Estimation of Various Physical Parameters from BSR and Quantification of Gas-Hydrates - A Case Study

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Summary

To determine various physical parameters like porosity, density, thermal conductivity, electrical resistivity, geothermal gradient or heat flow using associated probes at depth below the seafloor are not always feasible. The base of gas-hydrates stability field is marked by an anomalous reflector, known as BSR or bottom simulating reflector. The temperature at BSR can be determined from the pressure-temperature relation of the gas-hydrates phase curve. Using the seafloor temperature and the temperature at the BSR, we can calculate the geothermal gradient of an area. We present a case study to determine various physical parameters using the BSR identified on a seismic data set in the Arabian Sea. The depth of the BSR is found to be 495 m beneath the seafloor (1715 m). Taking the seafloor temperature from the oceanographic data, we determine the geothermal gradient as 34.34 ^{0}C/km. The seafloor porosity, average density, resistivity of background sediments at BSR, resistivity of hydrated sediments at BSR, average thermal conductivity, heat flow and the maximum saturation of gas-hydrates are calculated as 54%, 1.98g/cc, 2.4 Ù-m, 3.0 Ù-m, 1.267 W/m/K, 43.55 mW/m^2 and 13% respectively. From this study we show that presence of gas-hydrates increases the electrical resistivity and decreases the thermal conductivity of the sedimentary formations.

Introduction

Gas-hydrates have attracted the whole scientific community due to their widespread occurrences in nature, potential as future energy resources, possible role in climate change and geo-hazards (Kvenvolden, 1998). To understand these aspects, physical parameters like porosity, density, hydrate-saturation, thermal conductivity, temperature, resistivity, geothermal gradient and heat flow associated with the hydrates reservoirs provide important data. However, measurement of these parameters using probes at depth below the seafloor is not only difficult but also quite expensive. The most prominent marker for the investigation of gas-hydrates is the BSR, which very often represents the base of gas-hydrates stability field. Gas-hydrates are crystalline form of water and low molecular weight hydrocarbons (mainly methane). These are formed at high pressure (8-30 MPa) and cooled temperature (10 to 2^0 C) in submarine sediments where methane concentration is sufficiently high (Sloan, 1998; Kvenvolden, 1998). Guided by the thermo-barometric stability conditions, gas-hydrates are found within few hundred meters below the seafloor (Minshull et al., 1994; Lee et al, 1996; Yuan et al., 1996). The BSR is identified based on its characteristic features of (i) mimicking the shape of seafloor, (ii) cutting across the dipping strata, (iii) opposite polarity with respect to the seafloor event etc. Here we present a case study of how to quantify the amount of gas-hydrates and derive various other physical parameters from the BSR, identified on a seismic section in the Makran accretionary prism (Sain et al., 2000).

Since pure gas-hydrates have much higher seismic velocity than that of normal oceanic sediments, presence of gas-hydrates increases the seismic velocity that again depends on the concentration of hydrates, whereas free-gas underlying the gas-hydrates reduces the velocity appreciably up to few %. From the seismic data, we can determine the velocity-depth function across a BSR. The background or reference functions are defined as the variation of physical properties with depth in absence of gas-hydrates and free-gas.

Figure 1 displays the phase diagram of gas-hydrates in which the solid line represents the pure methane-hydrate phase curve with the pressure converted into depth assuming hydrostatic conditions in both water and sediments. The dashed line represents the hydro-thermal curve and the dotted-solid line represents the geothermal curve. The figure shows the zone from the seafloor down to a depth up to few hundred meters where gas-hydrates are stable. The base of the gas-hydrates stability field is associated with a seismic reflector, known as BSR, which represents a physical interface between the gas-hydrates bearing sediments above and the gas-charged or water bearing sediments below.

Estimation of Physical Parameters

Figure 2 shows a seismic section in the Makran accretionary prism, where a BSR at 495 m below the seafloor (1715 m) has been identified based in its characteristic features. Using the waveform inversion to the pre-stack seismic data, Sain et al (2000) determined the fine scale velocity structure across the BSR. Here we consider the velocity-depth function at CDP 4400 for calculating the hydrates saturation and other physical properties. The seafloor velocity is 1.78 km/s. The velocity at 285 m below the seafloor starts increasing and reaches to a maximum value of 2.2 km/s at BSR followed by a sudden decrease to a value of ~1.4 km/s. Since the velocity of free-gas bearing sediments below the BSR remains almost unaffected at more that 5% saturation, it