IMAGING AND CHARACTERIZATION FROM THE EARTH'S CRUST TO OCEAN INFERRED FROM AUTOMATIC VELOCITY ANALYSIS AND ROCK PHYSICS APPROACHES

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論 文 名　：IMAGING AND CHARACTERIZATION FROM THE EARTH'S CRUST TO OCEAN INFERRED FROM AUTOMATIC VELOCITY ANALYSIS AND ROCK PHYSICS APPROACHES
（自動速度解析と岩石物理学的手法から推定される地殻から海洋までのイメージングと物性評価）

区　　分　：甲

論 文 内 容 の 要 旨

Implementing and integrating innovative techniques such as automatic seismic velocity analysis, pre-stack waveform inversion and rock physics could break through exploration technical challenges in term of deep water and complex hydrocarbon systems in the plate convergent margin. Automatic velocity analysis in seismic data processing provided accurate and high-resolution P-wave velocity (*Vp*) structure compared to the conventional velocity analysis based on manual picking which can induce human errors, arbitrary interpretation and large uncertainty. Rock physic model allowed us to translate *Vp* into fluid saturation and pore pressure. These methodologies enhanced an exploration technique to quantify hydrate and gas resources in more accurate and high resolution, and provided insights to understand hydrate and gas formation processes, pore pressure mechanism, sedimentary processes and geo-hazards in the subsurface. Because of high-resolution velocity structure via automatic analysis, I further applied this technique to investigate and elucidate oceanographic processes resulting to thermohaline fine structure in the Kuroshio Current. This dissertation covers five chapters, and the main content in each chapter are given below:

Chapter 1 introduced the research objectives, background, and motivation. In this study, 3D seismic reflection and well data were mainly used. The integrated approach via automatic velocity analysis, pre-stack waveform inversion and rock physics were briefly described in this chapter.

In Chapter 2, the gas hydrate and free gas system in the forearc basin of the plate convergent margin was interpreted based on the seismic velocity model derived from automatic velocity analysis and rock physics models. The Kumano Forearc Basin in the Nankai Trough area, Japan, has been known to be in complex and dynamics deformation process due to the intensive tectonism in the Nankai subduction margin. A high-resolution seismic velocity analysis to the 3D seismic data via automatic velocity picking algorithm was performed. As a result, the accurate and high-resolution *Vp* structure was obtained, which we could interpret, delineate, and quantify widespread hydrate and gas distribution in the deep water sediments. Then spatial gas hydrate and free gas saturation were converted from this high-resolution seismic velocity integrating with borehole data via rock physics approach. As a result, saturation of gas hydrate ranges from 0% to 45% in the pore volume, and highly concentrated around the outer ridge where lateral faults are densely developed. Whereas free gas saturation ranges from 0% to 20% in the pore volume, and the gas reservoir is widely distributed below the hydrate layer and highly concentrated above ridge structure. These results demonstrate that main reason for widely distributed hydrate and gas accumulation is due to dynamics gas source enrichment in the accretionary prism underlying the basin. These gases migrated upward through the complicated structures (i.e., fault, fracture, and chimney) to form widespread gas hydrate and free gas in the shallow subsurface.

In Chapter 3, pore pressure prediction was performed in the Kumano Forearc Basin. Excess pore pressure decreases effective stress and induces reservoir instability and fault reactivation; therefore, subsequent geo-hazards could occur such as submarine landslides and earthquake. In addition, pore pressure information is important for guiding the drilling program of hydrocarbon exploration/production. Pore pressure is commonly predicted from seismic velocity. However, *Vp* is influenced both by pore pressure buildup and fluid saturation, and it is difficult to separate their effects. Therefore, I used simultaneous pre-stack waveform inversion to obtain a high-resolution S-wave velocity (*Vs*) profile. Using Vs information, I could separately estimate high pore pressure and gas saturation effects within this basin. High pore pressure can be determined from deviating normal compaction trend. In this study, the ratio of *Vp* and *Vs* was used to construct the normal compaction trend, although only *Vp* is commonly used for the construction of the trend. As a result, the pore pressure in the most part of forearc basin sediments is predicted as hydrostatic condition. Therefore, compressional stress and dynamic behaviors in the accretionary prism do not influence to increase in pore pressure in the overlying Kumano Forearc Basin. Based on the relationship between *Vp/Vs* and *Vp*; furthermore, I developed a method to classify (i) hydrate, (ii) gas and (iii) over pressure area.

In Chapter 4, because of cutting-edge technique via automatic velocity analysis, I applied this technique to the time-lapse multichannel seismic reflection data in the water column of the Kuroshio Current aiming to elucidate the oceanographic processes causing the thermohaline fine structures in the ocean. All reflection profiles and sound speed in the Kuroshio Current area directly derived from advanced seismic velocity processing presented a whole view of different thermohaline features variation through time and space. Sound speed profiles varied concurrently, and seismic images presented turbulent mixing, presence of internal waves, thermohaline staircases, warm/cold water vortex, and the features of deep water mass boundaries across the Kuroshio Current. The automatic sound speed analysis with the time-lapse seismic data revealed numerous ocean processes through the entire water column with high spatiotemporal resolution. Therefore, mapping time-lapse sound speed profiles in the Kuroshio Current without relying on discrete data is a great interest of probing time-variant oceanographic processes over a large-scale ocean current as well as importance for ocean-climate research.

Chapter 5 summarized the key results and findings of this research. In this study, the combining approaches via automatic velocity analysis, pre-stack waveform inversion and rock physics can provide effective and automated methods for delineating and quantifying widespread hydrate and gas distribution. All results demonstrated and allowed us to better understand geological mechanism and processes controlling hydrate and gas occurrence in the subduction zone. The automatic velocity technique was further applied to reveal spatiotemporal reflectivity and characteristics of fine structure in the seawater of the Kuroshio Current and probe oceanographic processes influencing on ocean currents and climate systems. All approaches studied in this thesis will offer the potential solutions and advanced exploration systems for geo-resources in other plate convergent margins and environmental problem.