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Gas hydrate and seismic data analysis by using theoretical approches

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In order to quantify the concentrations of gas hydrate and free gas in the pore space, we use a precedure based on theoretical model (Biot equations and approximations in case of seismic frequency). This approach models the different layers associated with the BSR (two solids -grains and clathrates- and two fluids –water and free gas-) including an explicit dependence on differential pressure and depth, and the effects of cementation by hydrate on shear modulus of the sediment matrix. The theory gives both compressional and shear wave velocities, and needs easy to hypothesise physical parameters (porosity, compressibility, rigidity, density, frequency dependence). These can be determined from available lithostratigraphic information, and experimental data sets if no direct measurements are available. In particular, a detailed geological knowledge of the area is essential in order to suppose a normal gradients of physical properties (porosity, density, rigidity, and compressibility) of marine sediments, in order to correctly associate the velocity anomalies to chlatrate and free gas presences and avoid misinterpretations, like the case of over- and/or under-consolidated sediments.

Our theory can be applied in the cases of i) full water saturation (to reproduce absence of gas in either hydrated or gaseous phase), ii) water and gas hydrates in the pore space, and iii) water and free gas in the pore space, even if the free gas is in overpressure condition. The effect of grains cementation when the concentration of gas hydrates is high, is considered by application of the percolation model, which describes the transition of a two-phase system from a continuous (grain cementation) to a discontinuous (no cementation) state. It is finally worth to mention that a coupling factor describes the degree of coupling between pore fluid and solid frame.

The concentrations can be estimated by fitting the theoretical velocity to the experimental P-wave velocity obtained from travel-time inversion. Supposing that positive anomalies are due only to the presence of hydrate, the discrepancies between the inverted velocity profile and the velocity for water-filled normally compacted marine sediments are interpreted as due to the presence of gas hydrate (where positive anomalies are present) and free gas (where negative anomalies are present). We can suppose four main relative distribution of free gas: (1) uniform, (2) 50% uniform and 50% random, (3) patchy and (4) random. In the first two cases, the velocity decreases with a small amount of free gas. In the two last cases, instead, the velocity decreases quite linearly versus free gas amount.

Finally, the BSR depth obtained by seismic data can be used to estimate the geothemal gradient fitting the seismic depth of the BSR with the theoretical depth evaluated by using modeling.

When only seismic data are available, the procedure to estimate gas hydrate and free gas consists essentially in two steps. In the first step, the acoustic velocity field associated to the BSRs is obtained from traveltime tomographic inversion. The second step consists in estimating the concentrations by fitting the theoretical velocities to experimental velocities increasing the amount of gas hydrate and/or free gas; it is obvious that the knowledge of the geological setting is indispensable to suppose the trend of physical properties of sediments versus depth. The theoretical velocities of gas hydrate- and free gas-bearing sediments are obtained using a Biot-type theory described above. A complementary approach is study the AVO effects in multichannel seismic profiles, that can give additional information, such us the Poisson's ratio of sediments, the presence of free gas, the cementation of sediments. Moreover, if avalilable from OBS or OBC, the S-wave velocity is very useful to contrain the estimation and to detect and estimate overpressure condition in the free gas zone.

In summary, with the appropriate geological information on the control of geology versus hydrate cementation on the velocity field, a 2D- or 3D-velocity section can be translated in gas hydrate and free gas concentration sections. This procedure was used to analyse the seismic data acquired during the last years offshore South Shetland Margin, in which there are evidences of gas hydrate and free gas in the marine sediments. During the Antarctic legs, the following types of data are acquired: multichannel seismic data at high and low penetration power, CHIRP, multibeam and gravimetric data. The geophysical data are included in a GIS project to improve the interpretation

of all type of data.

Analysing the seismic available data, we have determined the extension of the BSR and we estimated the potentiality of both gas hydrate and free gas layers. The depth of the BSR, obtained by the interpretation of the pre-stack depth migration section, was also used to estimate the range of the geothermal gradient.

The CHIRP and multibeam data allowed us to detect mud volcanoes and the fluid expulsions, confirming that this area is active.

Finally, we reconstructed possible scenarios to evaluate the quantity release of methane caused by the temperature and pressure change induced by a global climate change.