Geophysical Research Abstracts, Vol. 8, 09126, 2006
SRef-ID: 1607-7962/gra/EGU06-A-09126

Basin evolution, abnormal pore-pressure development and the maximum seal capacity of porous sedimentary rocks

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We have developed a methodology to determine underground permeability structures and pore-pressure distribution from surface and/or core samples. Tertiary to Quaternary sedimentary basins were selected because their history both in space and time is much simpler than that of basement rocks and sedimentary rocks are still undergoing compaction and cementation. Our basic strategy has been three-fold: (1) measure transport properties under deep conditions to estimate those properties at depths, (2) measure transport properties for samples collected from all stratigraphic horizons to evaluate long-term cementation empirically, and (3) analyze interacting processes of sedimentation, fluid flow and compaction using measured properties to model the basin development. A good example of (2) is the result for Miyazaki Group whose porosity decreases with time; data there can be used to test prediction of the cementation via solution/precipitation processes in the future.

A highlight result from our basis analysis is the prediction of the development of abnormal pore-pressure in the gas field and the focal area of the Chi-Chi earthquake in Taiwan. With an overburden of about 4 km thick sediments, permeability of shale/siltstones decreases down to the order of 10^{-18} m^2 and fluids cannot move much even in geological time scales. Then water below this depth range is trapped to form abnormal pore pressures. This process combined with release of water due to smectite-illite transition and supply of water from depth yields nearly perfect agreement with

the observed abnormal pressure in the production wells in the gas fields. Permeability decreases by a few orders of magnitude with increasing overburden pressure, and a good agreement cannot be obtained without taking this into account.

Another important problem is the effect of faults and fractures on fluid flow. Recent data on fault zone permeability, including ours on an active fault zone in the Niigata basin, have revealed that fault zones in porous sediments are more impermeable than host sediments. Also, our recent experimental data show that the presence of fractures in sedimentary rocks has little effect on overall permeability when these rocks are porous. Sedimentary rocks become more impermeable with increasing compaction and cementation, thus increasing seal capability. However, fluids can move easily along faults and fractures if sediments are almost completely cemented. Thus a "***maximum seal capacity***" should exist in between where sediments are compacted enough to reduce permeability, but not enough for easy fluid flow along faults and fractures. Natural oil and gas must have made full use of these sediment properties in their accumulation. Determination of maximum seal capacity under various sedimentary environments will lead to further insight into material circulation in the Earth, CO_2 sequestration, waste isolation and other Earth's environmental issues.