

Reverse Time Migration for Methane Hydrate Exploration Using Vertical Cable Seismic Survey

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Gas hydrates are ice-like solid materials in which gas molecules are trapped in lattices of water molecules and are stable only under low temperature and high pressure conditions. Arctic permafrost zones and deep water shallow basins are capable of bearing abundant amounts of gas hydrates. Seismic response of gas hydrate stability zone (GHSZ) is normally recognized with a high amplitude reflection. The impedance contrast between high velocity gas hydrate bearing zone above and low velocity free-gas zone below it makes a strong reflecting boundary which is known as bottom simulating reflector (BSR). The base of the gas hydrate stability zone is marked by BSR, which is indeed a physical phase alteration boundary rather than a geological one and may crosscut the reflections from sediments. Conventional marine seismic surveys using towed streamers can provide large scale subsurface images only and their resolution is not satisfactory for exploring these shallow targets. Alternative data acquisition methods like ocean bottom cable (OBC) or ocean bottom seismometer (OBS) surveys have been used for better understanding of gas hydrate resources (Dash et. al, 2009). Ocean bottom surveys can acquire high resolution data with an enhanced signal to noise ratio, but still with a costly and cumbersome deployment and maintenance process.

Vertical cable seismic (VCS) survey has been recently developed for efficient seismic imaging of shallow targets below seafloor. Vertical arrays of hydrophones are deployed near to the seafloor and seismic source is towed by a vessel. Asakawa et al. (2014) used VCS survey to explore submarine massive sulphide (SMS) deposits offshore Japan. Although VCS data acquisition technology has been developed, its data processing methods still require improvement for better depth imaging. Traditionally, only primary reflections in the VCS data are assumed to be the main source of information and multiple reflections from the sea surface are removed during data processing. On the other hand, these water column multiples have been used in the past for the migration of OBC and OBS data either in combination of primaries or separately. Considering the similarity between VCS and OBC/OBS data acquisition layouts, with deep receivers and shallow sources, the question is whether one could think about multiples in VCS data as signal rather than noise.

In order to solve this problem we developed a seismic reverse time migration (RTM) approach by using multiple reflections, which have a different travel path from the primaries and can cover a wider area of the target. The velocity model above sea level is filled with an imaginary water column and receiver points are mirrored into it. Downgoing multiples are separated and treated as primaries which could have been recorded by the mirrored receivers. Migrated image is obtained using the manipulated geometry and separated downgoing multiples. We could successfully identify BSR of the methane hydrate stability zone in Japan Sea using VCS data and the new mirror RTM approach.

References

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