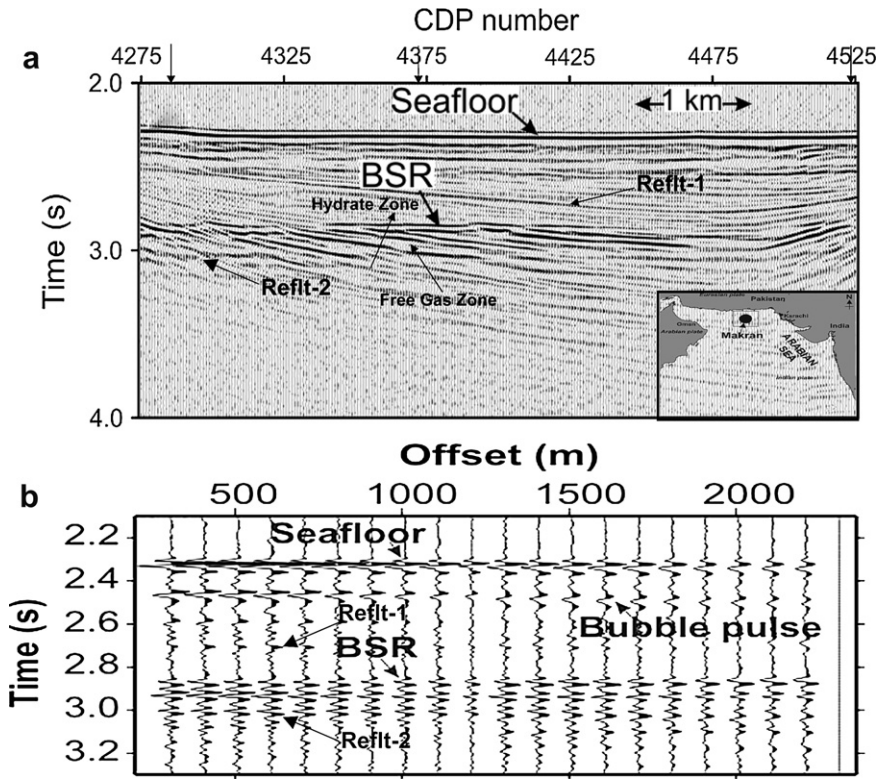

Figure 1. (a). Seismic stack section along a north–south seismic line (inset shows the study area (box) in the Makran accretionary prism). Amplitude spectra have been calculated around four reflectors: seafloor, reflect-1, BSR and reflect-2. (b) NMO corrected CDP gather at CDP 4372, showing the reflections at various offsets from the said four reflectors.

(2009) demonstrated that the hydrate-bearing sediments are associated with high Q or low attenuation compared to that of normal (without hydrates) oceanic sediments.

The BSRs are wide-spread on seismic data in the Makran accretionary prism (Minshull et al., 1992; Sain et al., 2000). Studies of seismic attributes such as the blanking, reflection strength and instantaneous frequency (Ojha and Sain, 2009) and the velocity anomaly (Sain et al., 2000) favor the presence of gas hydrates and free-gas across the BSR in the Makran offshore. Here we calculate the seismic Q at few CDP locations along a seismic line in the Makran accretionary prism with a view to understand the attenuation characteristics of gas hydrate- and free-gas-bearing sediments. The study

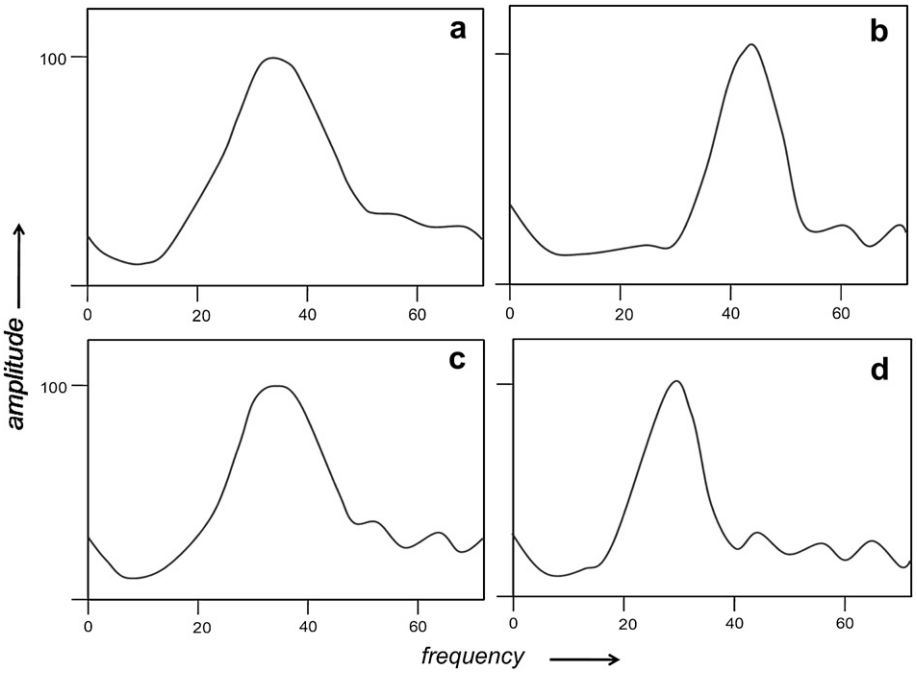

Figure 2. Amplitude spectrum of a representative seismic trace at offset 300 m of CDP 4372 for sea floor (a), reflect-1 (b), BSR (c), and reflect-2 (d), respectively.