CHAPTER I

INTRODUCTION

Japan is a country in the East Asia comprising several geotectonic units (Zhang, 1985; Taira *et al.*, 1989; Isozaki, 1996). Each unit shows its specific character. Southern Kitakami area, the study area of this research, comprises three geotectonic units, based on the newly proposed geotectonic subdivision of Isozaki (1996). Geology of this area is quite different from the other parts of Japan. It is interesting to note that this area, which situates in northeastern Japan, is composed of nearly complete sequences of Paleozoic and Mesozoic rocks, ranging from Silurian to Early Cretaceous (e.g. Saito and Hashimoto, 1982; Ehiro and Kanisawa, 1996). From this point of view, the origin of Southern Kitakami has been a focus of discussions, and many studies of this area have been done in the past (e.g. Saito and Hashimoto, 1982; Tazawa, 1993; Hisada *et al.*, 1995; Ehiro and Kanisawa, 1996; Dozen and Ishigi, 1997). As the result, a tectonic setting of this area has been proposed. However, the setting still requires further detailed evidences.

Due to the unclear origin of the Southern Kitakami area, this study is proposed in order to apply detailed chromian spinel analysis to interpret the tectonic settings of this area. This application for tectonic interpretation has been accepted by several geologists all over the world including Japan (e.g. Dick and Bullen, 1984; Press, 1986; Pober and Faupl, 1988; Huggesty, 1991; Cookenboo *et al.*, 1997; Arai and Okada, 1991; Arai, 1992; Hisada and Arai, 1993; Hisada *et al.*, 1994; Takeuchi, 1994; Hasada *et al.*, 1995; and Yoshida *et al.*, 1995). Petrochemistry of detrital chromian spinels have been used extensively to interpret their tectonic settings in many areas of Japan such as Kurosekawa region (Hisada and Arai, 1994), Kanto mountains (Hisada and Arai, 1993), Soma area (Hisada *et al.*, 1995), Eastern Hokkaido (Nanayama *et al.*,

1993; 1994), Northern Kyushu (Kadoshima and Arai, 1999), and others. In the Southern Kitakami area, geochemistry of some detrital chromian spinels were also reported in the Jurassic beds (Takeuchi, 1994), Devonian beds (Hisada *et al.*, 1995), and Silurian beds (Yoshida *et al.*, 1995).

It is notably important, however, that no study has been made for the detrital chromian spinels from Carboniferous to Triassic sedimentary rocks. Within this time span of 150 Ma, detrital chromian spinel has never been reported. Thus, it has long been proposed to search for more detrital chromian spinels carefully in the Southern Kitakami area, especially from this missing period. It is anticipated that the new crucial data given in this study can help interpretation of tectonic settings of the Southern Kitakami area more clearly.

1.1 Location

Kitakami, a Japanese word from "kita" which means north or northward and "kami" which means upper, is the mountainous area locating in northeastern part of the Honshu Island, Japan. It is far north from Tokyo, the capital city, about 400 km. The maximum length and width of the whole Kitakami area are 254 and 72 km, respectively. This area was subdivided into Northern and Southern Kitakami areas, the Hayachine mountain chain represents a dividing zone between these two sub-areas. The latter, Southern Kitakami, is the study area of the current research (Fig. 1.1). It lies between latitudes 38° 15' N and 39° 45' N and longitudes between 141° 5' E and 142° 5' E. The approximate area of the Southern Kitakami is 5,500 km^2 covering southeastern part of Iwate and northeastern part of Miyagi prefectures within the Tohoku region. It is bordered on the west by the Kitakami River, on the north by the Hayachine mountain chain and faces eastward the Pacific Ocean.

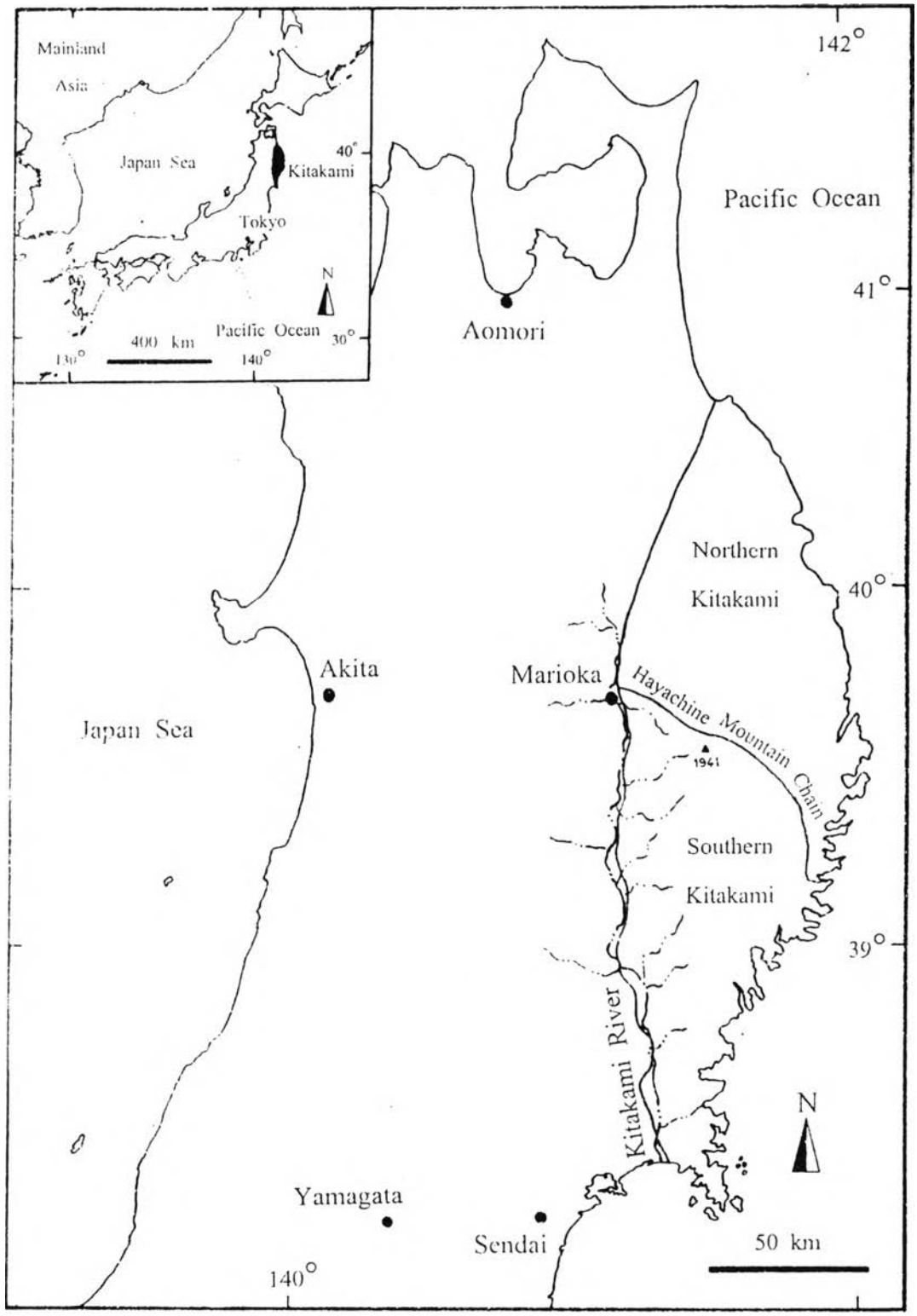

Figure 1.1 Map showing location of the Southern Kitakami area.

1.2 Accessibility

Within the study area, there is the local Hanamaki Airport which is situated in the northwestern part of the study area (Fig. 1.2). It takes about one hour and five minutes to go from Nagoya, about one hour and thirty minutes from Osaka, and about fifty-five minutes from Sapporo to this Hanamaki Airport. On the west of the area, there are both the Tohoku Express-Railway, for the Shinkansen, the bullet train, and the Tohoku Toll-Expressway, for the ordinary cars, which run from Tokyo pass through the northeastern Japan to the north. It takes about three hours from Tokyo to the area via Shinkansen and it will depend upon the car's velocity on the Toll-Expressway. Besides, there are many other ways to the study area as shown also in figure 1.2.

1.3 Objectives

The main objectives of this research are firstly to study petrography of the Middle to Upper Paleozoic clastic sedimentary rocks, especially sandstones and siltstones that have been found to contain detrital chromian spinels, within the Southern Kitakami area; secondly, to study chemical compositions of detrital chromian spinels detected from thin-sections of the above rocks; and thirdly, to interprete tectonic setting of the Southern Kitakami area.

1.4 Methodology

The methodology used to achieve the stated research objectives above can be divided into six main steps consisting of the pre-field, the field checking and samples collection, the laboratory studies, the data processing, the interpretation, and the

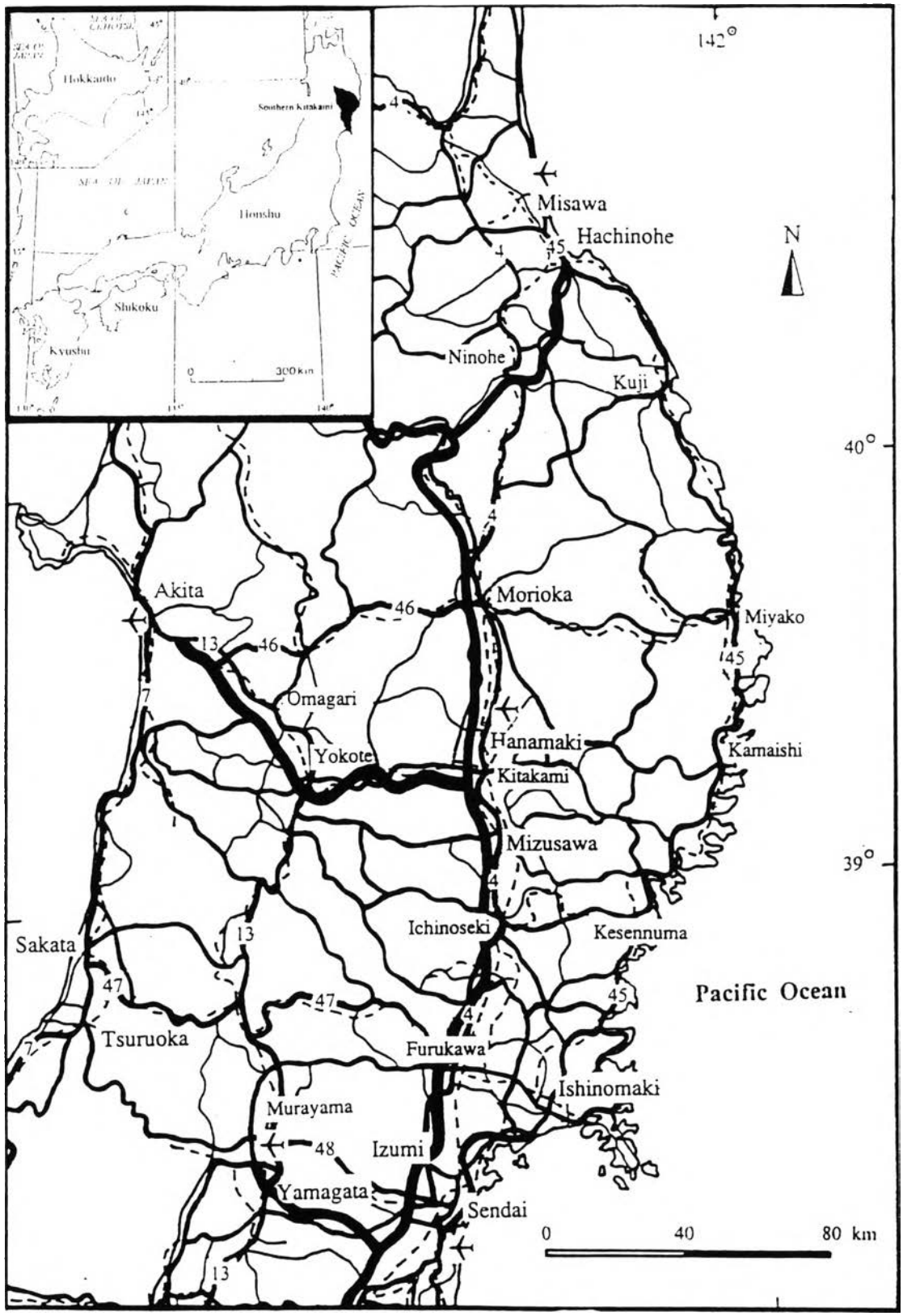

Figure 1.2 Map showing accessibility of the Southern Kitakami area.

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discussion and conclusion steps. Figure 1.3 shows the flow chart of methodology used in this research. Detailed works of each step are described below.

1.4.1 Pre-field

In order to orientate himself for this research, the author had to study the previous geological works together with geological maps, topographic maps and Satellite images of the study area. Moreover, theoretical aspects on chromian spinels, the most interesting mineral of this research, have to be comprehended. The importance of these spinels for tectonic settings of the provenance must be also understood well.

Before field survey, localities where clastic sedimentary rocks exist are carefully investigated in details, especially for the Middle to Upper Paleozoic rocks, based upon many previous geological maps produced by Japanese geologists, e.g. Kawamura, T., 1983; 1984; Kawamura, M., 1985; Kawamura, T. and Kawamura, M., 1989; and Mori *et al.*, 1992. These assisted the author in data preparation and samples collection.

1.4.2 Field checking and samples collection

Wthin the study area, based on the previous available geological maps and remote-sensing data, many locations had been visited, especially the places where detrital chromian spinels have never found, to collect rock samples of not only clastic origin but also those of the others. Both Paleozoic and Mesozoic rocks are the most plausible target for this research study. In addition, general geology and lithostratigraphy of the study area were also studied in order to support geological understanding of the study area.

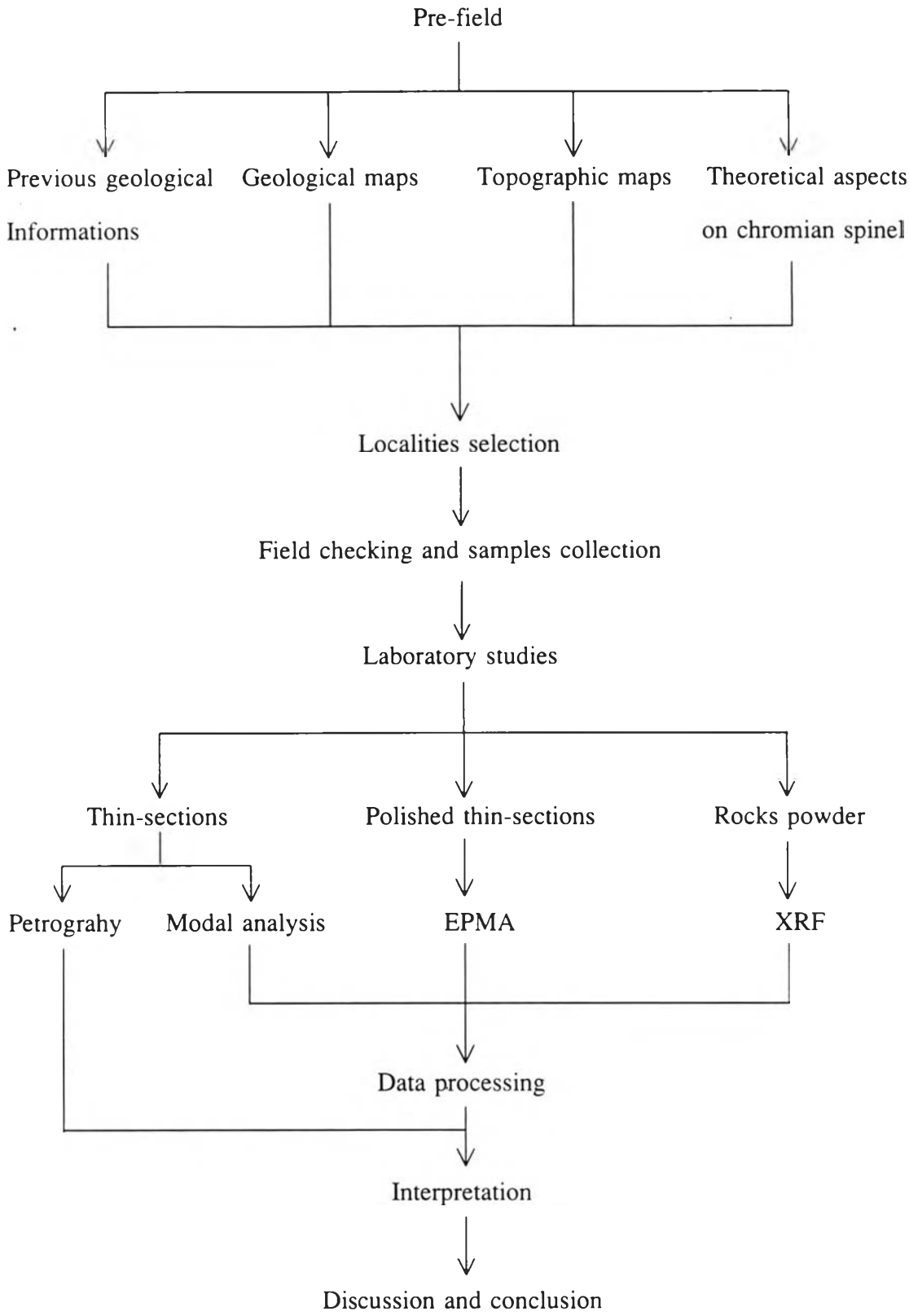

Figure 1.3 Flow chart showing methodology of this research study.

1.4.3 Laboratory studies

All samples collected from the field were cut to make thin-sections for detailed petrographic study. Each thin-section was then examined under polarizing microscopes to describe its textures, major and minor mineral compositions, and characteristics of its constituents. Some certained minerals, including quartz, feldspar, and rock fragments, were determined for their modal compositions.

Detrital chromian spinels are the target mineral grains that require careful analysis. For thin-sections containing detrital chromian spinels, the polishing need to be done until the smooth surfaces of those chromian spinels became larger than 10 microns in diameter, bigger than the tube diameter of the microprobe used. Subsequently, these polished thin-sections were coated with carbon in order to analyse chemical compositions of each chromian spinels using electron microprobe, JEOL JXA-8621, at the Chemical Analysis Center, University of Tsukuba in Japan.

Conditions of the electron microprobe used for the analysis are shown below.

Spectrometer: Channel 1 = 200 mm;
Channel 2 = 200 mm; and
Channel 3 = 200 mm.
Accelerating Voltage = 20 kV,
Probe Electronic Current = 1.0E-8 A,
Probe Diameter = 10 μ, and
OL Indicator = 80.

Eleven electron probe microanalysis (EPMA) standards used in this study are both natural and synthetic as given below:

Albite	for	Na
MgO	for	Mg
Al_2O_3	for	Al
SiO_2	for	Si
K-feldspar	for	K
$CaSiO_3$	for	Ca
TiO_2	for	Ti
Chromite	for	Cr
Mn-Fe	for	Mn
Fe_2O_3	for	Fe
NiO	for	Ni

Besides, some rock samples were milled for the major oxides analysis using X-ray fluorescence spectroscopy (XRF). This analysis was assisted by the Chemical Analysis Section of Clays & Minerals (Thailand) Co., Ltd.

1.4.4 Data processing

Results on chemical compositions of each chromian spinel grain obtained from the EPMA were then used for calculation of the $Mg/(Mg+Fe^{2+})$, $Cr/(Cr+Al)$, $Al/(Al+Cr+Fe^{3+})$, $Cr/(Al+Cr+Fe^{3+})$, and $Fe^{3+}/(Al+Cr+Fe^{3+})$ atomic ratios. Then, draw the relashionship diagrams between $Cr/(Cr+Al)$ and $Mg/(Mg+Fe^{2+})$, $Cr/(Cr+Al)$ and TiO_2, and triangular diagram among Al, Cr and Fe^{3+}. Likewise, the results from XRF were also used for calculation of Fe_2O_3+MgO, Al_2O_3/SiO_2, $\log(K_2O/Na_2O)$, and the discriminant functions 1 and 2. After that, draw the diagrams between TiO_2 and Fe_2O_3+MgO, Al_2O_3/SiO_2 and Fe_2O_3+MgO, $\log(K_2O/Na_2O)$ and SiO_2, and discriminant function 1 and discriminant function 2. Several diagrams and triangular diagrams from EPMA, XRF, and petrographic information were subsequently made.

1.4.5 Interpretation

All the results were then gathered and collectively interpreted for searching provenance of the host rocks of detrital chromian spinels. Tectonic setting of the Southern Kitakami area was then determined on the basis of their provenances.

1.4.6 Discussion and conclusion

The results from this study along with those of the other previous works were later discussed to unravel paleogeography and plate-tectonic scenario of the Southern Kitakami area.