Development of geothermal information system for South Korea

2009. 01.14
CTICC
Capetown, South Africa

Hyoung-Chan Kim, Seung-Gyun Baek, Jeongmin Park

Korea Institute of Geoscience & Mineral Resources

Contents

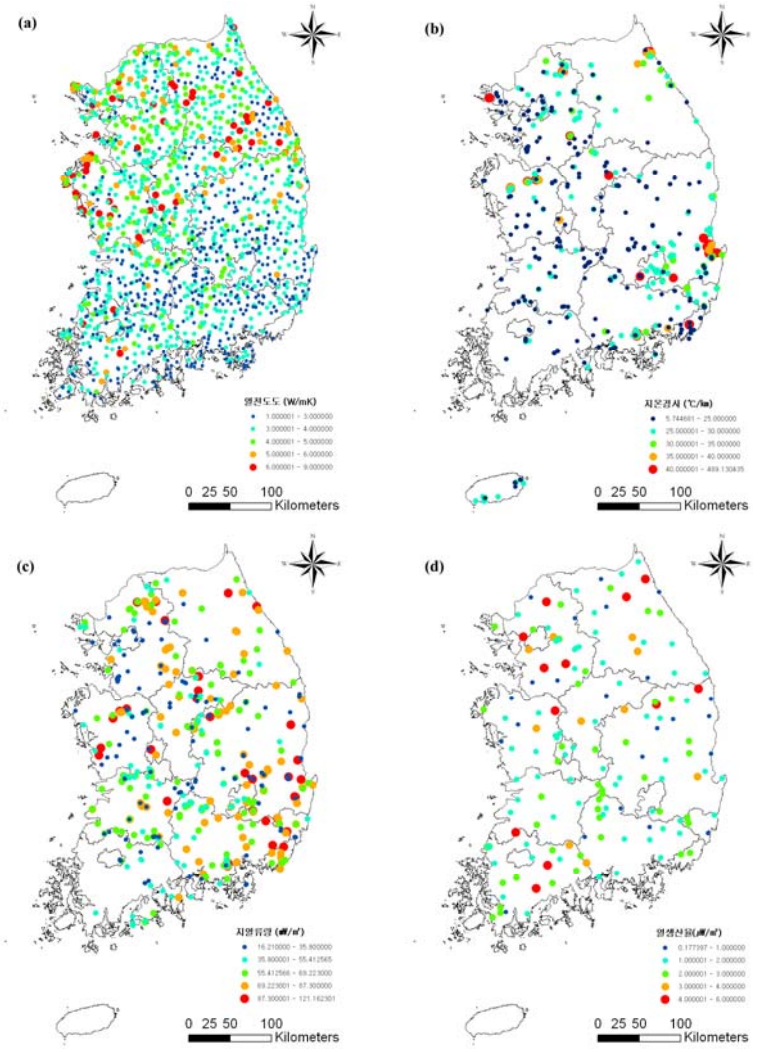
- Introduction
- Collecting of measurement data
- Measurement of thermal conductivity of rocks
- Construction of thematic maps
- Analysis on thermal characteristics of rocks
- Examine reliability of the database of the thermal properties
- Design of database
- Examples of database
- Architecture of system
- Layout of system
- Functions of system
- Examples of system
- Conclusion

Introduction

- In order to build information infrastructure for development and applications of geothermal energy
- The database of geothermal information system consist of 4 groups as roles
- Geothermal information system was developed as stand-alone system operated on desktop computer using ArcGIS engine software
- Users can find easily the geothermal data for interested area using the menu of the system

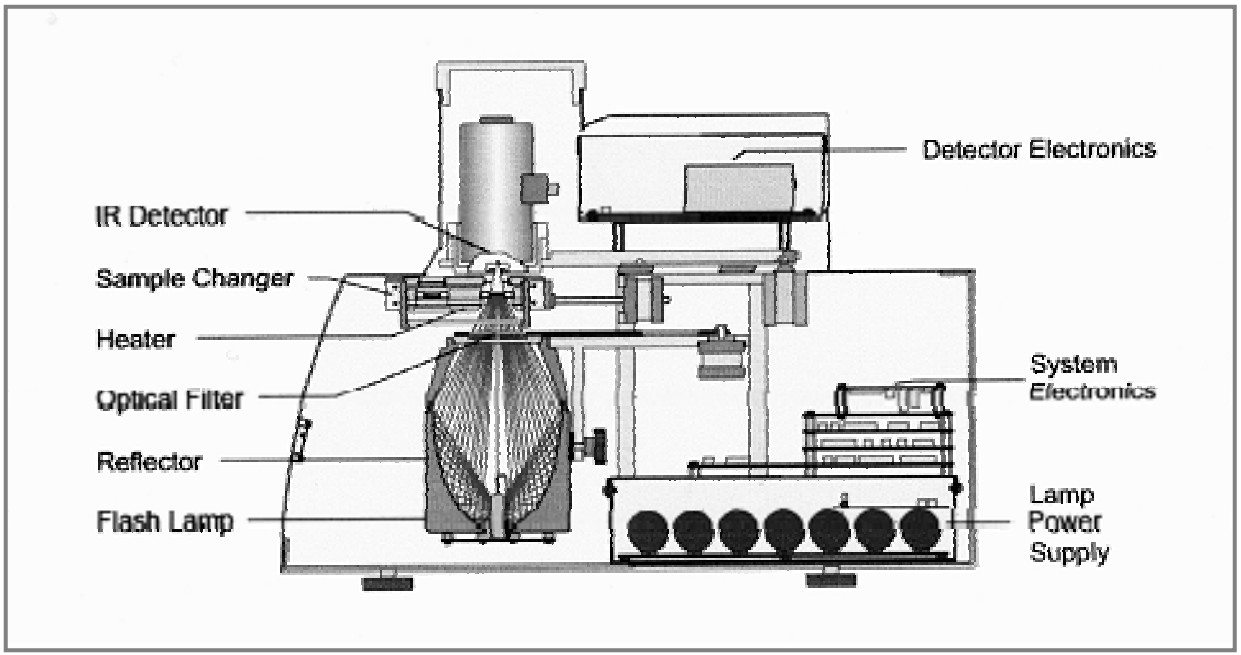
Collecting of measurement data

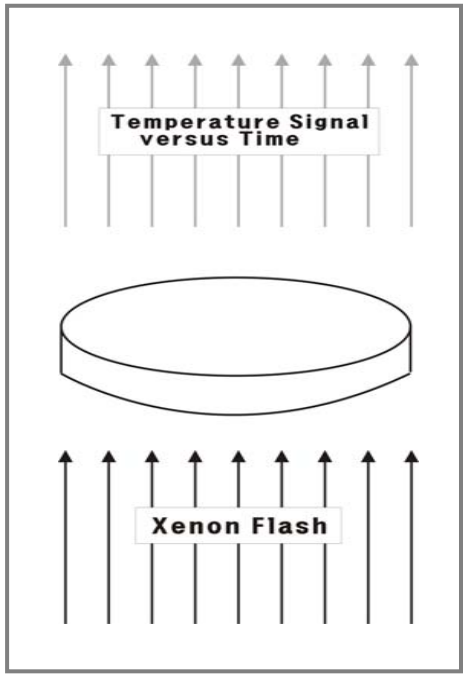
- A total of 2163 rock samples was collected from entire Korea
- 1516 rock samples were measured on thermal properties
- 180 heat production values was estimated
- Temperature logging data were measured in 715 drilled wells
- 492 heat flow data were estimated



Location maps of (a) thermal properties, (b) geothermal gradient, (c) heat flow, (d) heat production

Laser flash method





$$\lambda = \alpha \rho C_p$$

λ : Thermal diffusivity

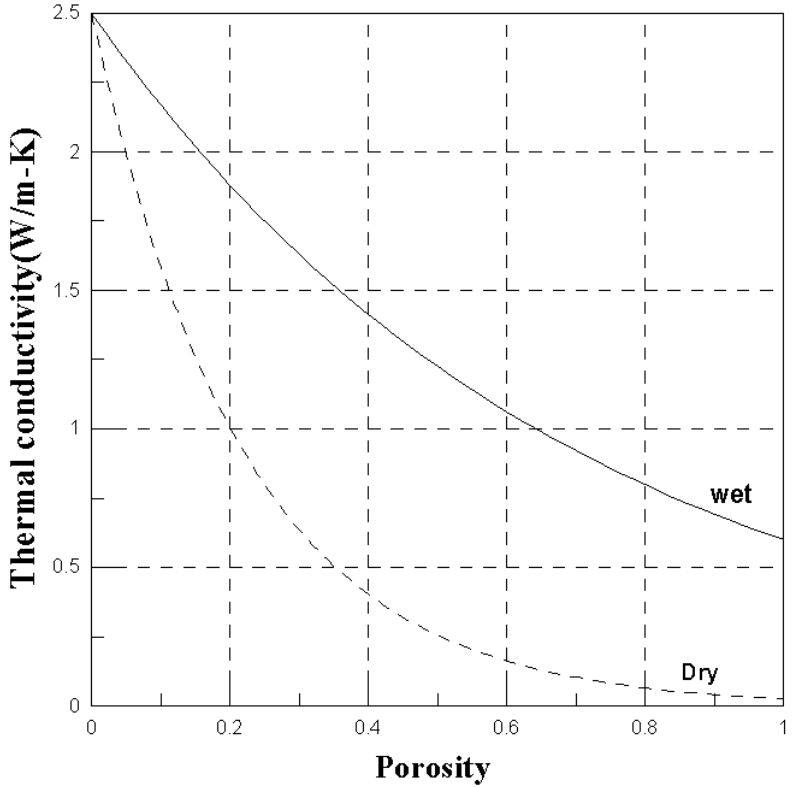
α : Thermal conductivity

ρ : Density

Cp : Specific heat

Geometric Mean Model

- **Geometric mean model (Woodside and Messmer, 1961) was applied to compensate for thermal conductivity of rock specimens saturated with pore water.**



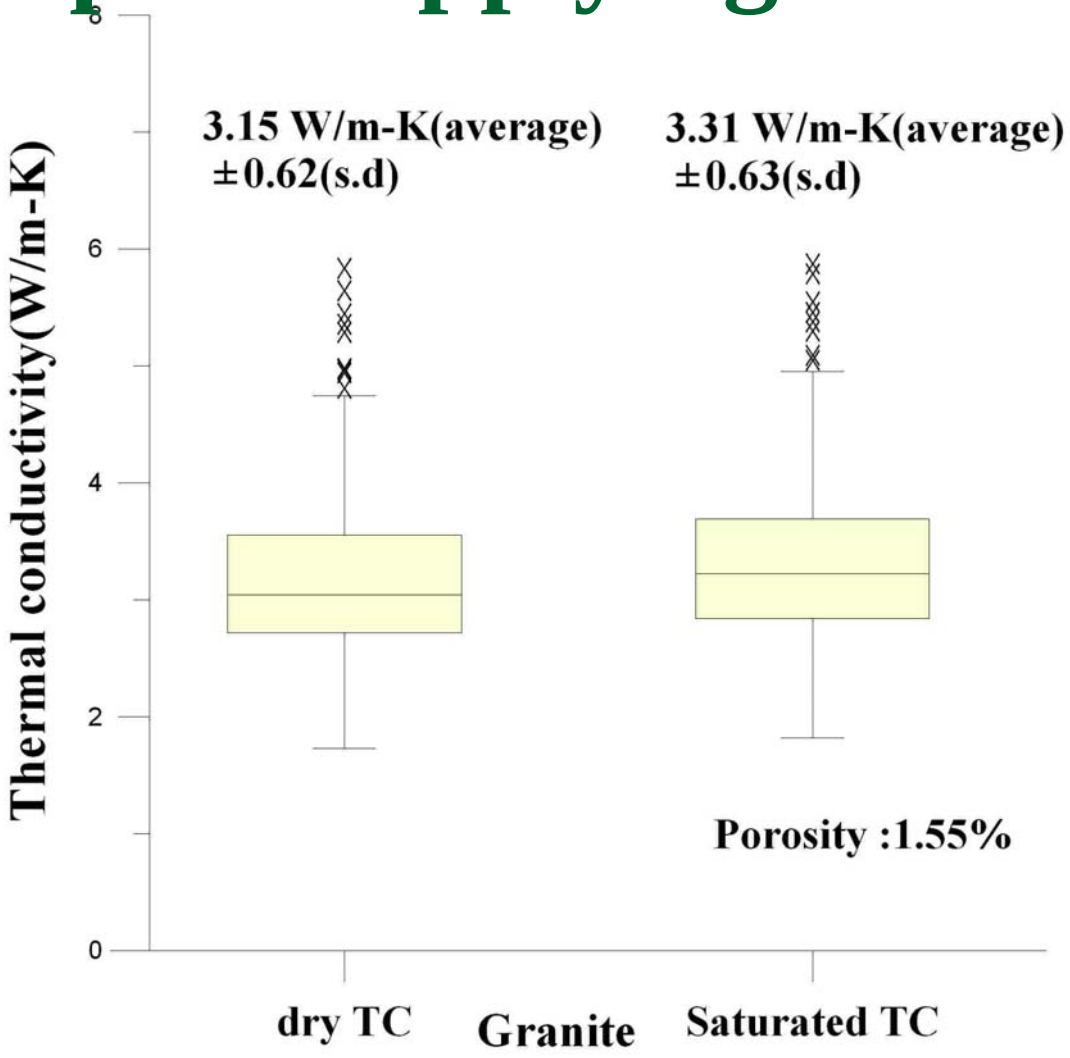
$$\lambda_{dry} = \lambda_{matrix}^{1-\phi} \lambda_{air}^{\phi}$$

$$\lambda_{in-situ} = \lambda_{matrix}^{1-\phi} \lambda_{water}^{\phi}$$

$$\lambda_{matrix} = \left(\frac{\lambda_{dry}}{\lambda_{air}^{\phi}}\right)^{\frac{1}{1-\phi}}$$

ϕ : porosity

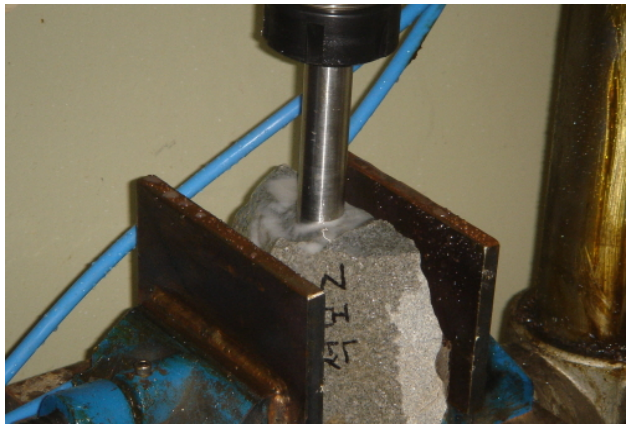
Example of applying GMM

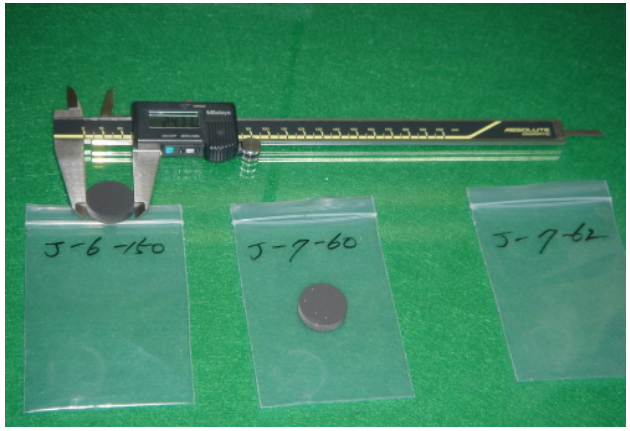


Distributions of dry thermal conductivity (TC) and corrected TC of granite samples.

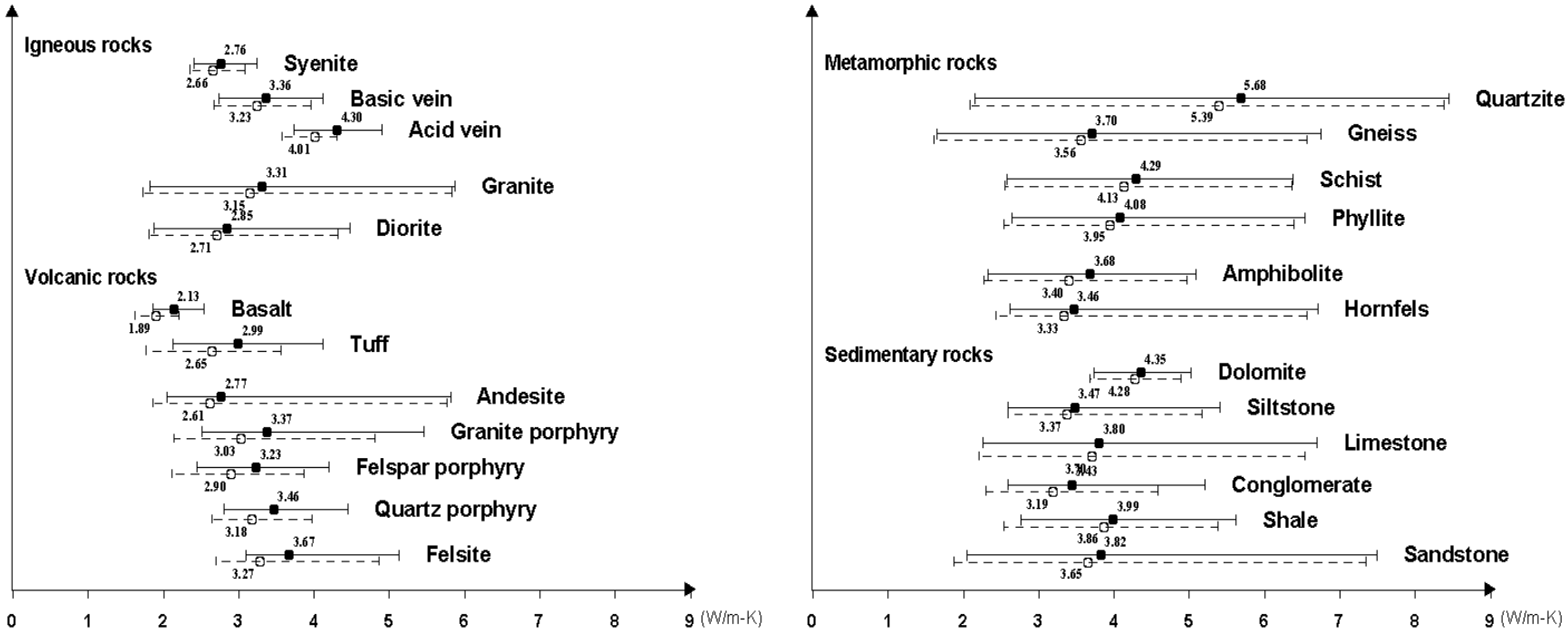
Preparation of rock specimens

- **Rock specimen for measuring thermal properties were processed with 1 inch diameter and 3mm thickness using core drilling machine.**



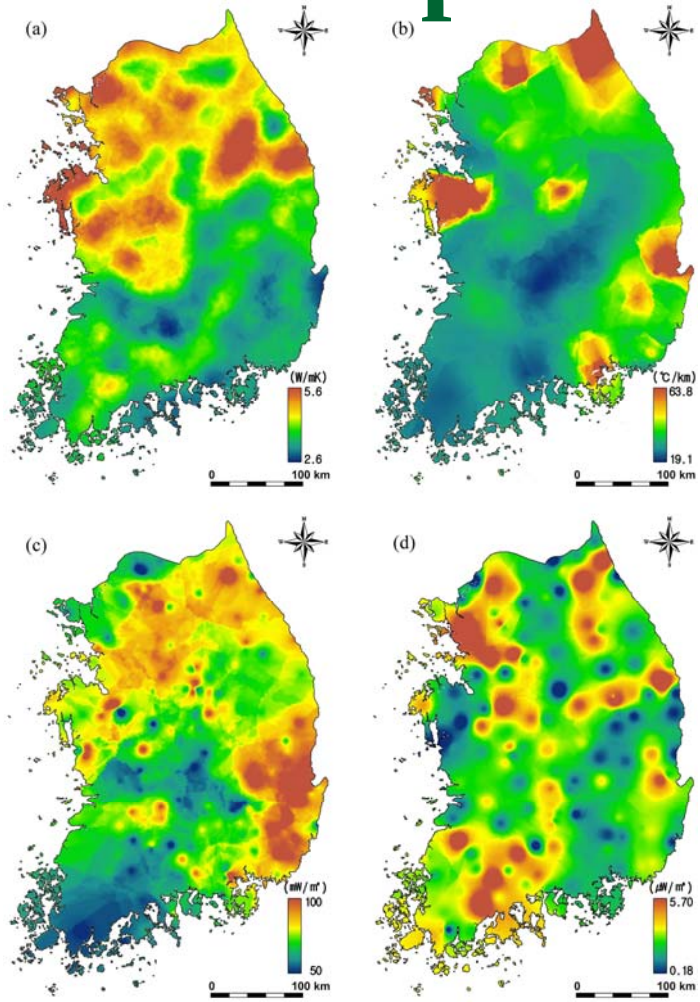


Thermal conductivity of different rocks



Construction of thematic maps

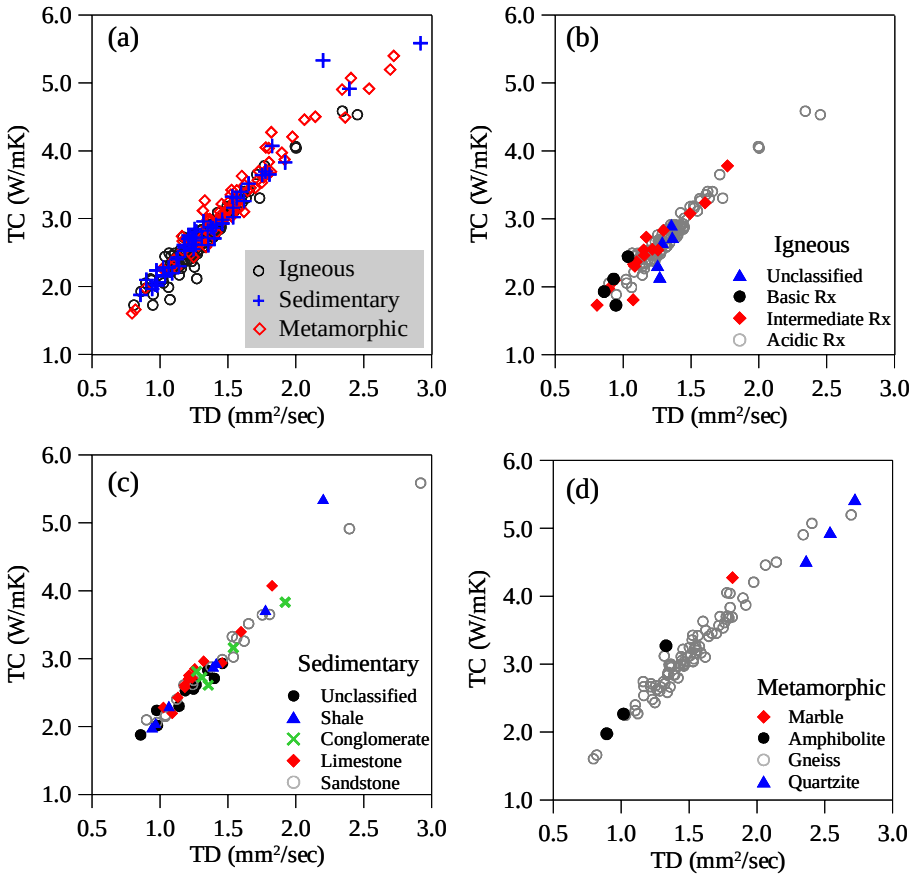
- Thermal conductivity ranges from 2.49 to 5.42 W/mK
- Geothermal gradient ranges from 18.6 to 62.3□/□
- Heat flow ranges from 42.4 to 100.7 □/□
- Heat production ranges from 0.18 to 5.70□/□



Thematic maps of (a) thermal conductivity, (b) geothermal gradient, (c) Heat flow, (d) heat production

Analysis on thermal characteristics of rocks

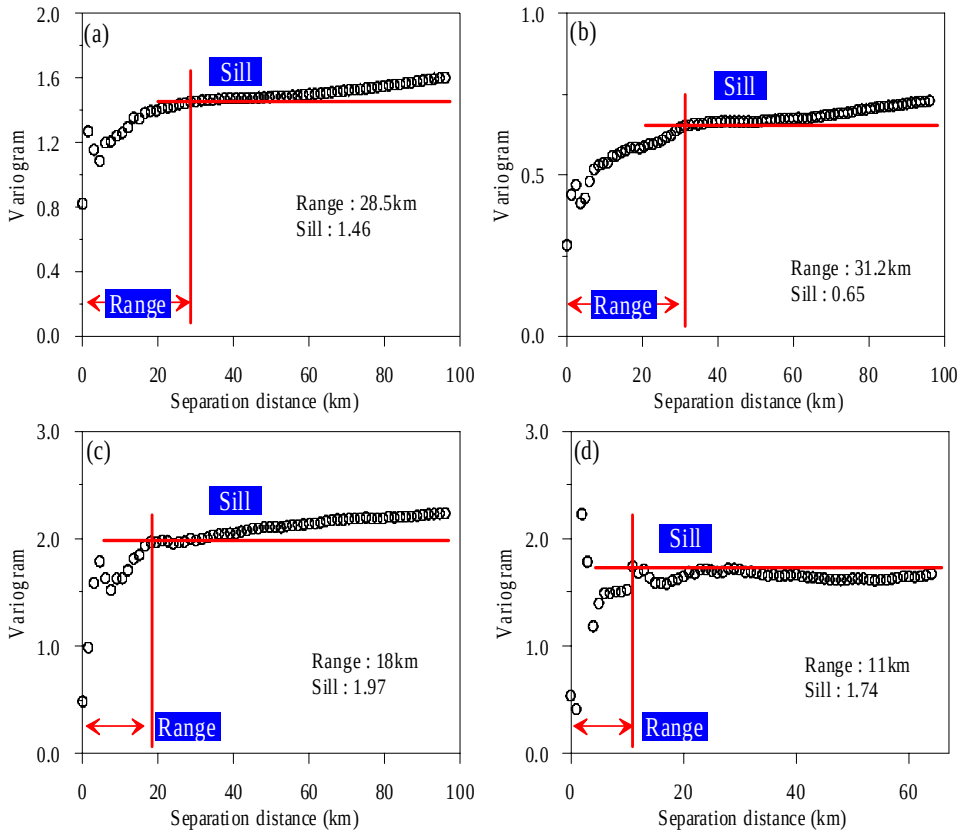
- To analyze thermal conductivity of rocks, thermal properties of samples consisting of 123 igneous, 55 metamorphic, and 88 sedimentary rocks were measured
- The thermal conductivity of rocks are mainly determined by the mineral composition; specifically, thermal conductivity is linearly proportional to the content of quartz
- Results of the normalized prediction interval illustrate that thermal conductivity and thermal diffusivity have higher variances than density and heat capacity.
- The metamorphic and sedimentary rocks have higher variances in thermal conductivity than the igneous rocks.



Relationship analysis between thermal diffusivity and thermal conductivity for different rock type

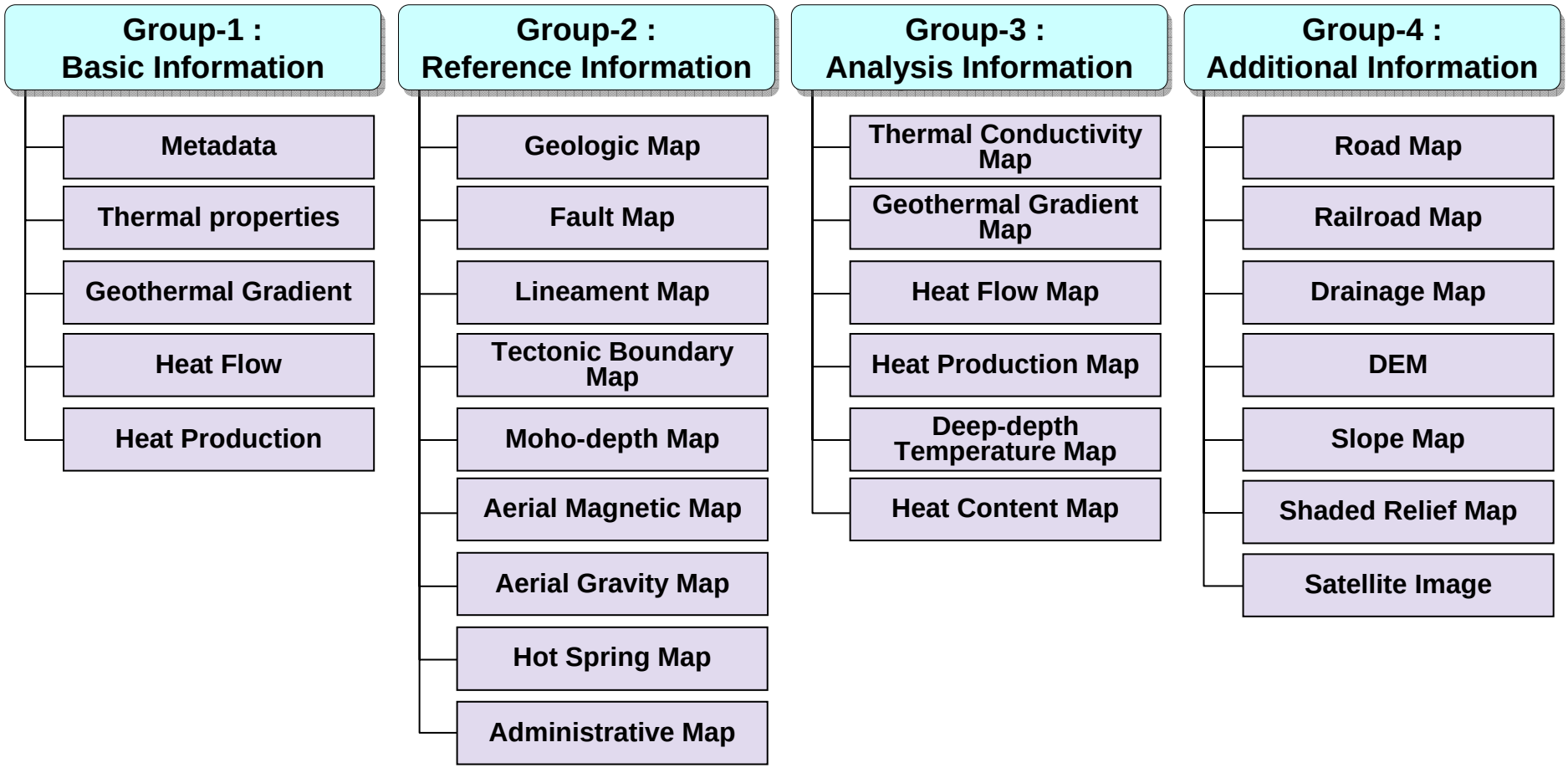
Examine reliability of the database of the thermal properties

- To examine reliability of the data base of the thermal properties, which has been collected, measured, and accumulated by KIGAM.
- A geostatistical analysis conducted for 1516 nationwide data show that igneous rocks have a relatively large value of the correlation length and a small value of the sill in thermal conductivity, as compared to metamorphic and sedimentary rocks.
- This results indicate that when the existing data are interpolated to predict the thermal conductivity at an arbitrary location, igneous rocks would give a more accurate value of predicted thermal conductivity.
- New experimental data for two local areas having intensive sampling points illustrated geostatistical results coinciding with the regional data.

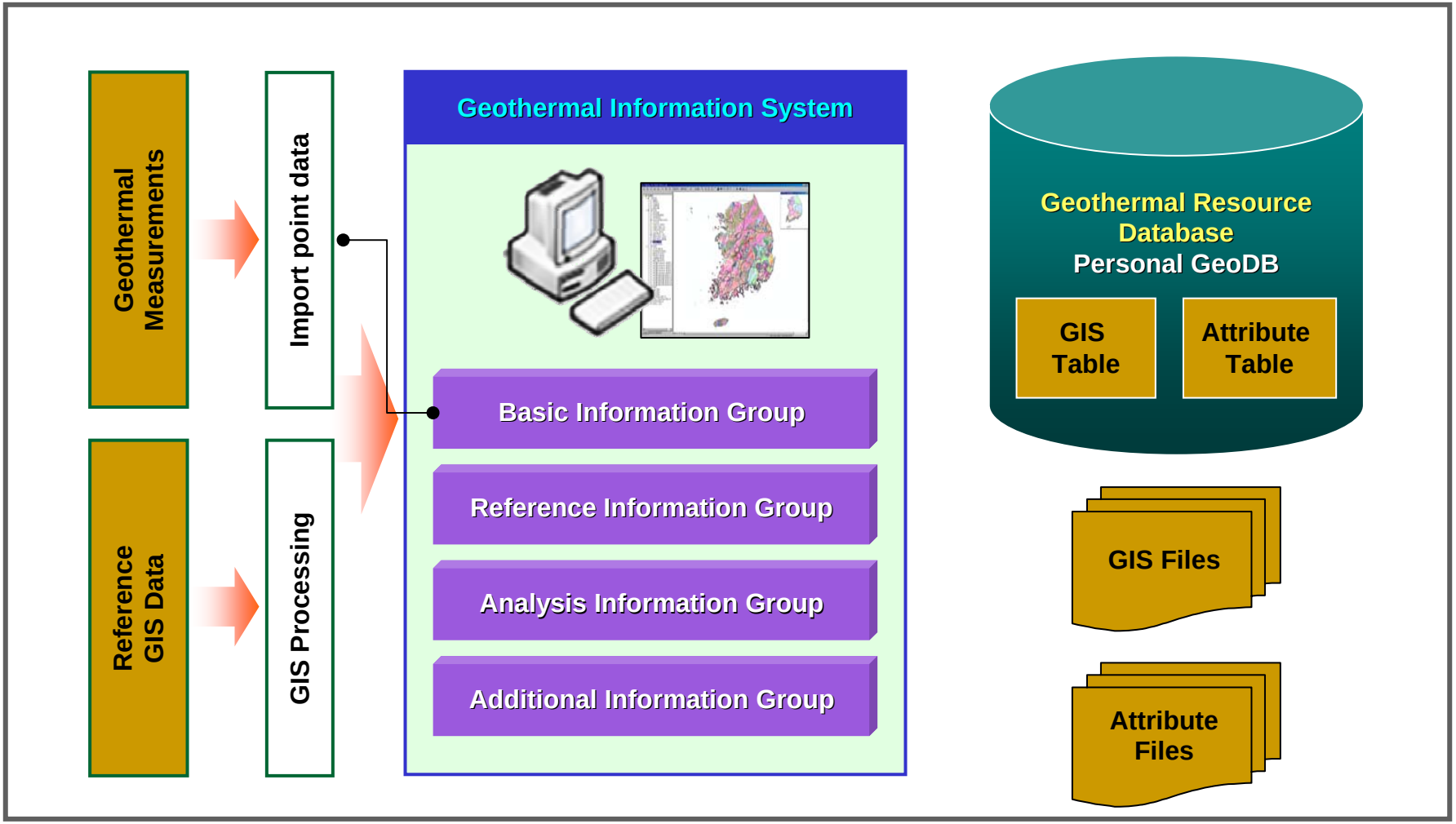


Variogram of thermal conductivity (a) all, (b) igneous rocks, (c) metamorphic rocks, (d) sedimentary rocks

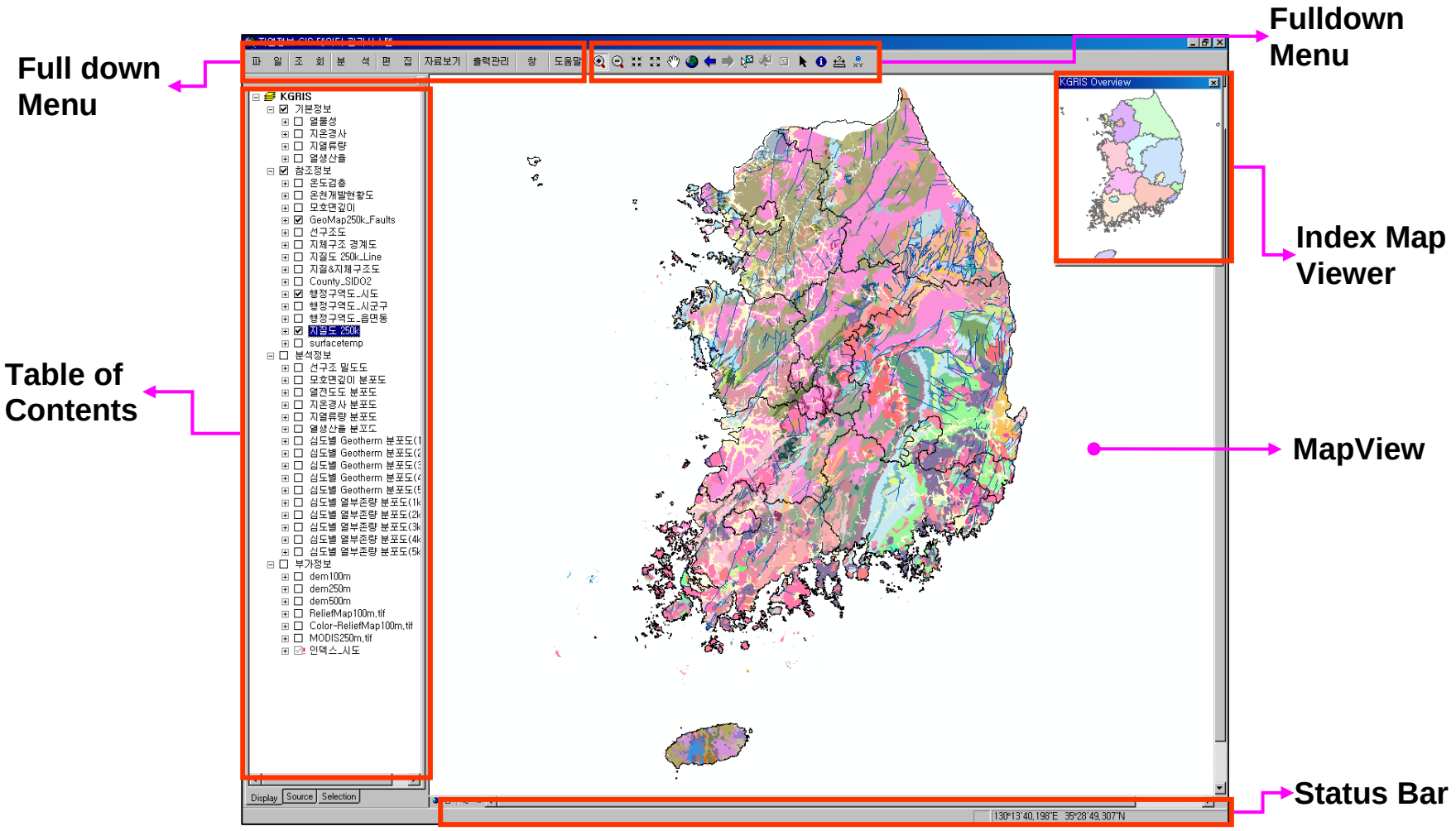
Design of database



Architecture of system



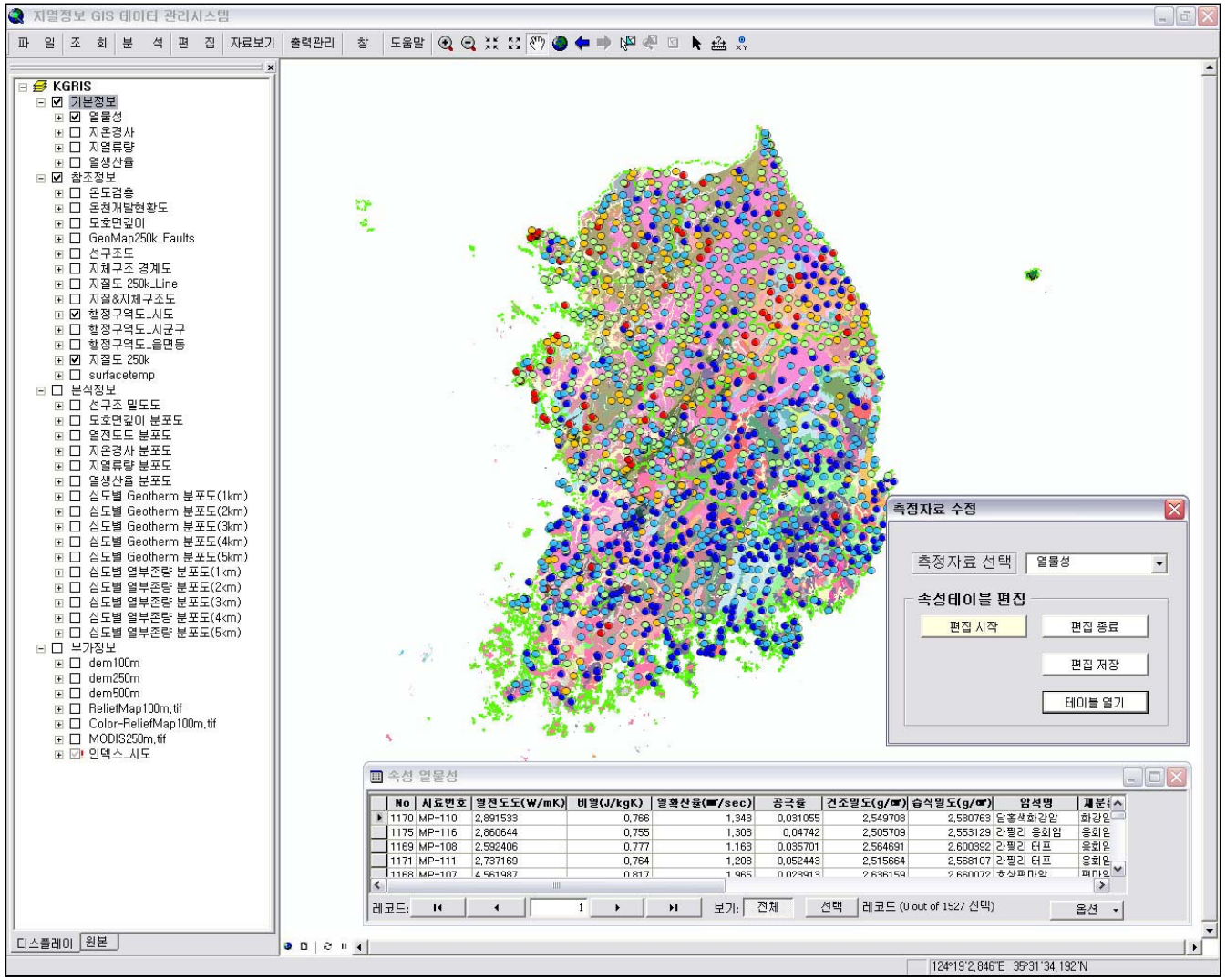
Layout of system



Function of system

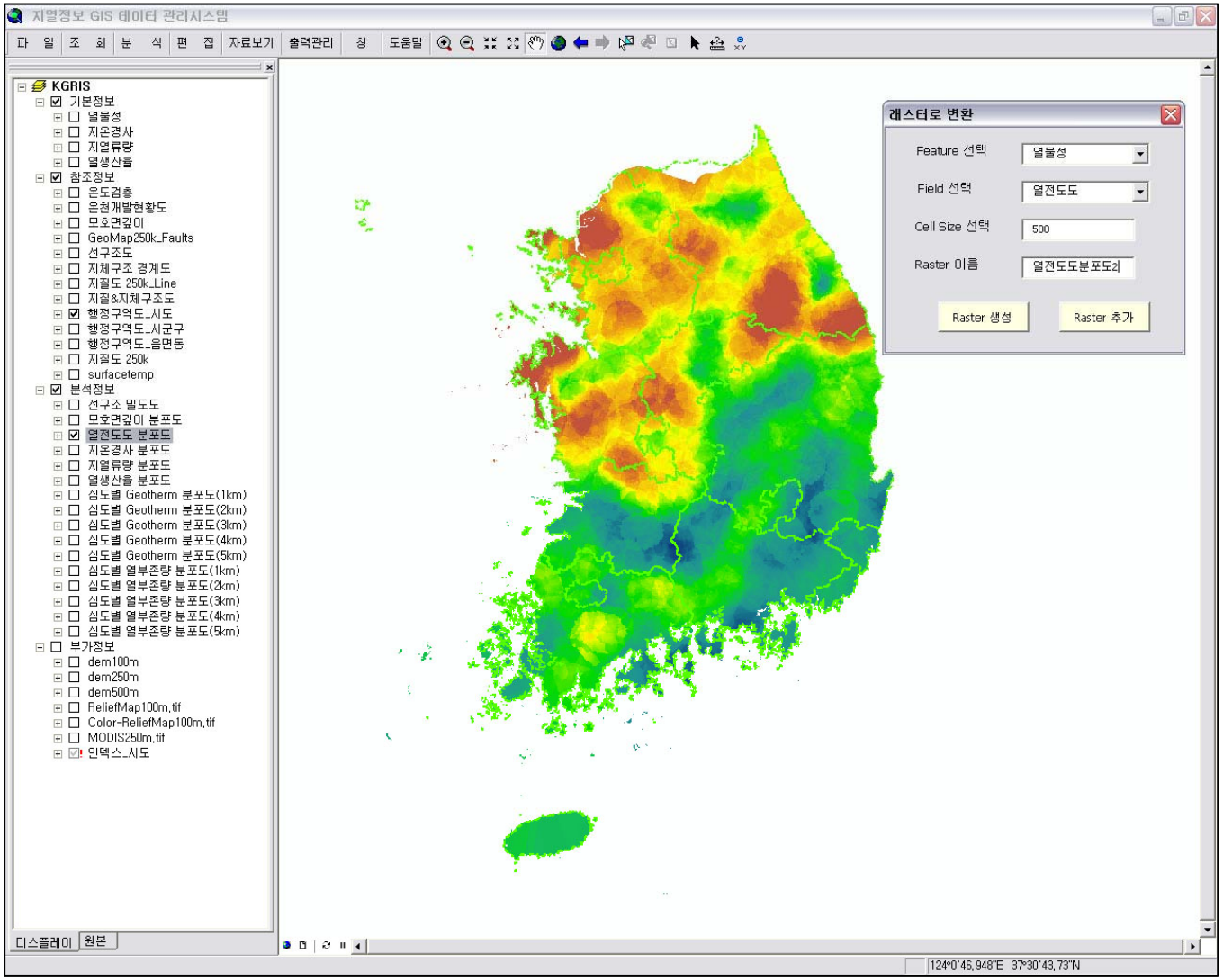
Menu	Submenu	Data Type	Target Data	Content
Edit	Add Point	point	Thermal Property, Geothermal Gradient, Heat Flow, Heat Production	Add new measured point to target layer
	Edit Point	point	Thermal Property, Geothermal Gradient, Heat Flow, Heat Production	Edit the location or attribute table
	Add Map	GRID	New map related with thermal information	Add new map layer
	Edit Map	GRID	Thermal Conductivity, Geothermal Gradient, Heat Flow, Heat Production, Geotherm, Heat Content	Replace with the updated map
Query	Query point	point	Heat Property, Geothermal Gradient, Heat Flow, Heat Production	- Query by selecting the administrative district, coordinates and rectangular region - Display the list of query results, and save the results as figure or excel format
	Query Map	GRID	Thermal Conductivity, Geothermal Gradient, Heat Flow, Heat Production, Geotherm, Heat Content	
Analysis	Statistical Analysis	GRID	Thermal Conductivity, Geothermal Gradient, Heat Flow, Heat Production, Geotherm, Heat Content	Show the statistical information (area, max & min, average, variance and histogram), and save the result as figure or excel format
	Profile Analysis	GRID	Thermal Conductivity, Geothermal Gradient, Heat Flow, Heat Production, Geotherm, Heat Content	Show the graph between distance and value along the specified line on thematic map
	Relationship Analysis	Point / GRID	point to point, point to GRID, GRID to GRID	Show the relationship graph of two selected data, and save as figure
	Regional Analysis	point	Thermal Property, Geothermal Gradient, Heat Flow, Heat Production	Make thematic map for specified region

Examples of system (1 Edit menu)



Add the point data of new measurements

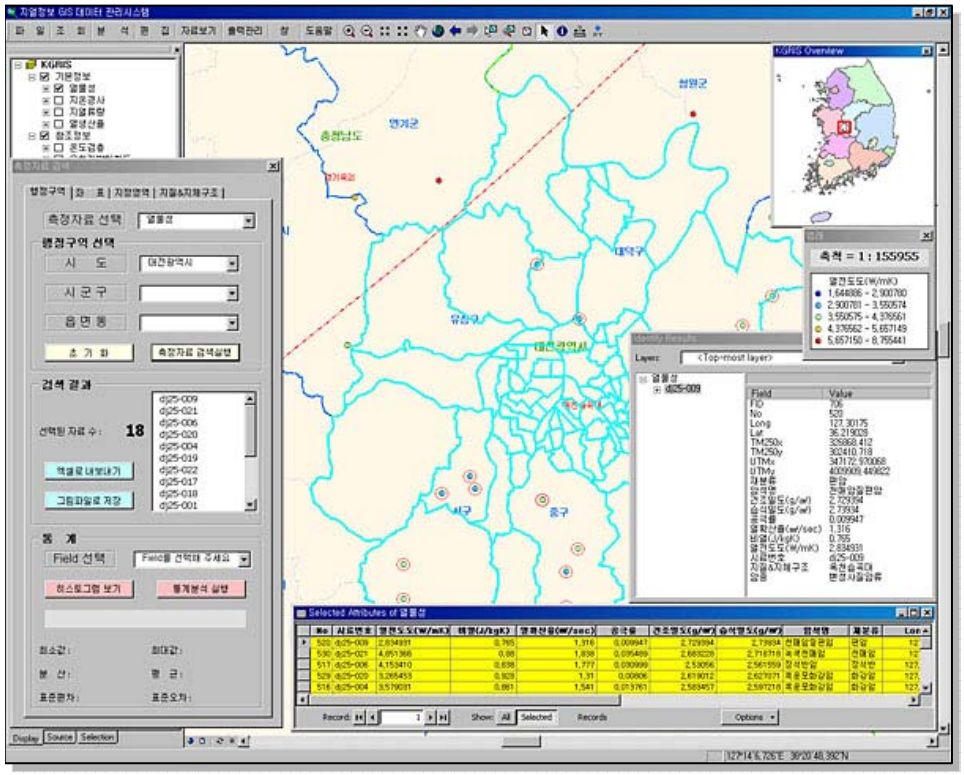
Examples of system (2 Edit menu)



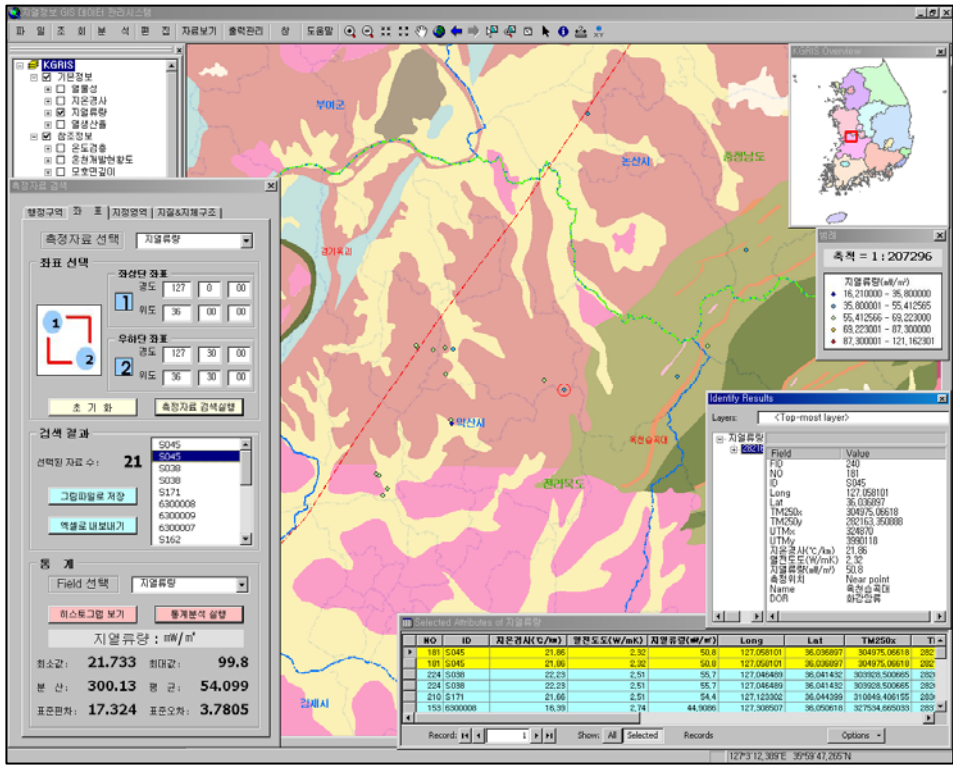
Add new thematic maps or replace with upgraded maps

Examples of system (3 Query menu)

- Query menu is used for searching the measurement data for interested region.
- The boundary options of query include administrative districts, coordinates and box drawing.
- The result of query is saved as a figure or spreadsheet data.



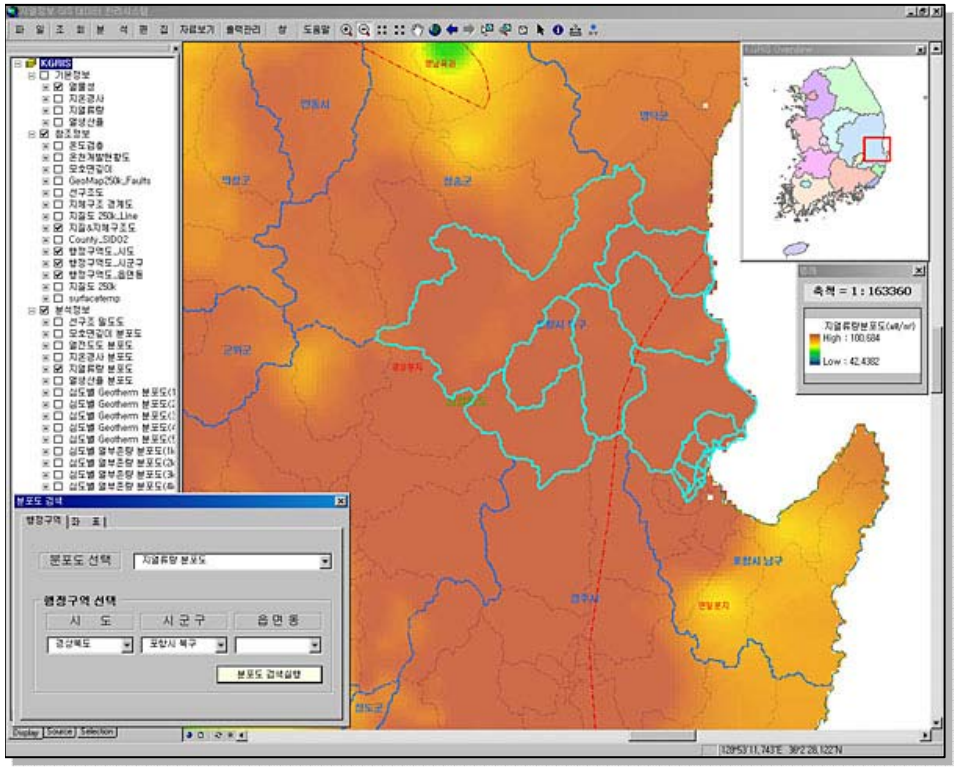
Query for point data by administrative district



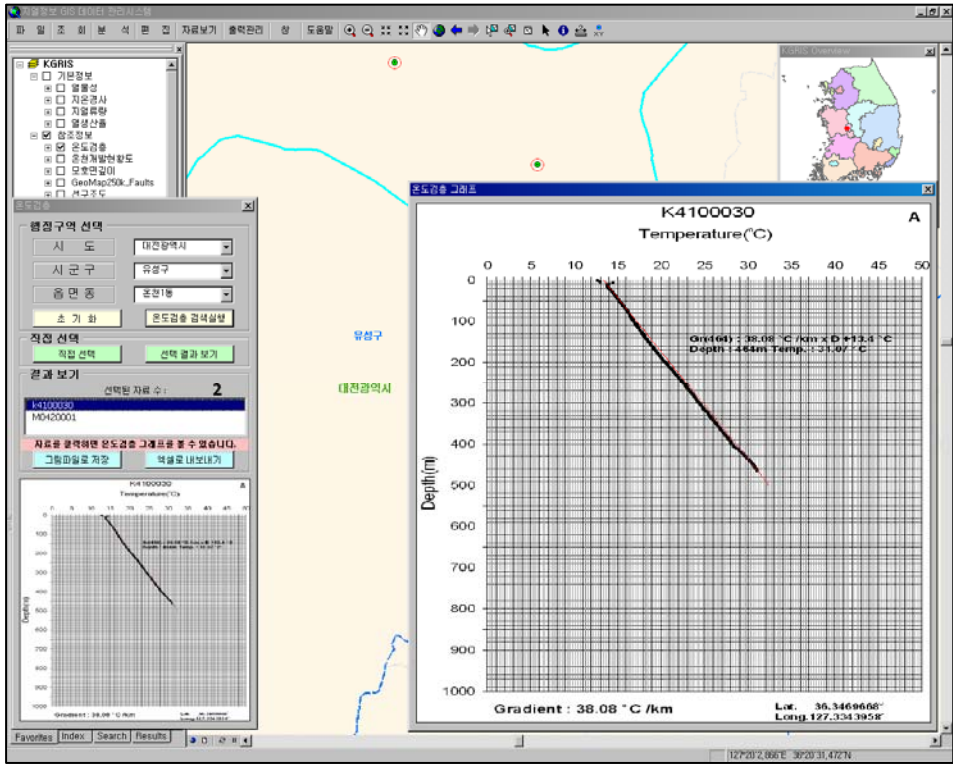
Query for point data by specified coordinates

Examples of system (4 Query menu)

- For the region without measurement data, the user can find the data by query on the thematic maps.
- Query for temperature logging data is also supported on query menu.



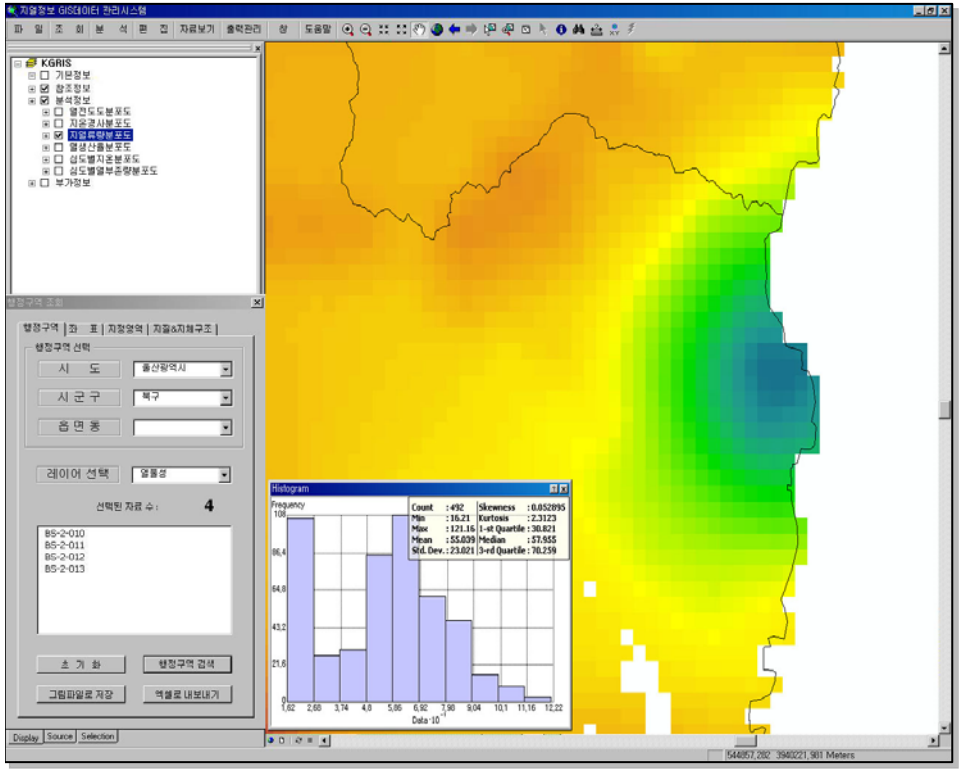
Query for thematic map by administrative district



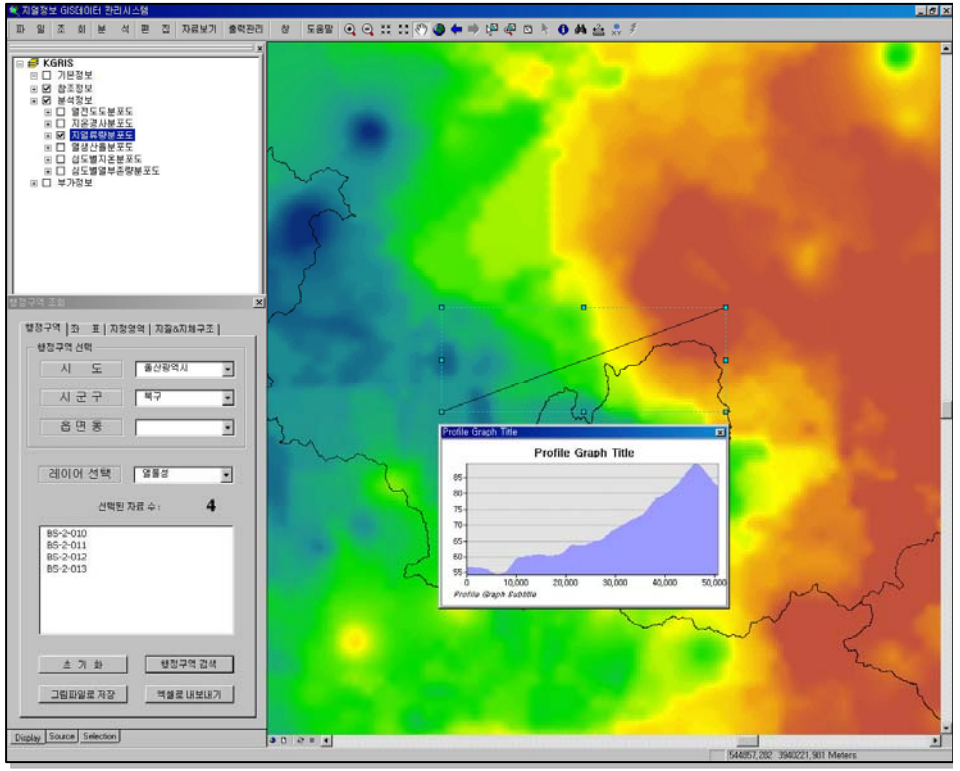
Query for point data of temperature logging

Examples of system (5 Analisys menu)

- Analysis menu consist of four submenu, ‘statistical analysis’, ‘profile analysis’, ‘relationship analysis’ and ‘regional analysis’.
- Statistical analysis shows the statistical information of selected data, such as average, maximum, minimum, variance and histogram.
- Profile analysis shows the graph between distance and value along the specified line on the thematic map.



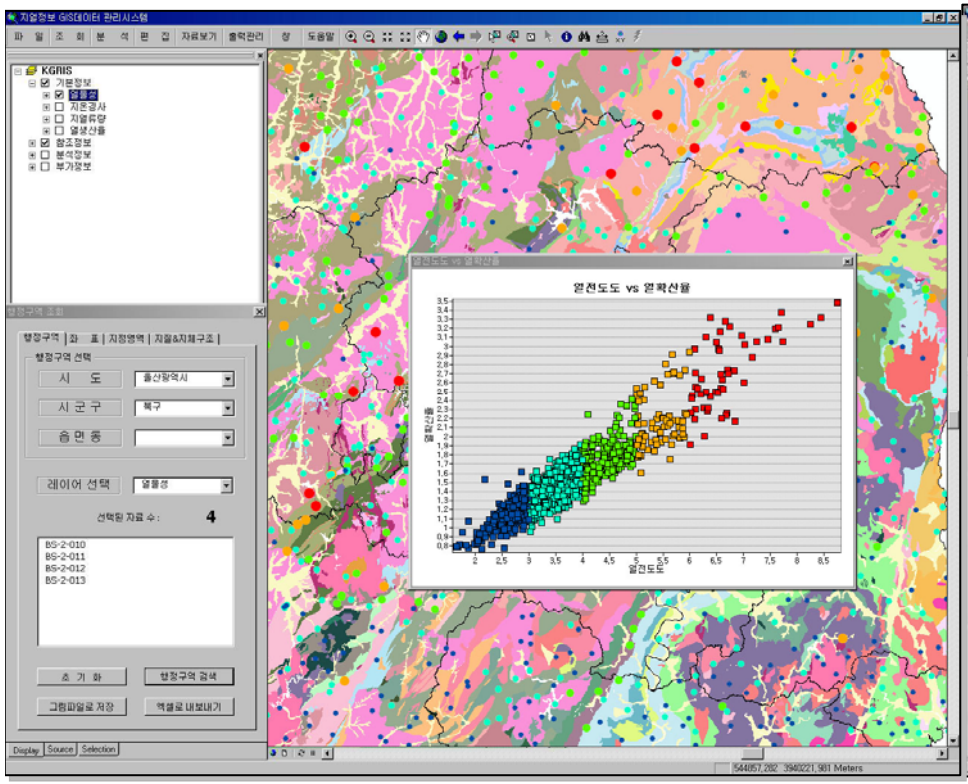
Statistical Analysis



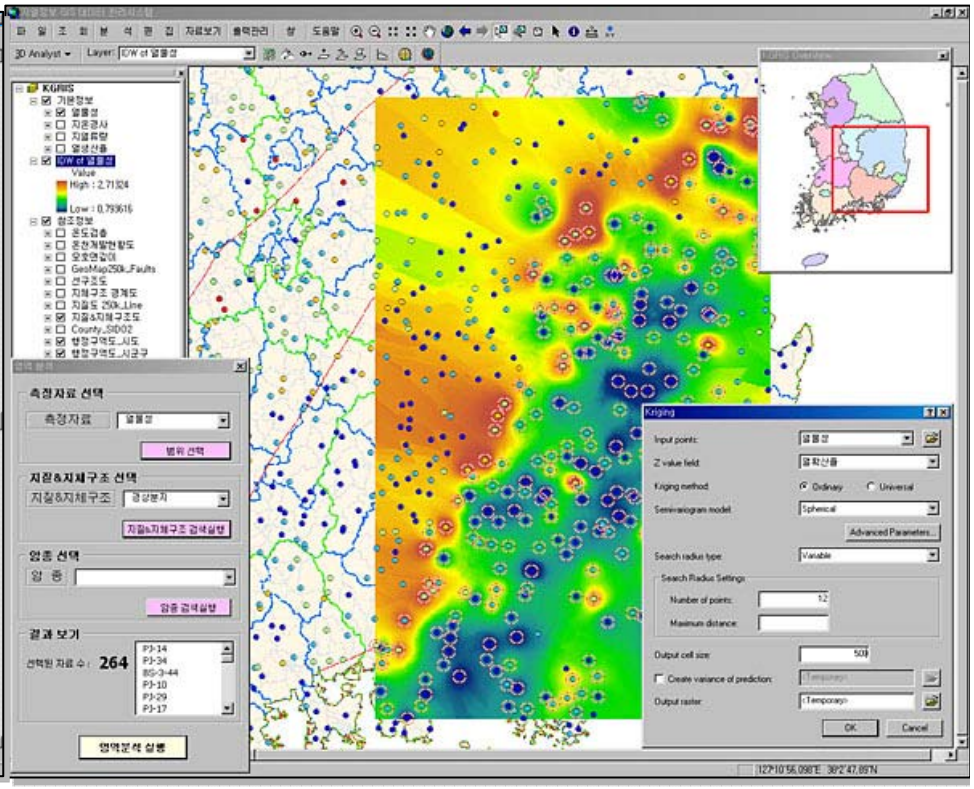
Profile Analysis

Examples of system (6 Analisys menu)

- Relationship analysis shows the relationship graph for two selected data in Group-1 or Group-3.
- Regional analysis is used for making the thematic map with selected point data for specified region and lithology.



Relationship Analysis

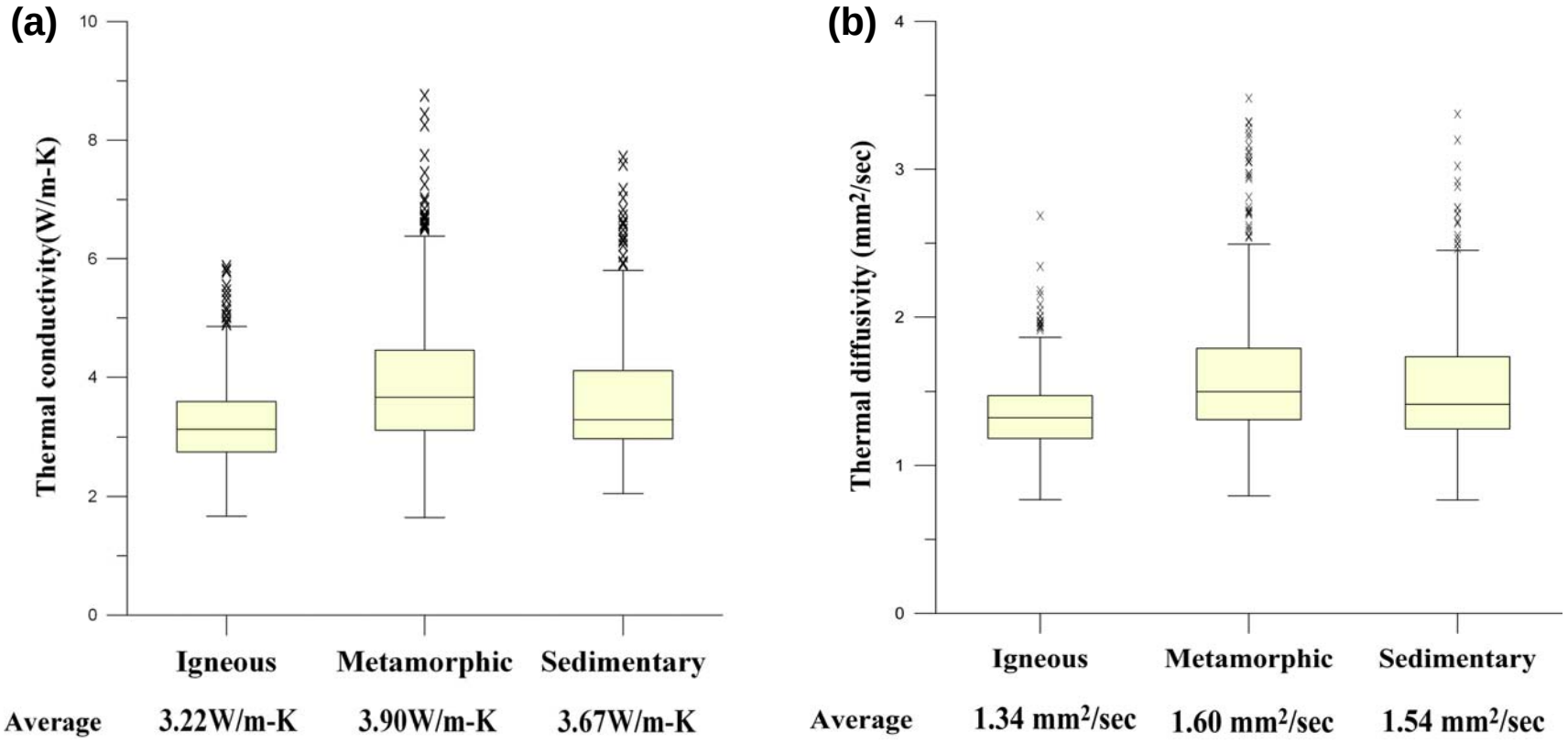


Regional Analysis

Conclusion

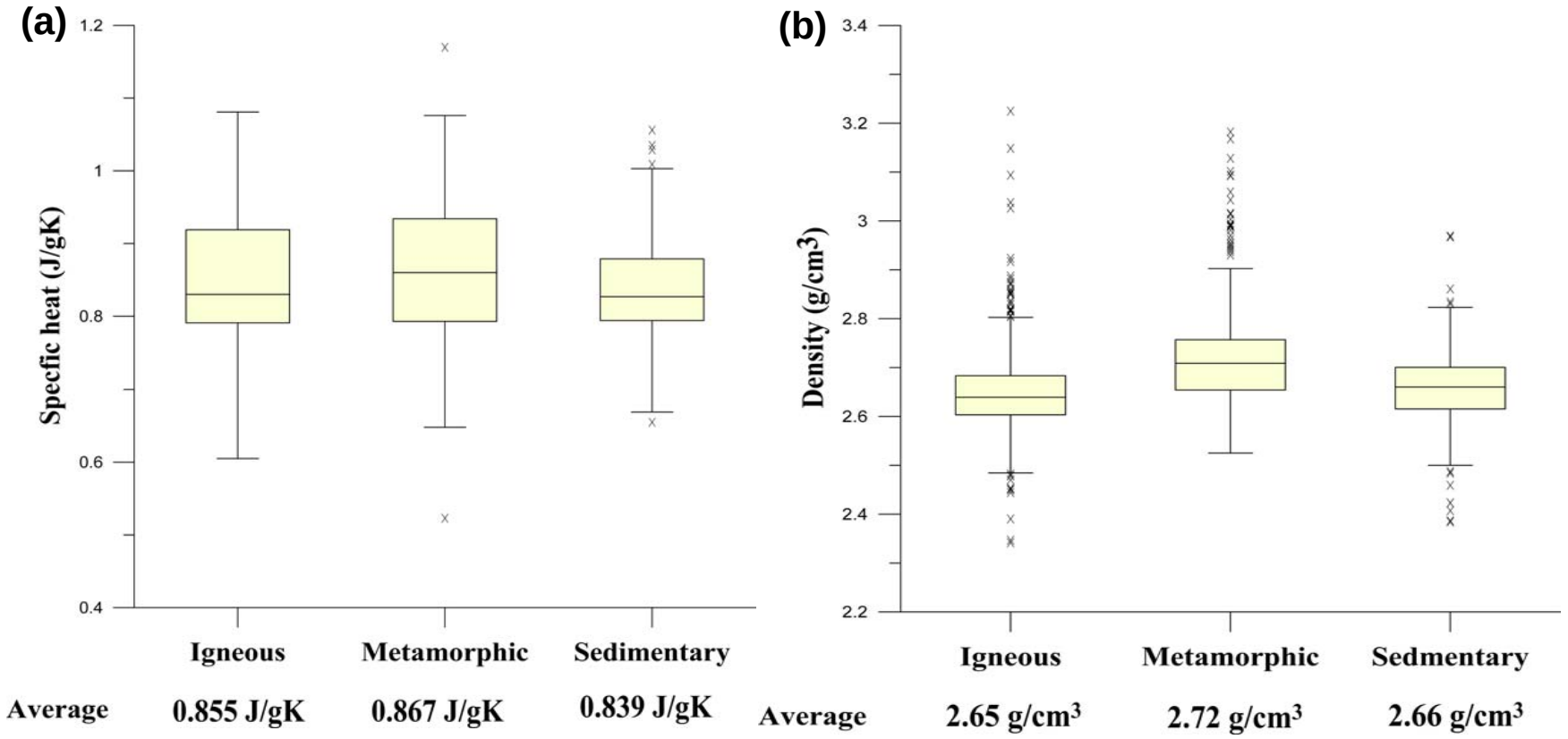
- To manage efficiently the geothermal resource information for Korea, Geothermal Information System was developed as stand-alone system operated on desktop computer using ArcGIS engine software.
- This system is improving as Web-GIS supported system that the user can get easily geothermal information by internet.

Thermal properties of rock types (1)



Thermal conductivities (a) and Thermal diffusivities (b) of igneous, metamorphic, and sedimentary rocks.

Thermal properties of rock types (2)



Specific heat and density (b) of igneous, metamorphic, and sedimentary rocks.

Measurement result of thermal properties of different rock types

Rock type	Density (g/cm^3)	Porosity	Thermal diffusivity (mm^2/sec)	Specific heat (J/gK)	Thermal conductivity (W/m-K)
Granite	2.64	0.016	1.38	0.864	3.31
Gneiss	2.71	0.011	1.53	0.871	3.68
Sandstone	2.68	0.016	1.63	0.840	3.82
Limestone	2.77	0.009	1.46	0.911	3.80
Schist	2.73	0.012	1.81	0.860	4.29
Phyllite	2.78	0.011	1.62	0.880	4.08
Quartzite	2.64	0.016	2.48	0.828	5.68