Conventional Traps in Unconventional Reservoir Rocks in Northern Japan*

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Abstract

Siliceous rocks, mainly porcelanite and chert of the same age as the Miocene Moterey Formation in California, are distributed in the northern Japan. The rocks are excellent petroleum source rocks as well as reservoirs and cap rocks. Reservoir and cap-rock studies of their burial diagenesis, chemical composition, porosity and permeability have been performed and revealed that there are at least three possible trap types as shown in Figure 1.

1) Diagenetic transformation trap (Yurihara Field Type): In the diagenetic process of the transformation from opal-CT to quartz porcelanite, ultra-micro pores (pore throat radius < 0.02 µm) abundantly exist in the opal-CT porcelanite disappear and well-connected micro pores (pore throat radius > 0.02 µm) newly develop in the quartz porcelanite. Accordingly, the permeability of the porcelanite improves in the process. If the transformation boundary is deeper than 1000 m, the opal-CT porcelanite above the boundary is compacted enough to form a cap rock and the quartz porcelanite below the boundary acts as a reservoir.

2) Differential compaction trap (Toyotomi Field Type): The newly formed micro pores generally reduce their sizes only by mechanical compaction with burial diagenesis. Clay-poor quartz porcelanite sustains good reservoir quality within a one thousand meter interval below the transformation boundary. If a clay-rich layer is interbedded in that interval, the layer is less permeable and mechanical compaction progresses selectively in the layer. As a result, the clay-rich quartz porcelanite layer plays the role of seal and the clay-poor porcelanite layer acts as a reservoir.

3) Fracture Type (possible trap type in Japan): The quartz porcelanite layer below the transformation boundary with the newly developed micro pores shows higher permeability than surrounding layers. If silica-rich formation water is supplied at the stage, the permeable quartz porcelanite layer changes to a chert layer. Chert is the most brittle among siliceous rocks and capable of forming fractured reservoirs. The

supply mechanism of silica-rich formation water could be differential burial diagenesis of siliceous rocks due to their different clay contents and discharge of formation water due to rapid porosity decrease in the silica transformation process.

Hydrocarbons reservoired in these traps of Toyotomi and Yurihara fields show higher maturities than the reservoir rocks themselves, suggesting that the hydrocarbons have migrated from deeper source rocks in the same manner as conventional petroleum systems, although the reservoir rocks are unconventional like gas shale and oil shale reservoirs.

1. The diagenetic transformation from opal-CT to quartz makes the pore size and its connectibity in porcelanite increase abruptly and the ductility decrease (1, 2, 3, 4, 5, 6, 7).

2. An increase in clay content makes the ductility of the porcelanite high and facilitates a reduction in the pore size with burial compaction (2, 7, 8, 9, 10).

3. In clay-rich quartzose porcelanite, the throat radii of pores are reduced by clay minerals, which emerge in the network pores generated by the opal-CT to quartz diagenetic transformation (7).

4. Under high effective confining pressures at depths deeper than approximately 1000 m, the permeability of opal-CT porcelanite is low enough to seal hydrocarbons in the clay-poor quartzose porcelanite. However, under lower effective confining pressures at depths shallower than 500 m, some opal-CT porcelanites have too high permeability to act as seal rocks (7).

5. Chertification of porcelanites is promoted by silica cement supplied by silica rich water at permeable zones (2, 10, 11, 12).

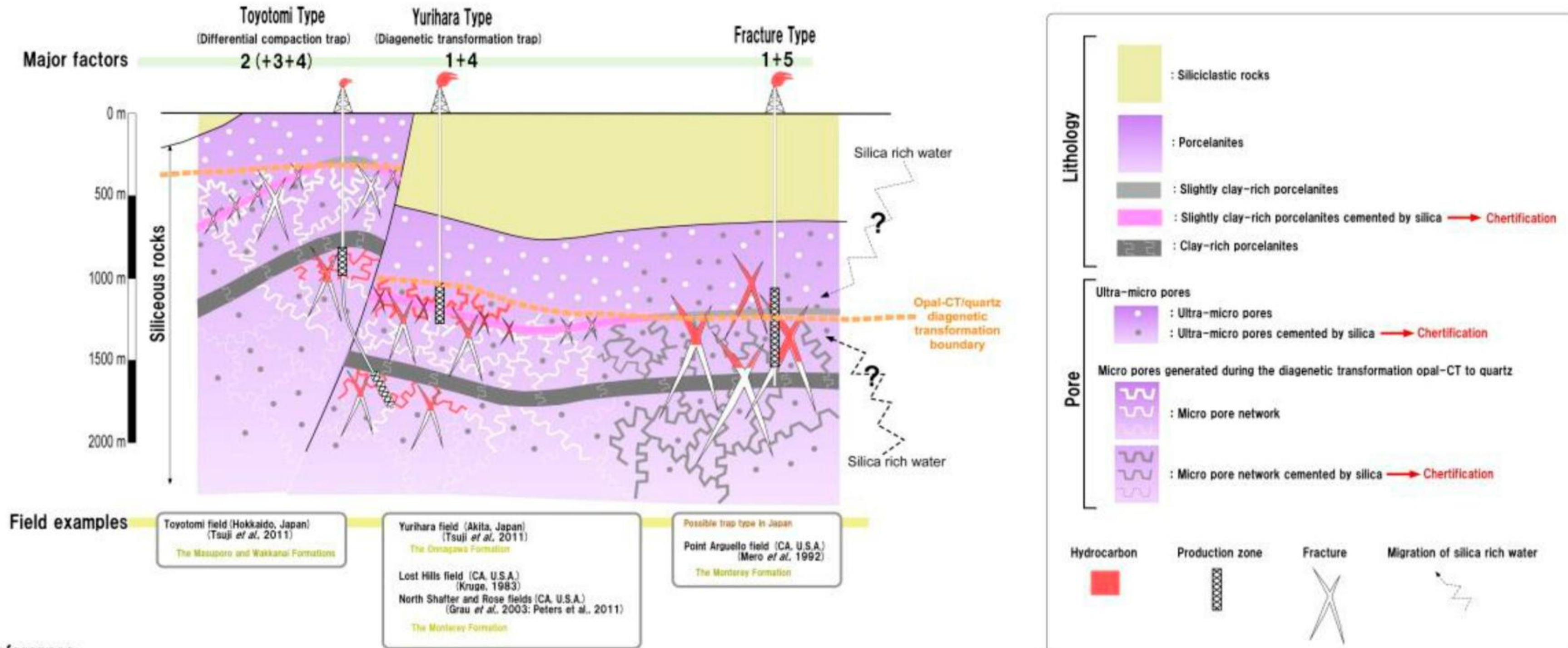

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Figure 1. Five major factors in forming traps in siliceous rocks.