[PS]Characterization of Organic Matter in Shale from the Gyeongsang Basin, Korea*

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Abstract

Because shale gas is one of the important natural energy resources of the future, many studies related to it have been carried out in Korea since 2010. To date, however, there are no results for the shale gas resource in Korean non-marine basins. The purpose of this study is to characterize organic matter in the Gyeongsang Basin, one of the Korean non-marine basins, and to document the potential of shale gas resources in this basin.

The Gyeongsang Basin is the largest Cretaceous non-marine sedimentary basin (~20,000 km^2) in Korea, and is divided into the Sindong, Hayang, and Yucheon groups, in decreasing age. During deposition of the Sindong Group, alluvial fan (Nakdong Formation), fluvial (Hasandong Formation) and lake (Jinju Formation) environments developed from the basin margin to the center. Black shale is observed in the Nakdong and Jinju formations. We collected shale samples from outcrops and core (YB-1) drilled to ~1.2 km from the surface and analyzed several geochemical analyses to characterize the organic matter in both formations. The results of Rock-Eval analysis show that most samples in these formations have low S2 (< 1 mgHC/gRock) and Tmax (< 400 °C), and their TOC content is less than 2.5 wt%. It is difficult to discriminate organic matter type in the HI-OI diagram due to low S2. These results indicated that organic matter has been over-matured to generate gas, which might have been stored in shale in both formations, or migrated into other formations, and the residual organic matter cannot produce hydrocarbons any more. From the low concentration of residual methane in the shale (<100 ppm) it is evident that the generated gas has migrated into other formations, which is consistence with the result of 1-D petroleum system modeling; more than 65% of produced gas in the Jinju Formation is discharged. These results point to low potential of shale gas resources in the Gyeongsang Basin. The relationship between TOC/TN and δ13Corg of organic matters from the Nakdong and Jinju formations is mostly located in the region of the terrestrial land plant, illustrating that the organic matter in these formations originated predominantly from a terrestrial source (Type III).

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Abstract

Because shale gas is one of the important natural energy resources in the future, many studies related to it have been carried out in Korea since 2010. To date, however, there are no results for the shale gas resource in Korean non-marine basins. The purpose of this study is to characterize organic matter in Gyeongsang Basin, one of the Korean non-marine basins, and to document the potential of shale gas resource in this basin.

Gyeongsang Basin is the largest Cretaceous non-marine sedimentary basin (~20,000 km^2) in Korea, which is divided into the Sindong, Hayang, and Yucheon groups with decreasing age. During the deposition of the Sindong Group, alluvial fan (Nakdong Formation), fluvial (Hasandong Formation) and lake (Jinju Formation) environments developed from the basin margin to the center. Black shale is observed at the Nakdong and Jinju Formation. We collected shale samples from outcrops and core (YB-1) drilled to ~1.2 km from the surface and analyzed several geochemical analyses to characterize the organic matter in both formations.

The results of Rock-Eval analysis show that most samples in these formations have low S_2 (< 1 mgHC/gRock) and T_{max} (< 400 ºC), and their TOC content is less than 2.5 wt%. It is difficult to discriminate organic matter type in the HI-OI diagram due to low S_2. These results indicated that organic matter has been over-matured to generate gas, which might have stored at shale in both formations or migrated into other formations, and residual organic matter cannot produce hydrocarbons any more. The low concentration of residual methane in shale (<100 ppm) is evident that the generated gas migrates into the other formations, which is consistence with the result of 1-D petroleum system modelling; more than 65% of produced gas in the Jinju Formation is discharged. It is appeared that various lines of above results point to low potential of shale gas resource in the Gyeongsang Basin.

The relationship between TOC/TN and $\delta^{13}C_{org}$ of organic matters from the Nakdong and Jinju Formation is mostly located in the region of the terrestrial land plant, illustrating that the organic matters in these formations are predominantly originated from a terrestrial source (Type III).

Study area

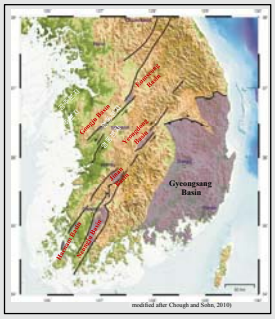

Fig. 1. The location of terrestrial basins in Korea.

Table 1. The area of terrestrial basins in Korea.

Basin	Area (km^2)
Gyeongsang	~20,000
Eumseong	~150
Yeongdong	~270
Gongju	~100
Jinan	~275
Neungju	~900
Haenam	~100

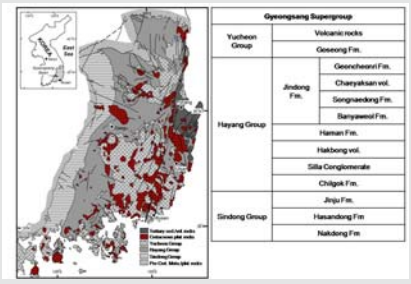

Figure 2. Geological map and stratigraphy of the Gyeongsang Basin (from Lee and Lee, 2003).

Sampling and methods

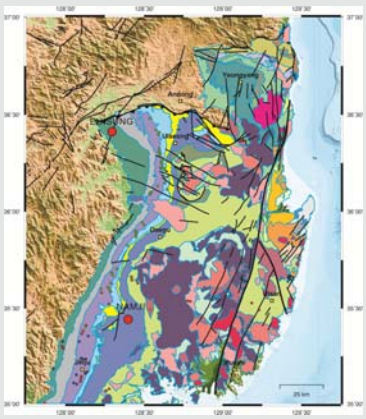

Figure 3. The sampling location of this study in the Gyeongsang Basin.

Figure 4. Outcrop and core photos of the Jinju Formation in the Gyeongsang Basin.

Table 2. Analytical method for this study.

Items	Instrument	Place	Etc.
Rock-Eval Pyrolysis	Rock-Eval Turbo 6	KIGAM	
Element Analysis (C, N, S)	CHN-900/S-144DR	KIGAM	
$\delta^{13}C$, $\delta^{15}N$	SIRMS (IsoPrime-EA)	NICHEM	
XRD	X'pert MPD, Philips	KIGAM	
Gas composition	Agilent 7890 GC	KIGAM	Headspace method

Results and discussion

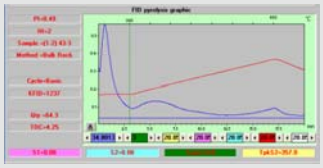

Figure 5. Results of Rock-Eval analysis from the Jinju Formation.

Table 3. Summary of the Rock-Eval analysis from the Gyeongsang Basin.

	Sample No.	S_1 (mgHC/gRock)		S_2 (mgHC/gRock		T_{max} (ºC)		TOC (wt%)	
		Range	Average	Range	Average	Range	Average	Range	Average
Jinju	71	0.02~0.66	0.04	0.02~0.17	0.06	304~609	383	0.09~2.28	0.80
Nakdong	6	0.03~0.06	0.04	0.07~0.14	0.10	321~609	422	0.03~6.18	2.12
YB-1	41	0.01~0.13	0.04	0.03~0.26	0.08	308~609	398	0.11~8.14	1.85

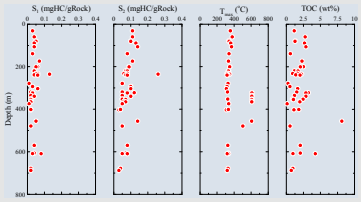

Figure 6. Downprofile of Rock-Eval analysis from the core YB-1.

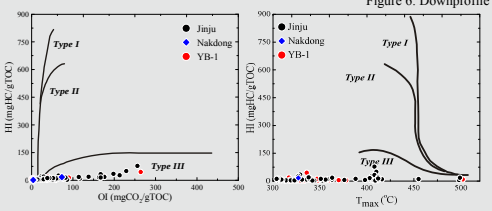

Fig. 7. The relationship between HI and OI, and between HI and T_{max} based on the Rock-Eval analysis from the Gyeongsang Basin.

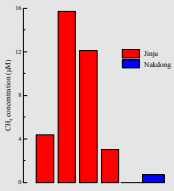

Figure 8. Gas concentration in the Gyeongsang Basin.

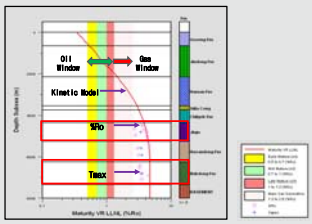

Figure 9. Thermal maturity modeling using LLNL Easy %R_o Kinetic Model in the Gyeongsang Basin.

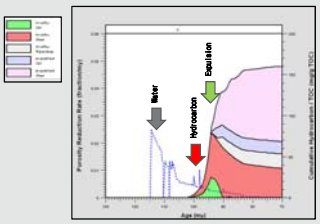

Figure 10. Cumulative hydrocarbon generation and expulsion model in the Gyeongsang Basin.

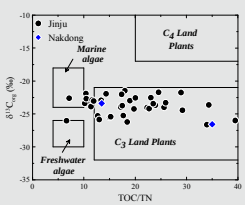

Figure 11. Correlation between $\delta^{13}C_{org}$ and TOC/TN (adapted after Lamb et al., 2006) from the Gyeongsang Basin.

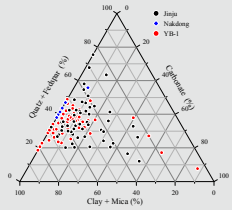

Figure 12. Ternary diagram of mineral compositions from the Gyeongsang Basin.

Conclusion

Most of shale samples from the Gyeongsang Basin have shown low S_1, S_2, and wide T_{max} variation with high TOC, illustrating that organic matter in this basin has been over-matured. In addition, 1-D petroleum system modelling implied that most generated gas discharged into the other formations. Moreover, clay content, organic matter content and its type do not have good conditions for shale gas development in comparison with North America. Therefore, we postulate that the Gyeongsang Basin has low potential of shale gas resource.