TEMPERATURE STRUCTURE UNDER THE JAPAN ARC ESTIMATED FROM MEASURED HEAT FLOW VALUES AND RADIOACTIVE HEAT GENERATION

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In recent years many heat flow measurements have been done in and around the Japan arc for the purpose of construction of temperature structure under the Japan arc. At the same time heat generation value of rocks which were sampled in a region where vertical section of Island arc is supposed to be exposed at the surface are measured. We estimate temperature structure in the crust and the shallow mantle under the Japan arc using measured new heat flow values and new heat generation data of the rocks of arc's crust. As a results some interesting features of temperature profiles related to volcanic activities and subduction of the oceanic lithosphere are clarified.

Island arcs are the regions where the oceanic lithosphere is subducting and tectonic activities such as volcanism, earthquake, accretion and so on are very active. These surface tectonic activities are considered to be the appearance of large scale convection in the earth which is induced by thermal energy. Estimating thermal structure in the earth is the most helpful way to understand processes which cause observed surface tectonic activities.

Temperature structure under the island arc has been estimated by many authors. Most of these works focus on flows in the mantle wedge and induced temperature structures (Bodri and Bodri, 1978; Toksoz and Hsui, 1978). These studies show general feature of temperature structure under the island arc which involves large lateral temperature anomary due to subduction of the slab. These studies show that temperature structure under the island arc is controlled mainly by advection of material because of higher heat transfer efficiency of advection than that of conduction.

Heat flow values are the direct evidence of deep temperature structure and important information for estimating temperature structures. Honda and Uyeda (1986) calculated temperature structure under the Tohoku arc in Japan on the constraint of observed surface heat flow distributions. The temperature structure under the arc was treated quantitatively. However, this model puts stress on the flow in the mantle wedge induced by subduction and thermal processes in the crust is not considered in detail. It is necessary for quantitative analysis of temperature structure that crustal contribution to the surface heat flow values is estimated.

As we can see at the surface, the continental crusts have very complicate structures because of its long tectonic history. It is supposed that there are many factors which affect observed heat flow values. In this paper radioactive heat generation and hydrothermal water circulation in the crust are taken into account and thermal structure under the Japan arc is simulated using measured heat flow and heat generation values and seismic velocity structure obtained from seismic studies.

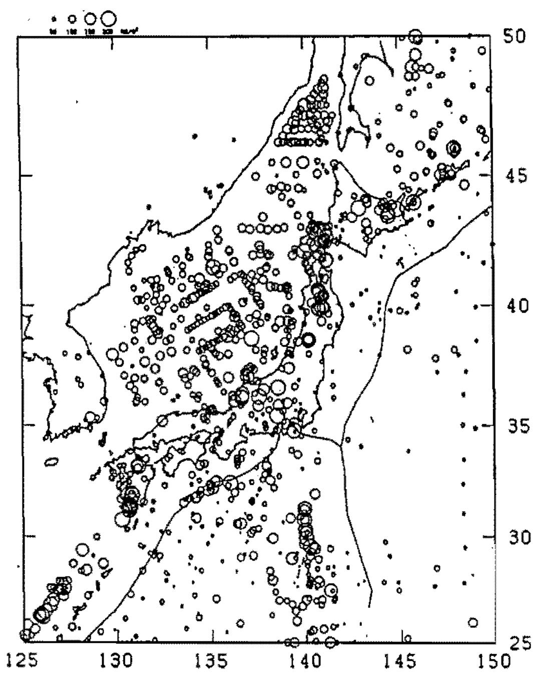

Fig.1 Heat flow data in and around Japan. Diameter of each circle is propotional to the heat flow value except the value higher than $200mW/m^2$ or lower than $20mW/m^2$.

The Japan arc is generally divided into two parts; the north-east Japan arc and the south-west Japan arc. The Pacific plate is subducting in relatively large speed under the north-east Japan arc for geologically long period. In this arc volcanic front and aseismic front and deeply penetrating seismic slab are observed and can be considered as typical matured arc. On the other hand volcanic activities are a little and seismic slab can be observed only to several ten kilometers in the south-west Japan arc. Subducting velocity of the Philippine sea plate under the south-west Japan arc is smaller than that of the Pacific plate. Some accreted bodies were recognized in the south-west Japan arc and it is supposed that accretion process is one of the dominant processes for its evolution. These contrast features of each arcs may give us comprehensive knowledge about the island arc.

Numerous heat flow measurements have been done in and around Japan in several years and two-dimensional distribution of heat flow values becomes clearer (Fig.1). General trend can be seen in this Figure that heat flow value vary abruptly at the aseismic front from low value in the sea side to high value in the back arc side in the north-east Japan arc. In the south-west Japan arc this feature cannot be seen. Very high values along the volcanic front are explained by hydrothermal circulation induced by high temperature anomaries of volcanoes. In these regions dominant transfer mechanism is supposed to be advection of water.

Contribution of hydrothermal circulation should be estimated to construct deep thermal structure. It is difficult to estimate a system of the hydrothermal circulation because of complex structure and uncertainty about heat source. Observed high heat flow value over a few hundred mili-watt per square meter is not caused by conductive contribution only. It is supposed that lateral scale of a convection cell is about the same with vertical scale of that and heat flow anomary is local as long as scale of heat source is not so large. In this study upper limit of heat flow value is set on the basis that the estimated temperature at the bottom of the crust is under the melting temperature. After this two-dimensional smoothing is made on the heat flow distribution and conductive compornent of surface heat flow is estimated.

Another important factor is contribution of radiogenic heat generation in the crust. One method to estimate radiogenic heat generation which is based on empirical relation between seismic velocity and heat generation value was proposed (Rybach and Buntebarth; 1982, 1984). This relation represents tendency to increase content of incompatible elements as major composition of rocks becomes felsic. This empirical relation includes large error but is used for rough estimate of heat generation value in the crust. In the European basin thermal structure was calculated from measured surface heat flow values along some profiles on which seismic velocity structure was obtained from seismic studies. In this calculation radiogenic heat generation was calculated from the empirical relation between seismic velocity and heat generation value (Cermak and Bodri, 1986). Contribution of crustal heat generation is estimated about the half of surface heat flow value and it is clear that the radiogenic heat generation cannot be

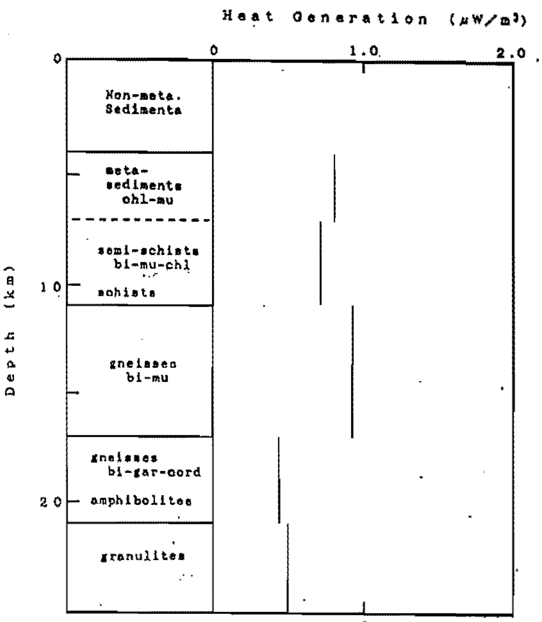

Fig.2 Vertical distribution of heat generation in Hidaka metamorphic zone. Rock types are also shown.

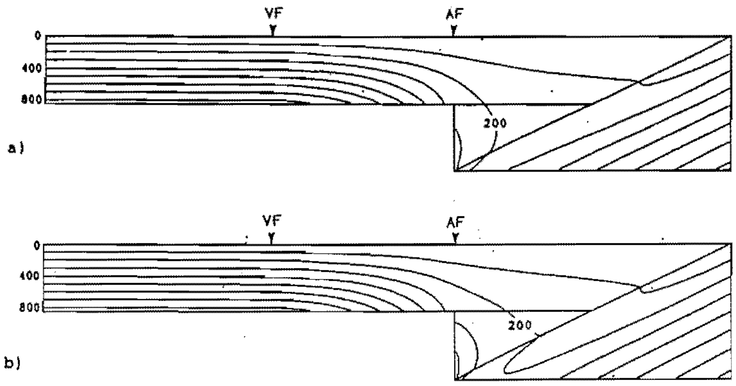

Fig.3 Calculated temperature structure in the crust. Two cases of shear heating are considered, a) constant through depth; b) linearly increase with depth. VF and AF denote the volcanic front and aseismic front respectively. Contour interval is 100 °C.

neglected for the estimation of the temperature structure in the crust and upper mantle.

Radiogenic heat generation values of arc's rocks was measured on INAA and gamma-ray spectrometry in this study. Sample rocks were collected in the Hidaka terrain in Japan where vertical section of the arc's crust is exposed at the surface. Rock types of measured samples are granite, gneiss and other metamorphic rocks of amphibolite and granulite facies. Estimated vertical cross section of the crust is shown in Fig. 2. As is shown in this figure, composition of the lower crust is not basaltic but more felsic one. Rocks collected in each layer are analyzed and heat generation value is calculated. Estimated heat generation profile of this vertical section is also shown in this Figure. Distribution of heat generation in the crust is estimated from our measurements and published data.

Two-dimensional temperature structures in some profiles across the arc were calculated to estimate the cooling effect of subducting slab. Fig. 3 shows a example of the calculation in the case of the Tohoku arc. It can be seen from this Figure that lateral temperature variation by subduction is significant.

Considering estimated distribution of surface heat flow values, crustal heat generation and subduction effects, temperature structure and Moho heat flow are obtained. These results are compared with other geophysical observations. Fig. 4 shows the comparison between heat flow pattern and seismic velocity perturbations in the depth of 16-17km (Ishida and Hasemi, 1988). Good agreement between them can be seen in this Figure. Low and high temperature anomaries coincide with subducting slab and active regions of volcanisms respectively. Extension and Intensity of temperature anomaries caused by such tectonic and geologic activities can be estimated in these studies.

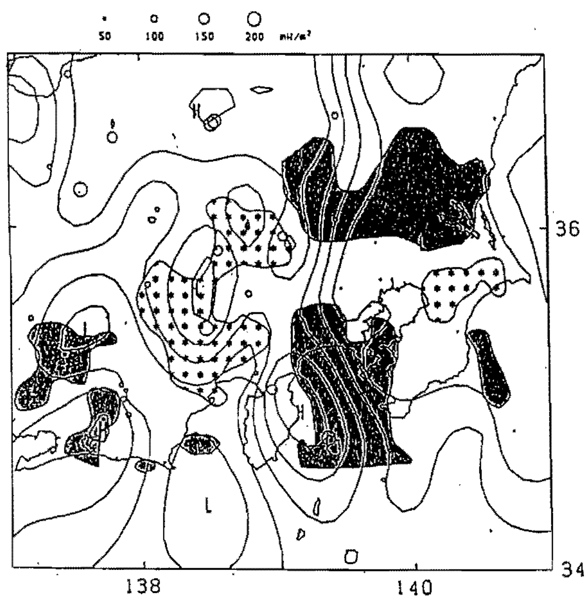

Fig.4 Regional heat flow distribution and velocity structure in the depth range of 16-47km. The starmarked and shaded portions indicate the low and high velocity areas respectively. The contour is drawn at 20mW/m^2 interval. H, L denote high and low heat flow zones respectively.

Estimating temperature structure, observed geophysical and geological features can be linked and mechanisms which cause tectonic and geologic activities will be clarified.

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