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Analysis of interval velocity vs amplitude blanking in a gas hydrate province

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Seismic reflection profiles across many continental margins have imaged bottom-simulating seismic reflectors (BSRs), which have been interpreted as being formed at the base of a methane hydrate zone. These reflectors might arise from an impedance contrast between high velocity layers, partially hydrated sediments overlying gas/water-saturated sediment. Our study was aimed at amplitude analysis and its relation with velocity on one of the profiles on the western continental margin of India. In our data BSR is found to be discontinuous in the profile and amplitude blanking is seen above the BSR. To get an idea about amplitude in the region with and without BSR, we have performed both amplitude and velocity analysis. The relation between amplitude variation and velocity variation is utilized to estimate range of velocity in the blanked zone.

GAS hydrates are ice-like crystalline solids that are formed when a cage of water molecule surrounds a guest gas molecule (mainly methane). Evidence for their existence has come from recognizing a bottom-simulating reflector (BSR) on the seismic profile that marks the base of the zone of occurrence of gas hydrates. No attempt has been made to quantify them through velocity analysis. This aspect of velocity value distribution would serve as good indicator for the presence of gas hydrates and its resource estimate.

Gas hydrates are known to increase interval velocity of sediments[1–4] by an amount that is proportional to the amount of hydrate[5]. These relations have been used by researchers to explain the velocity variation of 1.6 to 1.9 km/s as a result of variation in saturated hydrated sediments[2–4].

Another indicator of gas hydrates is amplitude reduction[6] or blanking typically observed above the BSR in reflection profile from regions of known hydrates. It has been proposed that the marked decrease in amplitude above the BSR to a reduction in impedance contrast across sedimentary interfaces is caused by the presence of hydrates[7].

Amplitude blanking, also observed over true-amplitude seismic sections, has been ascribed to hydrate formation[8]. These studies imply that amplitude information can be used as an indicator of hydrate concentration. Here, we have demonstrated the lateral variation of zone of blanking with continuity/discontinuity of BSR. We have also shown the relation between reflectance and average interval velocity estimated from the zone above and below the BSR.

The location of multichannel seismic profile used for investigation is shown in Figure 1. It was recorded in the early 2000s using tuned air-gun arrays of 2000 p.s.i. minimum pressure and 4000 in^3 volume. The data were recorded using 240 channels (short interval 50m and group interval 25 m) through IBM-3590 media with SEG-D format in the interval of 2 ms. These profiles provide 60-fold coverage with 6000 m stream length. We performed a 2D velocity analysis along the line shown in Figure 1. Prior to velocity analysis, the data were pre-processed. We first applied a time-varying spherical divergence correction. Subsequently, predictive deconvolution with operator length of 80 ms and prediction distance of 240 ms was performed to suppress a ringing in the data caused by air-gun bubbles. The deconvolved data were then band-pass filtered to their original bandwidth to remove spurious, deconvolutional, high-frequency noise. A final stacked section in near offset range is shown in Figure 2.

Detailed velocity measurements were made via stacking analysis at every 30 CDPs. It is difficult to draw an inference about amplitude blanking on the basis of interval velocities because reflections are weak and laterally discontinuous. Consequently, in this area, interval velocities, calculated from stacking velocities, are not consistently representative of the same geologic interval.

Our amplitude analysis was done in the interval of 400 ms thick section immediately overlying the BSR. The amplitude variation near the BSR can be examined using plots similar to those shown in Figure 3. In these plots, each dot represents the amplitude in an 8 ms window for six CDPs.

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The solid line is the five-point running mean reflectance of the average amplitude of six consecutive CDPs. In other words, the solid line is the running mean of reflection amplitude over a moving window that is 32 ms in duration vertically and six CDPs horizontally. Here, computation was done in decibel scale, as it is a standard unit. This scale is a logarithmic ratio that takes an amplitude measurement as a ratio to seismic reflection amplitude across any profile to a reference value. The formula used is:

$$\text{Amplitude (dB)} = 20\log_{10}(\text{amplitude})/(\text{reference}).$$

Figure 1. Bathymetry of Indian Continental Margin (from GEBCO data) and location of multichannel seismic reflection profile.

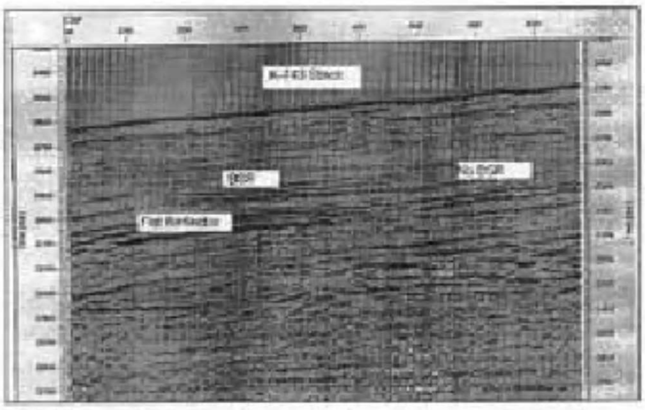

Figure 2. Seismic stack section obtained along the present profile.

Here the maximum reflection value for each CDP is taken as reference value.

The structure in the study area is quite smooth and simple, and the water depth is more than 1.8 km. Conventional NMO stacking velocity analysis was sufficient to obtain good RMS velocities. Finally, these RMS velocities are converted into interval velocity using Dix's equation, in order to determine the lateral variation of the hydrate and the possible underlying gas-saturated sediments.

Amplitude variation associated with the presence of gas hydrates is pronounced in the study area. Amplitude analysis was done for two regions one with BSR (CDP 315–320) and other without BSR (CDP 495–500). These two regions are in the same profile of the Kerala–Konkan region (Figure 1). (Figure 3) shows the amplitude of reflected energy for both the cases. A low amplitude or blanking zone is observed just above the BSR; the thickness of this zone varies spatially, while in the absence of BSR (as a case II) there is no blanking zone[9]. The average seismic amplitude immediately above the BSR is as small as –8 dB. Amplitude blanking above the BSR is a common feature throughout the region wherever the BSR is recorded[10].

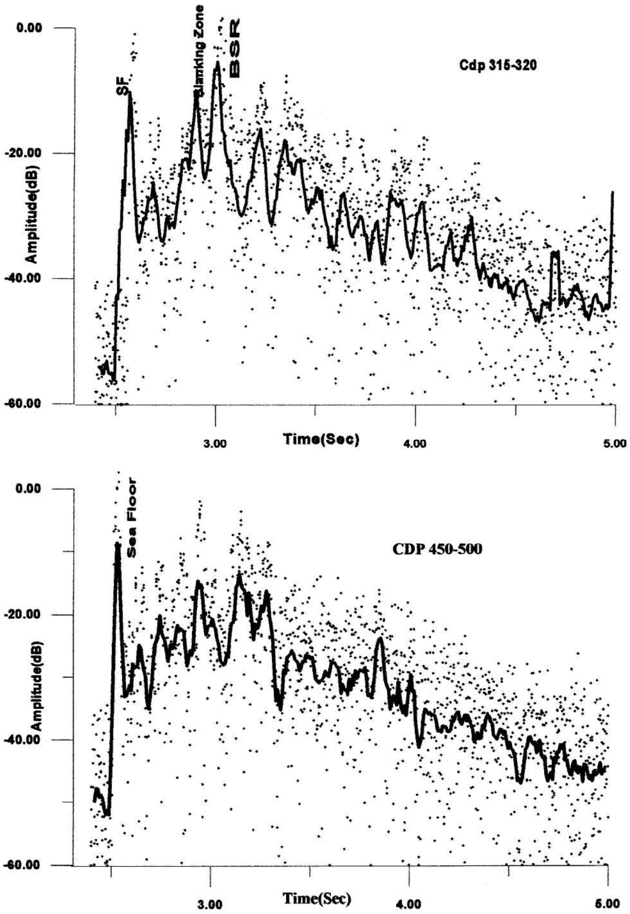

Figure 3. Graphs showing amplitude analysis for selected CDPs 315–320 and 495–500. Each dot represents the amplitude of an 8 ms window and solid line represents a five-point running mean of six consecutive CDPs. SF, Sea floor.

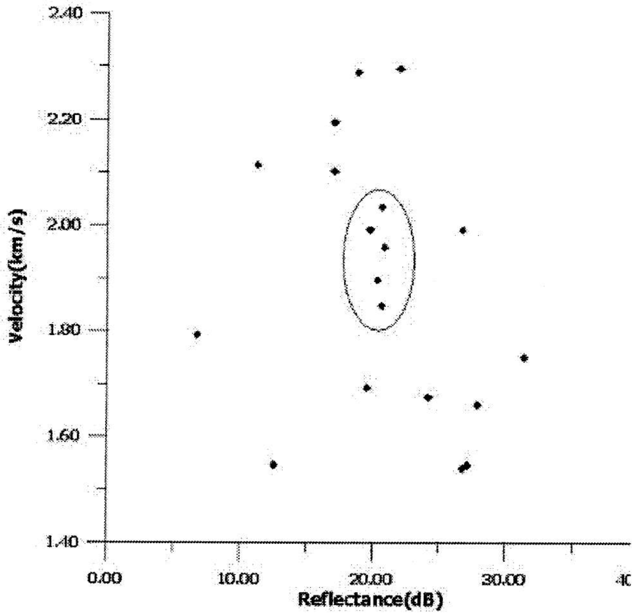

Figure 4. Relation between reflectance (dB) and velocity (km/s).

The zone of blanking is quite prominent and wider for the CDPs 315–320 than for CDPs 495–500 (Figure 3). There is a sharp change in the zone of blanking for CMPs 315–320; it is quite transitional in character for CDPs 495–500. The average amplitude for the section between the water bottom and the BSR is about –32 dB for CDPs 495–500 and about –30 dB for CDPs 315–320. If the amplitude blanking indicates the presence of gas hydrates, then it implies that thicker zone of hydrated sediments occurs near CDP-300 than near CDP-495.

A composite plot is shown in Figure 4 for interval velocity derived from stacking velocity vs mean reflectance. This plot is used to assess the relation between amplitude blanking and interval velocity. Mean reflectance is calculated for a window about 400 ms above the BSR. The maximum amplitude variation for a given interval velocity is about –20 dB at an interval velocity of about 2000 m/s and the interval velocity changes between 1700 and about 2000 m/s for a reflectance of –25 to –35 dB point. One significant result that emerges from the present figure is that the gas hydrate bearing layer has the velocity in the range 1.8 to 2.0 km/s, which is well constrained with smaller scatter (encircled values). Uncertainty in velocity picking may also be a factor that contributes to the large scattering of interval velocity versus reflectance.

The amplitude of seismic reflection within the hydrate zone is generally much lower in the area where there is an observed BSR. Hence, amplitude reduction can be a useful seismic attribute to the presence of gas hydrates.

On the basis of stacking-velocity data, the average interval velocities of sub-bottom sediments between the sea floor and the BSR are similar to the average interval velocity of non hydrate-bearing marine sediments. This implies the small amount of hydrate concentration in this region.

The interval velocity in the part associated with blanking varies from 1600 to 2000 m/s and the reflectance varies from –15–30 dB.

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Lateral and vertical crustal velocity and density variations in the Southwestern Cuddapah Basin and adjoining Eastern Dharwar Craton

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Seismic, gravity and aeromagnetic data are reviewed to understand the complex nature of the structure of the Cuddapah basin. Deep Seismic Sounding analogue data acquired along Kavali–Udipi profile, covering middle

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