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AN ANALYSIS OF GEOTHERMAL POTENTIAL IN KOREA

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ABSTRACT

The heat flow anomaly in South Korea was analyzed with Geographic Information System (GIS) using spatial overlay analysis technique in the aspects of lithology, geologic time and Mohorovicic (Moho) depth. A total of 247 heat flow data over South Korea were constructed to the spatial database (D/B) and digital geologic map including lithology, geologic time, and Moho depth was also made. The average of heat flow is 64 ± 14 mW/m^2 in South Korea. In the aspect of lithology, the area of sedimentary rock contains high heat flow of 74 mW/m^2, sedimentary/volcanic rock area 62 mW/m^2, plutonic rock area 63 mW/m^2, and metamorphic rocks area 61 mW/m^2. In the geologic time sequence, the Cenozoic strata has 91 mW/m^2, the Mesozoic and Paleozoic strata 65 mW/m^2, the Proterozoic strata 55 mW/m^2, and the Archean strata has 61 mW/m^2. In Moho depth aspect, the shallow depth area has higher heat flow than the area of thick crust. Considering that the geothermal water has close relation to the geologic lineaments, overlay analysis on the lineament density and above heat flow anomaly has finally been made. As the result, several areas in Pohang, Gyeongju, Uljin, Yeongyang, Gunwi, Samcheog, Jeongseon, Yeongwol, Danyang, Sogcho, Yangyang, Sangju, Whasun, Boryeong, Cheongyang, Gongju, Whaseong, Yongin, Pocheon, Yeoncheon, Jeongog and Cheolwon appeared to be highly potential geothermal resources developing sites and also matched well with the newly developed as well as old hot spring areas.

Keywords: heat flow, GIS, lithology, Moho depth, geothermal, geologic time

1. INTRODUCTION

The previous research of geothermal in South Korea has begun with 'Colombo Plan' that was a Korea-Japan joint research work from 1969 until 1972. We have continuously collected terrestrial heat flow data up to 247. Although we have no the active volcanic areas, there are some places for low-enthalpy geothermal potential. A clear evidence of geothermal is the distribution of hot springs over the Korean Peninsula. Furthermore, the drilling technique for deep well is continuously improving. In order to select the promising site in some quantitative way, we adopted GIS based analysis technique using existing heat flow data and geologic and geophysical information.

2. ANALYSIS WITH GIS

This study is to analyze the relationship between heat flow and geological data of South Korea using GIS. For the analysis, a total 247 heat flow data (Figure 1) and 1:1,000,000 scale geological map of South Korea (Figure 2) were constructed to spatial D/B. Then spatial relationship between heat flow spatial D/B and geological D/B were analyzed using spatial overlay analysis technique in the aspect of lithology and geologic time by ArcView Software. The distribution map of Moho depth from the spectral analysis of from Bouger anomaly map (Cho et al., 1996; Kim et al., 2003; Figure 3) was also constructed into spatial D/B and we analyzed it and heat flow D/B with overlap method.

In this study, the heat flow data acquired during the period of 1970-1997 were used to analyze the relationship between the items such as lithology, geologic time and Moho depths. The information of heat flow data collection is as follows; First, Mizutani et al. (1970) started with 12, Chang et al. (1970) added 6, Suh (1976) 17, Lim et al. (1989) 6, Lim et al. (1996) 177, Lim and Kim (1997) 4, and finally Yum et al. (1997) added 30 to make total of 252. In this year (2004), it was added 62 heat flow data of southeastern part of Korea. However, It was not include for analysis. Although the heat flow data is total 252, the data from offshore and Jeju Island were excluded to analyze the in-land Korean Peninsula to result in a total of 247.

3. RELATIONSHIPS BETWEEN HEAT FLOW AND EACH SPATIAL D/B

The relationship between heat flow and geologic data were elucidated using the overlay with each item. The average heat flow is 64 ± 14 mW/m^2 in South Korea. In the aspect of lithology, the area of sedimentary rock contains high heat flow of 74 mW/m^2, sedimentary/volcanic rock area 62 mW/m^2, plutonic rock area 63 mW/m^2, and metamorphic rocks area 61 mW/m^2 as shown in Figure 4. The reason why sedimentary rock area shows the high heat flow is that

the sedimentary rock covers the plutonic; the residual heat from igneous activity remains being covered with sedimentary rocks of low thermal conductivity.

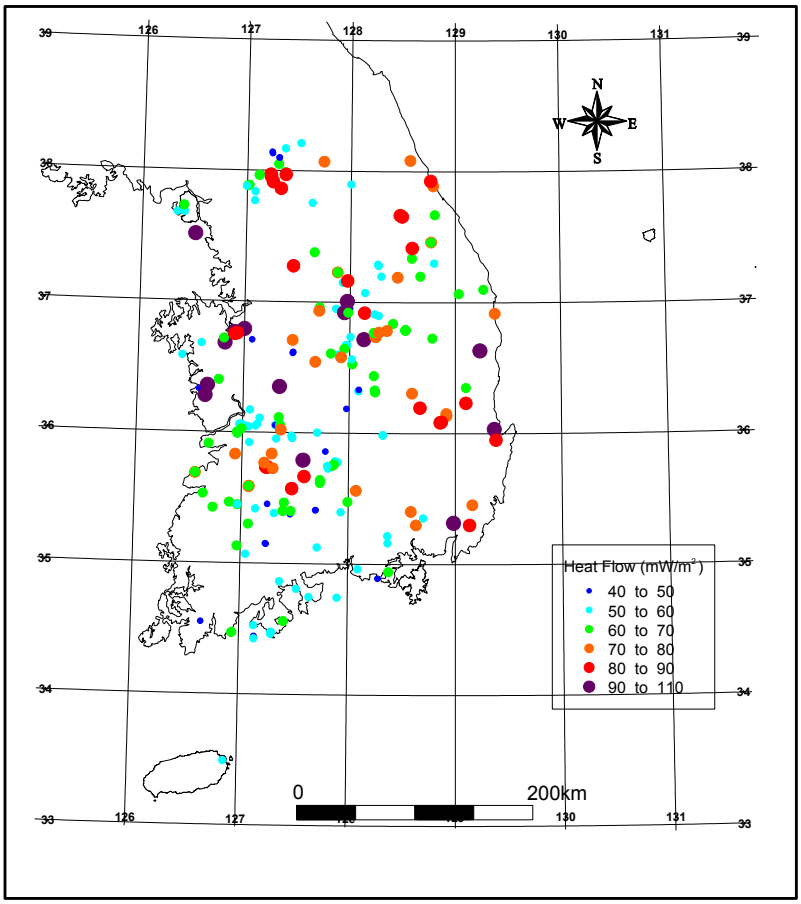

Figure 1. The location map of heat flow measurement points in-land South Korea.

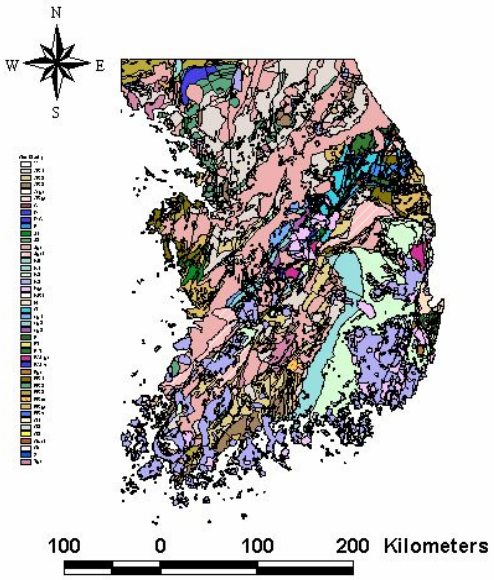

Figure 2. Digital Geologic map of Souyh Korea (KIGAM, 1995, modified). It was made out of the digital geologic map by ArcInfo and spatial D/B of geologic map has polygon property.

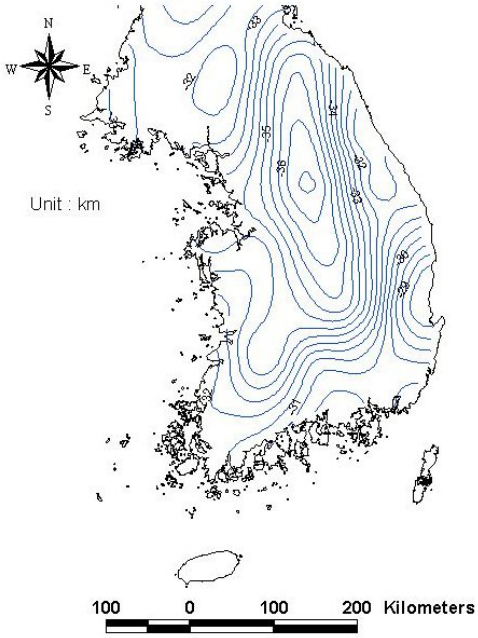

Figure 3. Moho discontinuity depth of South Korea (Kim et al., 2003).

In the geologic time sequence as shown in Figure 5, the Cenozoic strata has 91 mW/m^2, the Mesozoic and Paleozoic strata 65 mW/m^2, the Proterozoic strata 55 mW/m^2, and the Archean strata has 61 mW/m^2. It is already known result that the younger geologic strata show higher values than the older ones (Stein, 1993; Han, 1992). In the aspect of Moho depth (Figure 6), the shallow depth area has higher heat flow than the one of thick crust, which is also the same result as published by Han (1992) for the study on geothermal model.

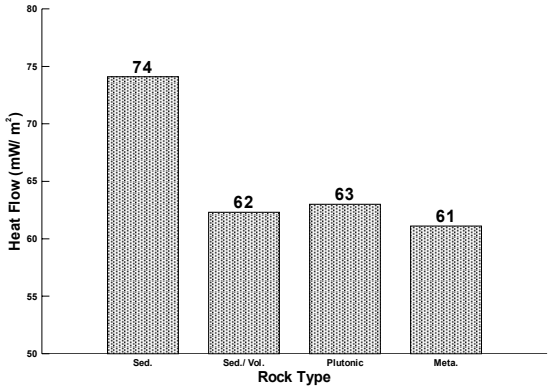

Figure 4. Average value of heat flow vs. rock type (sedimentary, sedimentary/ volcanic, plutonic, metamorphic rock).

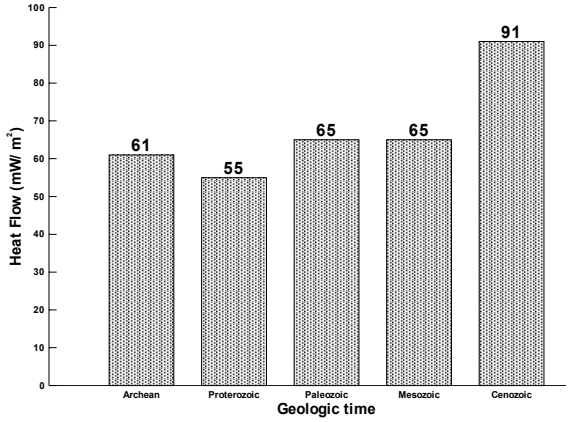

Figure 5. Average value of heat flow vs. geologic time.

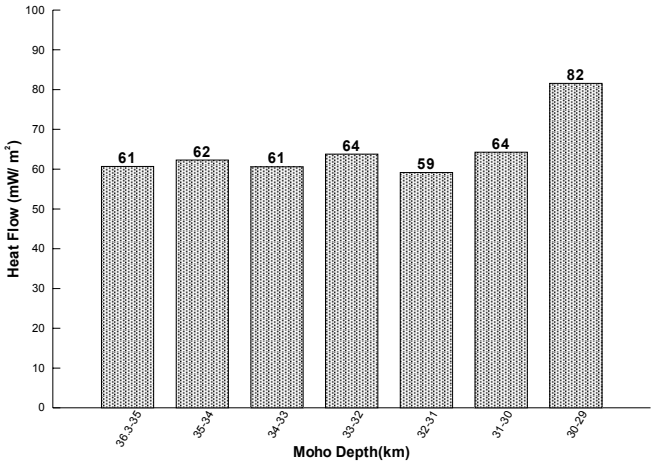

Figure 6. Average value of heat flow vs. Moho depth

Next, it is necessary to determine the rating values for reverse model to analyze the geothermal anomaly. The summary of the results related to each item and heat flow is listed in Table 1.

Table 1. Heat flow rating values about each item for estimating suitable area in South Korea

Rock type	Sedimentary	Sed./Vol.	Volcanic	Plutonic	Metamorphic		
Avg. H.F (mW/m^2)	74	62	62 (temporary)	63	61		
Geologic time	Archean	Proterozoic	Paleozoic	Mesozoic	Cenozic		
Avg. H.F (mW/m^2)	61	55	65	65	91		
Moho depth(km)	29-30	30-31	31-32	32-33	33-34	34-35	35<
Avg. H.F (mW/m^2)	82	64	59	64	61	62	61

We use the average heat flow values of each item (listed in Table 1) as the rating values for analysis of geothermal anomaly. The total sum of values of each item indicates the geothermal anomaly. The heat flow anomaly is to be analyzed using the rating value of heat flow, which is closely related with lithology (qa), geologic time (qb) and Moho depth (qc). Therefore,

$$qa + qb + qc = \text{Heat Flow Anomaly (Q)}.$$

Then, it shows the heat flow anomaly area as shown in Figure 7. The Pohang and Ulsan in the southeastern part of Korean peninsula appears to be the highest anomalous area. The next would be Ulsan-Pohang-Uljin, Jinju-Haman-Changnyung, Pocheon-Yuncheon and Samcheok areas. When superimposing the location of the hot spring on this result as shown in Figure 7, the anomaly coincides well with hot springs which are clear evidence of geothermal activity.

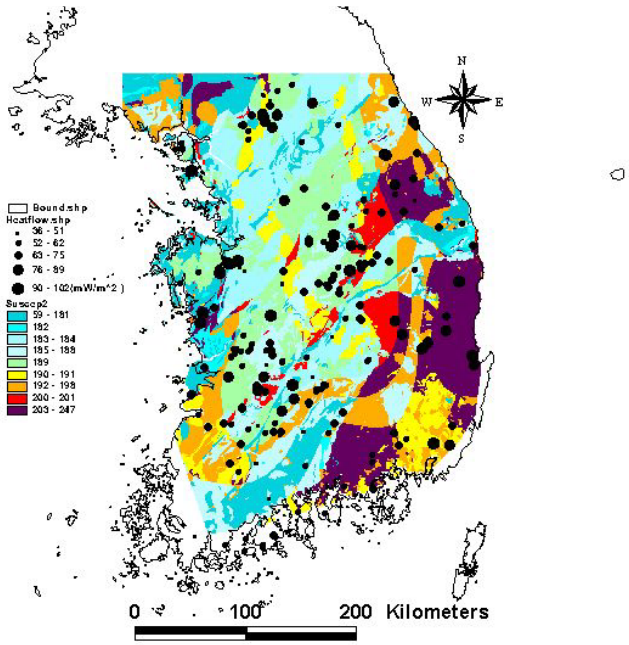

Figure 7. Result of heat flow anomaly over South Korea.

4. RELATIONSHIPS BETWEEN HEAT FLOW ANOMALY AND LINEAMENTS DISTRIBUTION

However, in the view point of utilization, geothermal potential should be considered along with lineament distribution that is closely related with deeply connected fracture which, in turn, would act as conduit of geothermal water. Figure 8 shows lineament density map of South Korea. The lineament density map was based on the 1:1,000,000 geologic map and represents length of lineament per unit surface area.

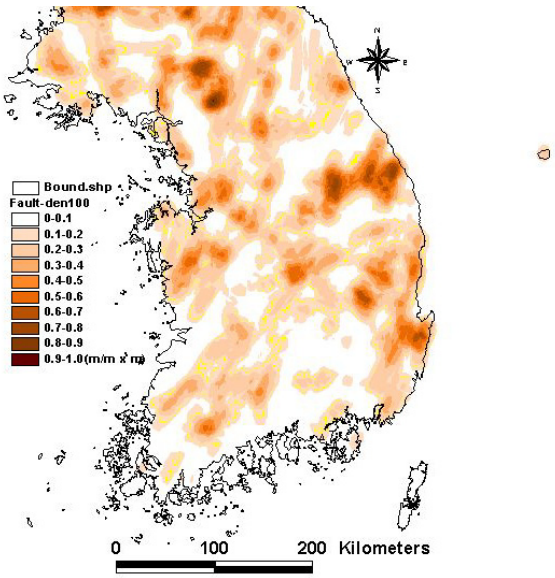

Figure 8. Lineament density map in South Korea.

Figure 9 shows a geothermal anomaly map resulted from overlay analysis between heat flow anomaly (Figure 7) and lineament density (Figure 8) maps. This could be regarded as a potential map for geothermal development since it is derived from both heat flow and lineaments. Several areas in Pohang, Gyeongju, Uljin, Yeongyang, Gunwi, Samcheog, Jeongseon, Yeongwol, Danyang, Sogcho, Yangyang, Sangju, Whasun, Boryeong, Cheongyang, Gongju, Whaseong, Yongin, Pocheon, Yeoncheon, Jeongog and Cheolwon appeared to be highly potential geothermal resources developing sites and also matched well with the newly developed as well as old hot spring areas.

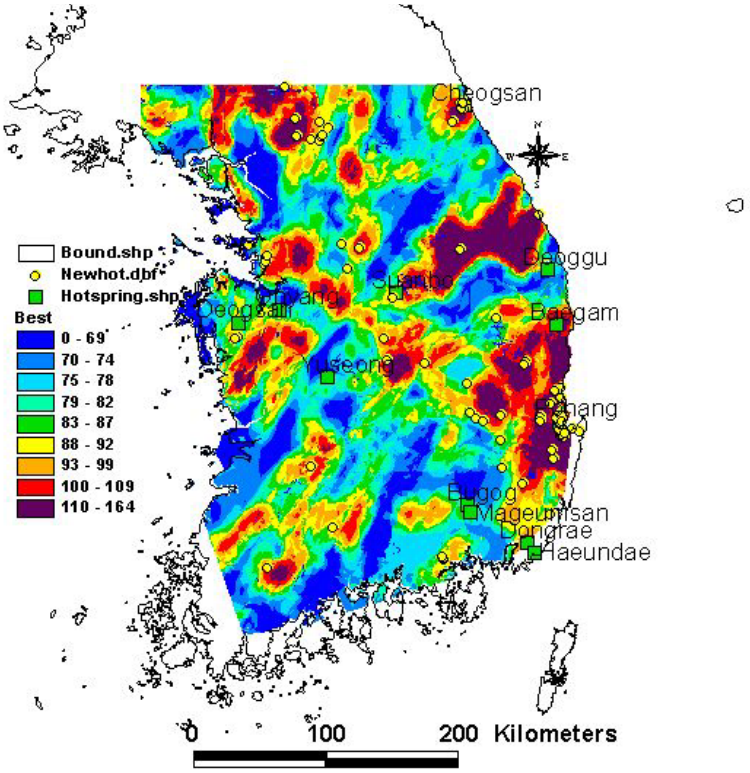

Figure 9. Distribution of potential geothermal resources as a result of overlay analysis on the correlation between lineament density and heat flow anomaly. Superimposed are the locations of the major hot springs and new hot springs.

5. DISCUSSION AND CONCLUSIONS

It is clear that the number of heat flow data collected is crucial. If more data is used for the construction of D/B, it can be more detailed. We will continuously collect heat flow data from borehole temperature logging and nearby rock samples through this new geothermal development project as a fundamental study on the geothermal potential of Korean Peninsula. Furthermore, we used the 1:1,000,000 geological map in the analysis so far, which is so sparse in scale, and thus there exist some errors in estimating geologic time and rock types those are to be corrected in near future. The spatial analysis using GIS is a quite useful and easy approach to regional analysis. D/B and system for spatial analysis of South Korea has already been made and we expect them to be easy to upgrade.

We have also tried to analyze the relationship between heat flow and heat production rate by radioactive decay of K, U, and Th. But we could not notify any clear relationship partly because the data were concentrated on a part of granite area and partly because no analysis data of core sample was available.
On the other hand, overlay analysis on the correlation between lineament density and heat flow anomaly provided quite reasonable geothermal potential map in the viewpoint of matches to the major hot springs and new hot springs. Therefore, future work will be focused on the collecting more data to cover the territory as evenly as possible and to make detailed overlay analysis such as 1:250,000. Analysis on the other thematic map such as radioactive isotope should be also tried along with the effort of collecting more data.

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