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Indicators of gas hydrates: Role of velocity and amplitude

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Methane hydrates/gas hydrates are now viewed as a promising alternate energy source in the near future. Studies are now more focused to find the indicators of these deposits and aid in exploration purposes. Bottom simulating reflectors (BSRs) identified on the seismic reflection records are the most important indicators of gas hydrates. BSRs are recognized on the seismic records as strong negative-polarity reflectors mimicking the seafloor. Velocity and amplitude (VAMP) are essentially the pseudo-structures that are associated with the massive hydrate deposits and are also observable on the seismic records as a series of pull-ups directly above the push-downs. These features have been used to delineate free gas in the Aleutian, Bowers and Berings basin. Investigations are being carried out in Indian offshore regions to evaluate the presence of gas hydrates. Therefore studies regarding the occurrence of VAMPs gain importance. In the present communication we studied VAMP anomalies identified in the marine reflection data off Kerala–Konkan region, western India.

METHANE hydrate/gas hydrates are increasingly recognized as being a potential future energy source. Initial estimates indicated that the energy available from hydrate reserves far exceeds all conventional forms of energy. Gas hydrates, also called gas clathrates, are naturally-occurring solids comprised of water molecules forming a rigid lattice of cages, with most of the cages containing a molecule of natural gas, mainly methane[1]. These gas hydrates are formed at high pressures and low temperatures. In marine environments, these conditions are met within continental margin sediments at water depths greater than 500 m. Gas hydrates have become a major focus of international research because of the increasing demand for hydrocarbons. According to Hovland and Judd[2], the favourable areas occupy more than 90% of the ocean basins. Gas hydrates are found mostly on the continental slopes, which are characterized by thick sediments, rich in organic content. It may also be noted that gas hydrates occur near the places of discharge of deep fluids and gas-escape features such as gas seepages, gas vents, mud volcanoes, etc. The high tectonic activity in these regions also favours the release of fluids. Two models have been proposed to account for the formation of hydrate and development of bottom simulating reflector (BSR). In the first model, the BSR is caused by the hydrate overlying gas-saturated sediment, wherein the impedance contrast at the base of the hydrated zone and the top of the gas layer provides the required strong reflection. In the second model, the BSR is caused by the hydrate overlying brine-saturated sediment, and impedance contrast between the overlying sediments containing substantial amounts of hydrate and the underlying brine-saturated sediments gives the required reflection.

Seismic reflection technique is the main tool to infer natural gas hydrates within the marine sediments. The presence of gas hydrates is mainly inferred from the appearance of the BSR, a strong negative-polarity reflector mimicking the seafloor, as well as bright spot anomalies in combination with the velocity and amplitude (VAMP) features. Another special reflection seems to be acoustic blanking[2]. In addition, gas-venting features sometimes also testify the presence of gas hydrates below the seabed. Several publications of the last decade highlighted the presence and significance of these gas hydrates. However, for ready reference, some of the frequently used terms with details are presented below.

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The BSR, seen on a seismic reflection record, is due to the occurrence of the lower velocity, potentially gas-bearing sediment beneath the higher velocity, potentially hydrate-bearing layer and in theory, generates a high amplitude, phase-inverted reflection event[3,4]. This prominent reflection horizon follows the subsurface isotherm marking the base of the hydrate stability field, roughly parallel to the seafloor. The BSR occurs at a few hundred metres beneath the seafloor. This reflector usually cuts layered sediments. Therefore, the BSR is a phase boundary between gas hydrate charged sediments above the BSR and the free gas charged sediments below it. In principle, the BSR can result either from a relative increase due to the presence of hydrates, or from a velocity and density decrease due to free gas beneath the hydrate, or from a combination of the two. Often, a lithological boundary with distinct impedance contrast would give a similar appearance of the BSR. Adequate precaution needs to be exercised while interpreting such sections.

The zones of very low reflection amplitude above the BSR are commonly referred to as acoustic blanking. The blanking results from the presence of soft clay or consolidated clay zones. Blanking is also a possibility if the subsurface layers are porous and filled with free gas.

VAMPs are compound velocity pseudo-structures (a pull-up over a push-down) recording a localized body of massive gas hydrates of high acoustic velocity overlying a column of low-velocity sediment containing free interstitial gas. Distinctive VAMPs are displayed on the reflection records as vertical columns (1–2 km wide) of down-flexed horizons commonly stacked directly beneath the crestal region of a series of arched or domed horizons. VAMPs are most commonly recorded within flat-lying beds and in non-structural settings. The massive accumulations (> 10–20%) of hydrate deposits are generally localized at VAMP structures. Most of the VAMPs are related to the apparent structural relief within the sedimentary section, as gently domed or arched reflectors[5].

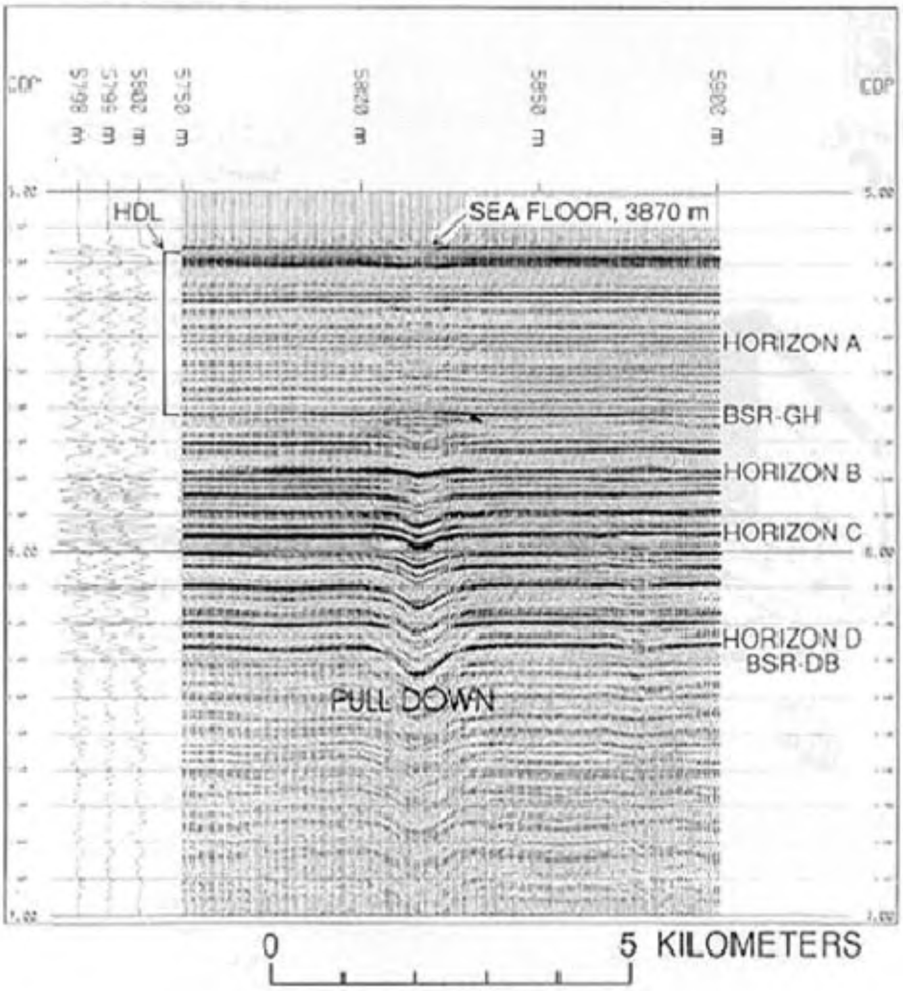

Figure 1. Migrated stack section of velocity and amplitude structure depicting the prominent velocity pull-downs observed in the Bering Sea Basin. Horizon A marks the velocity pull-up, while horizons B and C show the time-delay effect of an underlying velocity push-down, presumed to be caused by free flow of interstitial gas. Horizon D marks the silica–diagenic boundary of the BSR (after Scholl and Hart[8]).

The conditions that cause localization of dense hydrate concentrations result in the formation of VAMPs. If massive deposits of interstitial hydrate cause the arched reflection horizons, then the pooling of gas beneath their central region is the reason for pull-down. VAMPs usually appear over bathymetrically deepest areas. The abundance of VAMPs is the strongest evidence for the presence of the structural and stratigraphic traps within the upper part of the sedimentary section. Detailed surveys by Cooper *et al.*[6] show that the VAMPs commonly occur above the basement ridges, but not always related to basement topography.

Cooper *et al.*[6] have also suggested that VAMPs can be identified using the following general relations:

(i) The sets of domed and down-flexed horizons are vertically superimposed.
(ii) The sets of domes and down-flexed horizons occur as isolated deflections within otherwise flat-lying beds.
(iii) A prominent negative-polarity reflection horizon lies at the base of the arched horizons and at the top of the down-flexures.
(iv) The BSR separating the opposite flexed horizons occurs at a subsurface depth, theoretically equivalent to that of the base of the methane-hydrate stability field.
(v) The recorded relief of both the down-flexed and up-domed horizons increases with subsurface depth.

Based on these observations, VAMPs are not interpreted as deformational structures, but rather as acoustic artifacts or pseudo-structures of large size (> 1 km across). They are thought to be caused by the vertical superposition of a velocity pull-up over a more prominent velocity push-down. It may be of interest to note that the domes, upper half of VAMP structures, are not always observed (approximately 58%; ref. 7); hence the defining diagnostic attribute of the VAMPs is the anomalous column of the down-flexures.

In the late 60s and 70s, reconnaissance reflection profiling with low-power, single-channel seismic technology first recorded the anomalous structures beneath the abyssal floors of the Aleutian and Bowers basins. VAMPs were successfully used to delineate the presence of massive hydrate deposits in the Bering Sea Basin[8], wherein around 1200 VAMPs are located. The total volume of methane occurring in them is approximately 1100 trillion cubic feet (tcf) – about 900 tcf as massive hydrate and about 200 tcf as free gas. Minshull and White[9] reasoned that the acoustic pseudo-structures from the Gulf of Oman are akin to the VAMPs. These are pods of gas entrapped beneath localized concentrations of hydrate deposits. Typical records of VAMPs from the Berings Sea Basin are shown in Figure 1.

Multichannel seismic reflection data from the Kerala–Konkan area of the Western Continental Margin of India (WCMI) have been analysed for the presence of the gas hydrates (Figure 2). The multichannel data used here were collected over the WCMI in the early 1990s, for the exploration hydrocarbons. The data were made available to us by the Gas Authority of India for reprocessing and identification of possible location of gas hydrate-bearing zones. Preliminary analysis of the data[10] has resulted in the identification of the BSRs. The BSRs depict characteristics of mimicking the seafloor. The seismic records show blanking, reversal of polarity and to some extent, coincidence of the deepening of the reflector with the seafloor depth. These markers are confined to the two distinct structural/tectonic configurations like areas of diapirism/crustal upwarp and areas of parallel bedding. Earlier studies[11] in this region suggested the presence of gas-charged sediments offshore western India. Of particular interest are the acoustic wipeouts noticed at four locations in the western offshore region, which underlie the BSRs[12,13].

A migrated stack section obtained along one such profile is shown in Figure 2 *b*. A prominent up-warp can be seen in the stack section. As discussed earlier, VAMPs

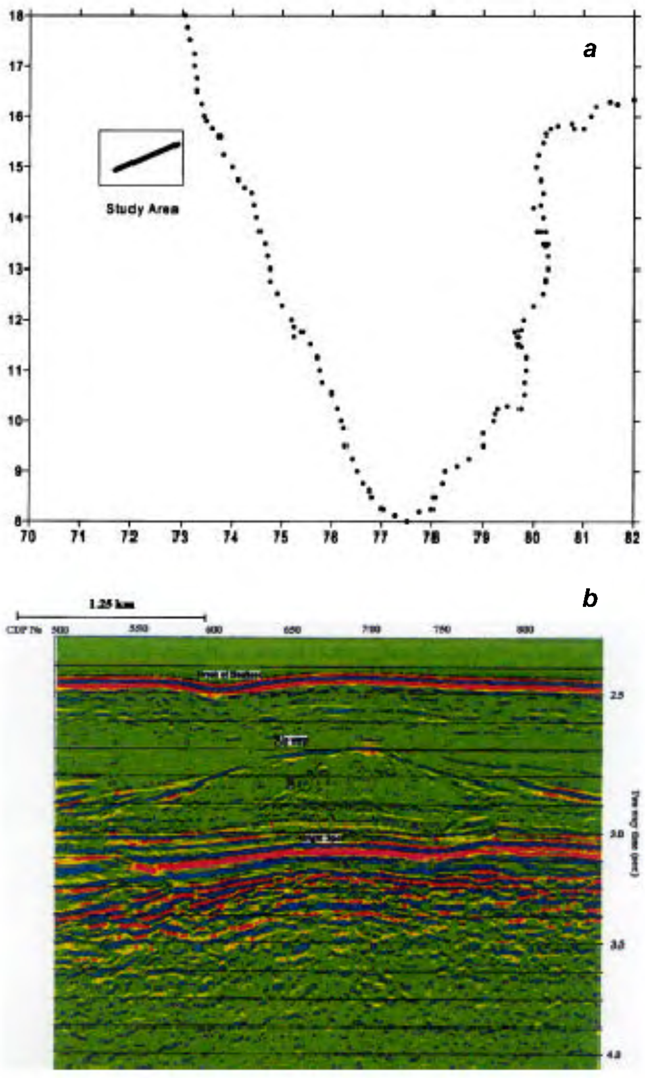

Figure 2. ***a***, Study area in the offshore region of western India. ***b***, Migrated stack section obtained along the seismic line in the study area.

are generally noticed in the areas that are structurally controlled. Keeping this aspect in mind, this line was finally selected to study the presence of VAMPs, if present. A bright spot is also clearly observed at ~ 3200 ms, which has the same polarity as that of the seafloor and may be marking the base of the free gas zone. On inspection of the stack section, we noticed only a few features resembling the velocity pull-ups (like at 'A' and 'B'; Figure 2 *b*), but they are not associated with any pull-downs.

Preliminary studies over the WCMI indicate the absence of VAMP anomalies in the multichannel seismic data, which implies that the acoustic impedance across the hydrate bearing and the free-gas zone is not quite significant.

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Demography of fan-throated lizard, *Sitana ponticeriana* (Cuvier) in a cotton field in Dharwad District of Karnataka State, India

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The demographic studies on *Sitana ponticeriana* show that the species is abundant in Gabbur village. The lizards exhibited a diurnal variation in their activity pattern (basking, foraging, seeking refuge, etc.). They were active in the morning hours when air temperature was ≤ 33°C and census yielded maximum numbers (45 ± 2.19 in 18,748 sq m or ~ 1.9 ha area). The study provides a pilot index as well as a reliable and accurate methodology for population survey of the lizard. The pilot index is essential for any large scale monitoring project and population trend analysis in future.

THE general distribution of Indian reptiles is well known[1]. It is believed that they are sparsely distributed and some species are endangered though in reality they are still abundant in a given area of their distribution. Hence, it is necessary to monitor populations of Indian reptiles in the wild by surveying a large number of sites periodically during specific periods of time, based on their activity pattern and breeding season. This will help in assessing changes in the species abundance. Such data represented as indices, using the first/pilot year as a base year, are essential for assessing the present status and also for long-term monitoring of the population dynamics[2,3]. The findings of such studies will help in evolving conservation and policy-making strategies.

Sitana ponticeriana is a medium-sized (adult snout vent length, 5–8 cm), ground-dwelling agamid lizard (Figure 1) distributed throughout India, preferably in dry and more or less open country[4]. They are diurnal and insectivorous. The body of these lizards is brown above with a series of dark brown, black-margined, rhomboidal, vertebral spots on the back. The throat fan in males is brilliantly coloured with red, blue and dark shades during the breeding months. These lizards run with a considerable speed and on the approach of danger dash away with tail tip erect, until they find refuge in some bushes or crevices in the ground. When running quickly they often adopt bi-pedal mode of locomotion. These lizards are oviparous, polyautochronic, multi-clutched and breed from May to August in Southern India[5–7].

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