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Hiroshi Oda[1] (1) Geological Survey of Japan, AIST, Tsukuba, Japan

Cretaceous and Paleogene Coals in Japan as Source Rocks of Natural Gas and Petroleum

Introduction

Nowadays coals are considered as good source rocks for petroleum and natural gas resources all over the world. For example, there are a lot of giant oil and gas fields in Mahakam area, East Kalimantan Indonesia. Source rocks for them are Miocene coals and coaly shells deposited there.

In Japan there were once numerous coalfields. And most of them are closed now. However the coal resources are still calculated as more than 20 billion tons. So we are hopeful to find the petroleum and natural gas resources generated from these coals. But it is necessary to develop the unique evaluation method of Japanese coals. Because Japanese coals are richer in hydrogen than other coals and they contain "degradinite". So the authors have investigated the characteristics of Japanese coals which generate petroleum and natural gas.

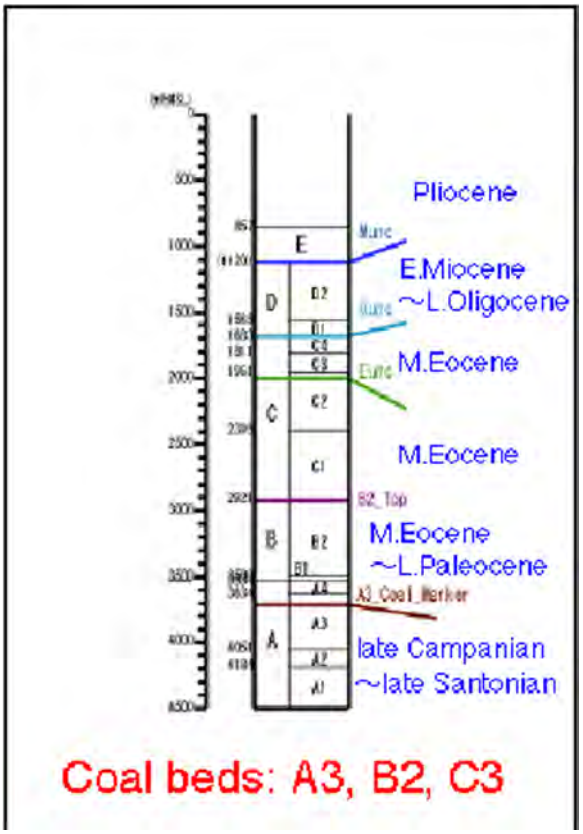
The MITI Sanriku-Oki borehole was drilled in 1999 to a depth of 4,500 m to explore offshore gas resources derived from the Cretaceous and the Oligocene coals and coaly shales. The borehole site is located 857 m deep below the sea level and about 60 km offshore Hachinohe City, Aomori Prefecture, north Japan. And the coal bearing beds correlated with formations of the MITI Sanriku-Oki are exposed inland along the coast. The authors have been conducting a sequence stratigraphic, sedimentological, and geochemical study for the reconstruction of sedimentary facies and organic features of the natural gas reservoirs derived from coal and coaly shale in this area. The data of vitrinite reflectance of these coals indicate around 0.5 %, showing that these coals are still immature However Rock-Eval data show between 100 and 180, showing these coals are classified as organic type II / III. Coals from Kuji area, north Japan, are still immature but high potential for petroleum and natural gas resources. There are numerous coalfields in Japan. So they can be new targets for petroleum and natural gas explorations.

Geologic Settings and Coal Samples

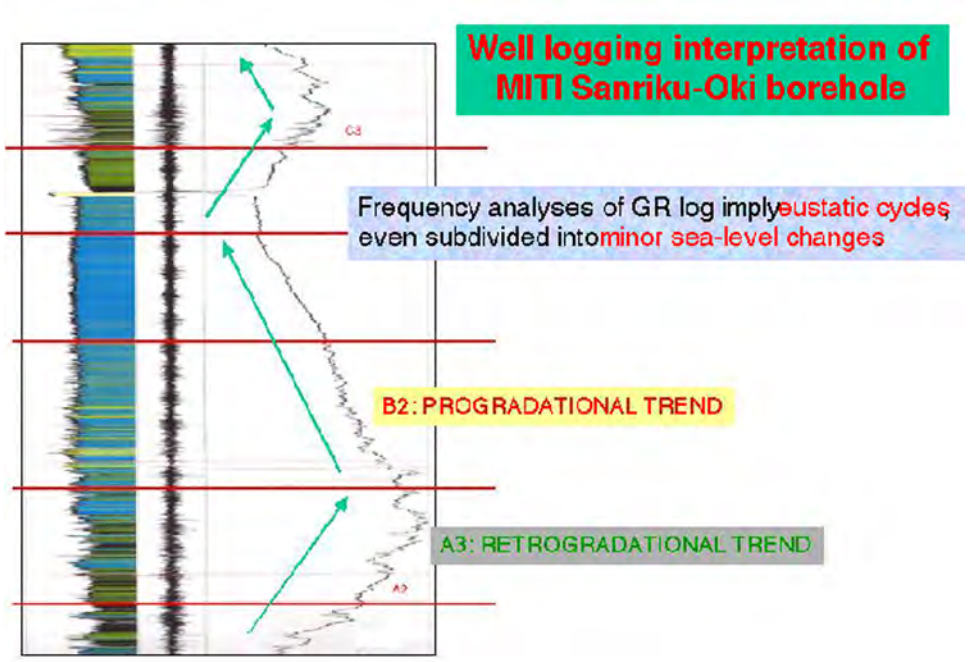
Upper Cretaceous Kuji and lower Oligocene Noda Groups are distributed along Iwate Sanriku coast, north Japan. Kuji Group is dated as Early Campanian from molluscan biostratigraphy including *Inoceramus*. And the Noda Group is correlated with the Lower Oligocene. Both groups were not tectonically modified, but show slightly inclination eastward. In 1999 the MITI Sanriku-Oki was drilled offshore Hachinohe City and natural gas derived from coals and/or coaly shales were explored in this site.

Kuji Group is overlain by Cretaceous Miyako Group and granite, and it inclines northeastward. Kuji Group is divided into three formations: Tamagawa, Kunitan, and Sawayama Formations. Lithological change of Kuji Group is interpreted as transgressive sequence including peat, medium-to-coarse sandstone, trough cross-stratified sandstone, hummocky cross stratified sandstone, and bioturbated sandstone. Kunitan Formation contains various coal beds. But this thickness is very thin, around 50 to 60 cm and coal ranks are low. Peat layers were deposited in river mouth and natural levee of swamp. Coal beds of Kuji Group are characteristic with bearing a lot of amber.

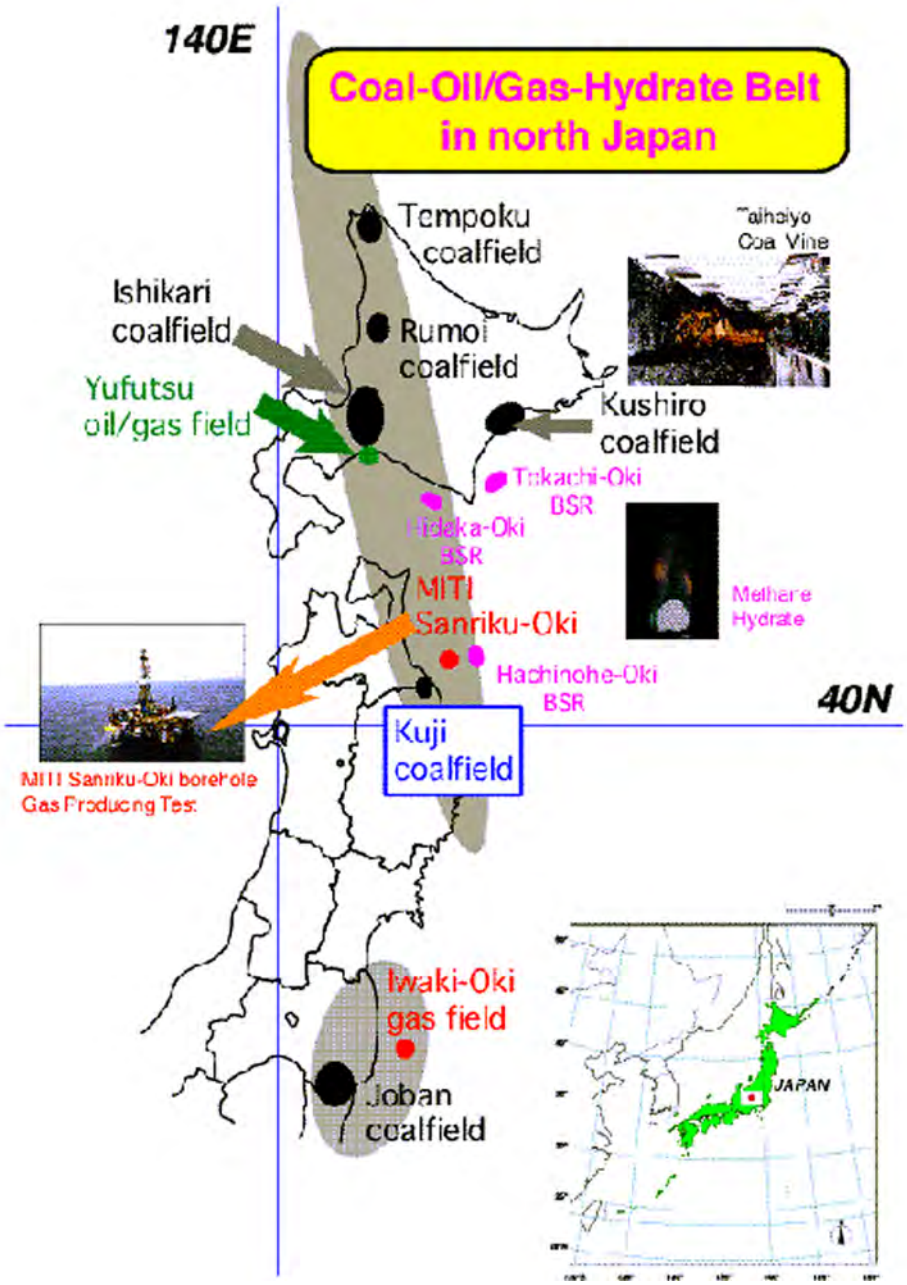
Noda Group overlays Kuji Group with unconformity. And it is divided into two formations: Minato and Kuki Formations. Noda Group is correlated with the lower Oligocene by fossil flora, which are similar to those of Ishikari coalfield in Hokkaido, north Japan. Minato Formation is characterized by abundant round pebble layers deposited in river channels. And it also has various coal beds which are about 60 cm in thickness and continuous. Lithlogical cycles are



Stratigraphy of MITI Sanriku-Oki borahole



Source Rock Potential of Coals from Kuji Coalfield



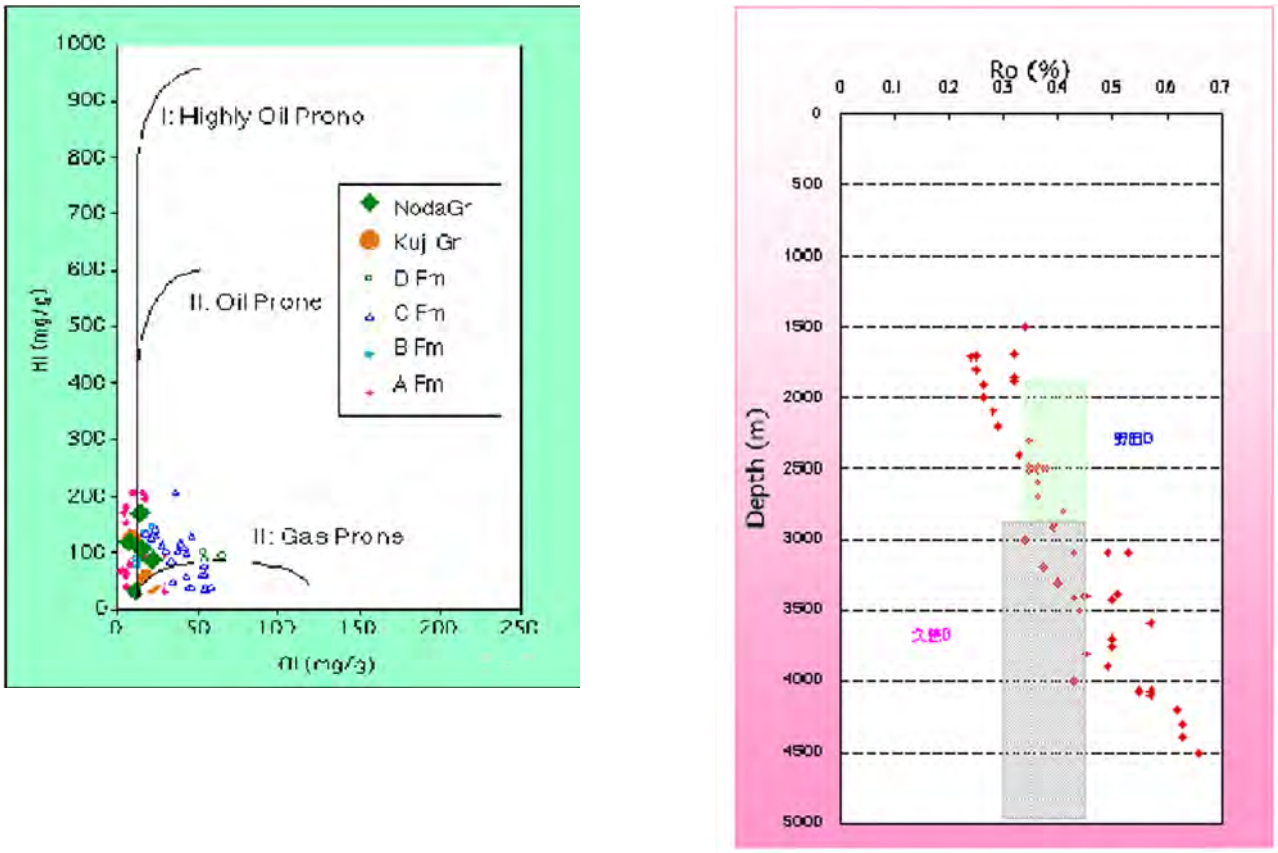
%. Hydrogen index (HI) data of them are between 34 and 172 mgTOC/gTOC, TOC values are ranging from 31 to 64 %.

observed in Minato Formation including conglomerate, sandy tuff, siltstone and mudstone, showing deltaic formation.

Frequency Analysis of Wireline Log Data

A time series frequency analysis of wireline log data was applied to evaluate a sequence stratigraphic framework in the reservoirs of the MITI Sanriku-Oki borehole by using CycloLog (a trademark of ENRES International).

In the frequency analysis, GR log data was processed using Maximum Entropy Spectral Analysis (MESA). Firstly, part of



Pseudo van Krevelen diagam (left) and Ro versus depth diagram (right) of coal samples from MITI Sanriku-Oki borehole and outcrops

a series of data points is analyzed to predict the next points in the series. In MESA, the prediction error calculation is conducted to evaluate the degree of deviation or best fit within the next point in the series. The prediction is based on an assumed pattern of cycles within the data series. Secondly, based on the prediction error calculation, Prediction Error Filter Analysis (PEFA) calculates the position and amplitude of breaks in the frequency successions or breaks in the phase of each cycle present within the total frequency. Finally, the integration of one set of PEFA values is carried out to produce an Integrated Prediction Error Filter Analysis (INPEFA) curve.

Based on foraminiferal and other biostratigraphic data, the MITI Sanriku-Oki borehole is interpreted to have deposited in the late Santonian to the late Early Miocene, which can be related with third order eustatic cycles. By analyzing all available data, these cycles are further subdivided into smaller cycles related with forth sea-level changes.

The authors have performed vitrinite reflectance (Ro) measurements for 12 samples and Rock-Eval pyrolysis analyses for 8 samples from Kuji coalfield. Ro data of coals from the Cretaceous Kuji Group range from 0.29 to 0.45 %. Hydrogen index (HI) data of them are between 46 and 122 mgTOC/gTOC, total organic carbon contents (TOC) ranging from 40 to 64 %. And Ro data of coals from the Oligocene Noda Group range from 0.35 to 0.45

As a result, all coals of Kuji coalfield are less than 0.6 % (oil window) and immature mainly because burial depth is shallow there. Thus oil and gas will not be generated from coals in this area. However they could be good source rocks. Because organic types of them are classified as type II/III with medium-to-high HI values. This idea is supported by amber in those coals. In addition, from MITI Sanriku-Oki borehole they succeeded in producing natural gases from the Cretaceous and the Oligocene coals and or coaly shales. It implies that coals in Kuji coalfield can generate oil and natural gas if they are buried deep enough.

Discussion

Japanese Paleogene coals mainly consist of two groups of maceral constituents, telinite/collinite and degradinite. Intercellular spaces of telinite and collinite were filled with substance dominant in aliphatic compounds, derived from the algae and/or bacteria and diagenetic transportation of plant biopolymers under the anaerobic condition. In the case of telocollinite, the intercellular spaces were completely filled with and are no longer readily distinguishable from cell walls under anaerobic condition. Also, "degradinite" was originated from residue probably derived from the algae and/or bacteria and the other residue of degraded plant materials.

Activities of petroleum explorations have been focused on backarc (Sea of Japan) side in Japan. Because the back-arc basins of Japan have good reservoirs, the Neogene "Green Tuff". And partly because coals have not been considered as good source rocks in Japan without enough source rock evaluation. However, in the forearc (Pacific Ocean) side of Japan there are a lot of sedimentary basins bearing coalbeds, deposited in Cretaceous and Paleogene. Source rock potentials of Cretaceous and Paleogene coals from forearc basins, especially in Ishikari, Kushiro, Kuji, and Joban coalfields, north Japan, can be good enough to generate oils and natural gases. So it is necessary to develop the unique evaluation method of Japanese coals to explore potential petroleum and natural gas resources in Japan. And this method will be applied to coalfields including in Brazil, Colombia, Indonesia, and so on.

Ro data of coals from Kuji coalfield show that these are still immature However Rock-Eval data imply that these coals are classified as organic type II/III and have high potential for petroleum and natural gas resources. There are numerous coalfields in Japan. So they can be new targets for petroleum and natural gas explorations.