CHAPTER IV

PETROGRAPHY OF THE CLASTIC ROCKS

Although one of the objectives of this research is to study petrography of the Middle to Upper Paleozoic clastic sedimentary rocks, the author also collected rocks from the Mesozoic beds in the Southern Kitakami area for investigation. The clastic sedimentary rocks are the major rock types collected for this research because the previous discoveries of detrital chromian spinel, the most interesting mineral of this work, were from sandstones and siltstones. As it will be stated in Chapter V, chromian spinel is a useful petrogenetic indicator because its compositions have the potential to provide more detailed information of tectonic setting in the source area. Since another important objective of this research is to interpret tectonic settings of the Southern Kitakami area using physicochemical characteristics of detrital chromian minerals, most careful attention has been paid in searching for various discreminating types of detrital chromian spinels in all thin-sections of the clastic sedimentary rocks.

Due to the very large area of the Southern Kitakami and the time constrain, the author had to limit the field investigation and sampling locations. Several regional and detailed geologic maps and columnar sections made by earlier workers were used as the fundamental information for this work. Only the places where clastic sedimentary rocks are well exposed were, thus, selected for systematic sampling.

The total number of samples that were collected is 83 samples. Most of them, 55 samples including mafic and intermediate volcanic rocks, are from Carboniferous units because clastic sedimentary rocks are more widely exposed, and no detrital chromian spinel has been found yet in these rocks. Six sandstones of Devonian period occurring in a close association with those of Carboniferous (see a map in Fig. 3.1) were also collected for petrrographic investigation. Five samples of Permian sandstones were collected in spite of the fact that clastic rocks are rarely exposed, most dominant Permian rocks in the Southern Kitakami area are limestones. Some of the Mesozoic sandstones were additionally collected for microscopic study, These include 4 samples from Triassic, 11 from Jurassic, and 2 from Cretaceous in order to fulfil the petrographic task, which is occasionally useful for the tectonic interpretation.

4.1 Mesoscopic description

Most of sandstones collected from Carboniferous and Devonian successions show similar characteristics, i.e. greenish gray to greenish black in color, and very poorly to moderately sorted (Figs. 4.1 to 4.6). Their grain sizes vary from silt up to pebble in Wentworth size class. These phenoclasts are composed mostly of rock fragments and feldspar. These grains show almost moderate sphericity, and are angular to sub rounded. Some specimens show the calcareous characteristic by effervescence with hydrochloric acid. Fragments of crinoid stem were also observed in some specimens (Fig. 4.4). The well-defined sedimentary structures that were found in some specimens are cross-lamination and graded bedding.

The sandstones grouped into Permian to Cretaceous are much different from those of Carboniferous and Devonian. They are whitish gray to yellowish brown in color, well to very well sorted. Their grain sizes are generally fine sand, but some specimens contain very fine sand or medium sand particles. Almost all the feldspar-grains constitued these rocks, they exhibit moderate to high sphericity, with roundness ranging from angular to sub rounded. Some specimens are calcareous, especially those of Permian and Triassic. Sedimentary structures of these rocks are lamination (both continuous and discontinuous) and cross-lamination. A yellowish brown sandstone belonging to Triassic contains chiefly feldspar as shown in figure 4.7.

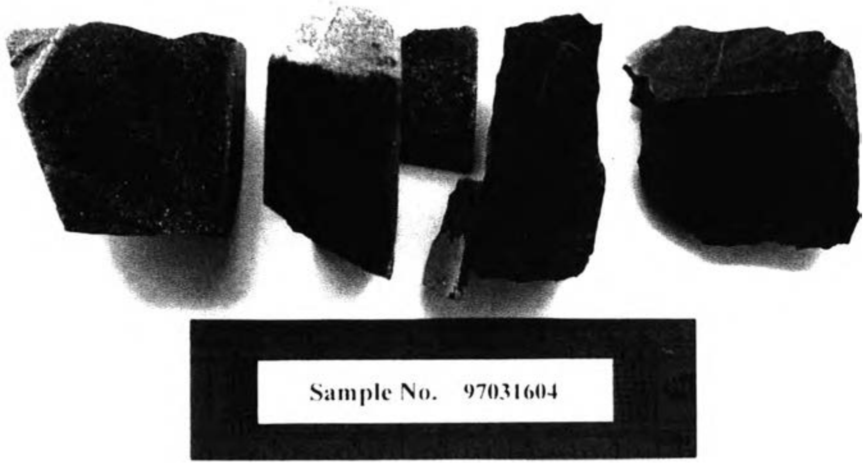

Figure 4.1 Poor-sorted greenish gray fine- to medium-grained sandstone of Devonian Nakazoto Formation.

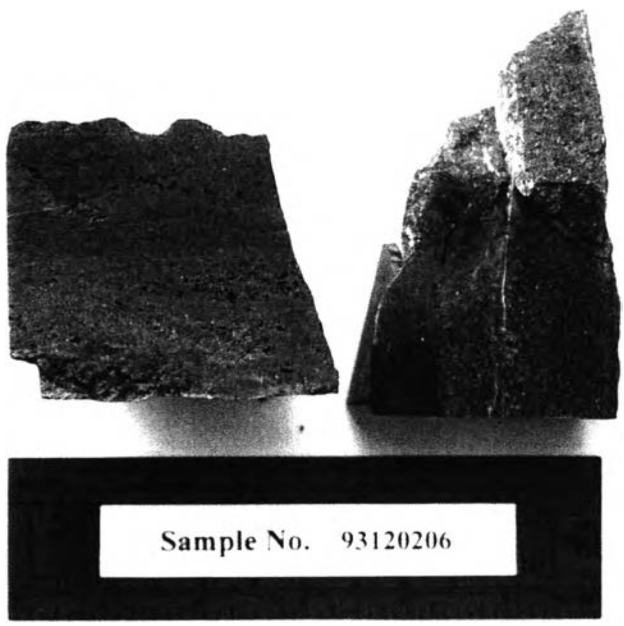

Figure 4.2 Very poorly sorted light gray fine- to very coarse-grained Carboniferous sandstone from Hikoroichi Formation showing graded bedding together with cross lamination.

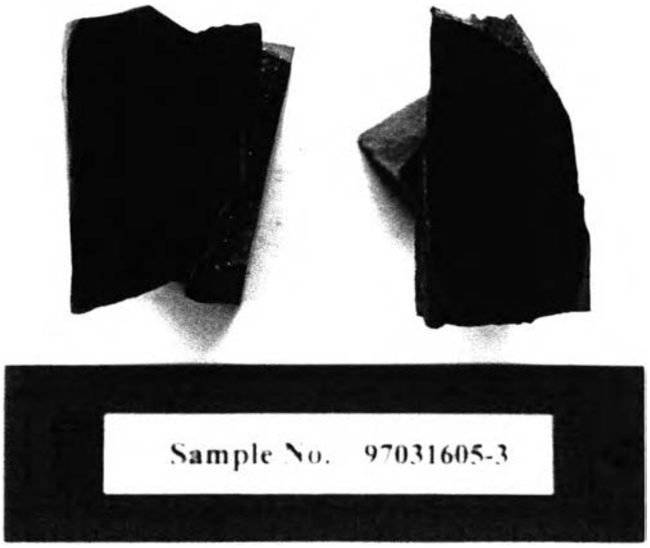

Figure 4.3 Moderately sorted fine- to coarse-grained dark greenish gray calcareous carboniferous sandstone from Hikoroichi Formation. It seems to have the lineation in elongated-grains.

Figure 4.4 Poor-sorted blackish gray very fine- to very coarse-grained, with some gravel-size crinoid stems, of calcareous sandstone in Carboniferous Odaira Formation.

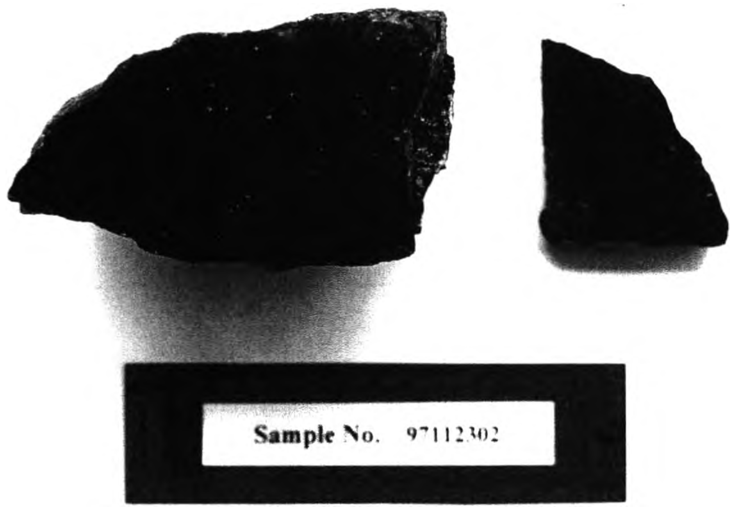

Figure 4.5 Very poorly sorted greenish sandstone of Carboniferous Hikoroichi Formation. Grain sizes very from silt up to pebble and seem to arrange as lamination.

Figure 4.6 Moderately sorted very fine- to medium-grained gray siliceous sandstone of Carboniferous Hikoroichi Formation.

Apart from sandstones, which are more dominant rocks of Carboniferous, siltsones were also collected for petrographic analysis. They are generally light gray in color, with some blackish bands alternating, and often show lineation fabric (Figs. 4.8 and 4.9). In some specimens, the texture is also defined by sand and silt mixtures. Most of the siltstones collected are calcareous cemented .

In addition to the clastic sedimentary rocks described above, Carboniferous basalts were also collected. They are greenish gray to greenish black in colors, comprising mainly plagioclase with some olivine and hornblende, and other mafic minerals. The general textures of these volcanic rocks are flow and porphyritic textures. Phenocrysts are plagioclase and olivine, with some hornblende while groundmass are dominantly microcrystalline plagioclases. Average size of the phenocrysts is 1 mm, but some phenocrysts are up to 4 mm. Figure 4.10 is an example of greenish gray porphyritic basalt of the Carboniferous.

4.2 Microscopic description

Sandstones from this study were classified based on classification of Folk (1974), see figure 4.11. Devonian sandstones are characterized by feldspathic litharenite, and lithic arkose; Carboniferous sandstones include lithalinite, feldspathic lithalinite, and lithic arkose; whereas Permian to Cretaceous sandstones are mostly arkose. Quartz is observed to be absent in several specimens (see Table 4.1). Many of the Paleozoic sandstones have often calcareous cement, some contain carbonate fragments with some fossils. Names and methods of investigation of all rock samples are listed in Appendix I. Details of these rocks are given below.

Figure 4.7 Well sorted fine-grained yellowish brown Triassic sandstone from Osawa Formation of Inai Group.

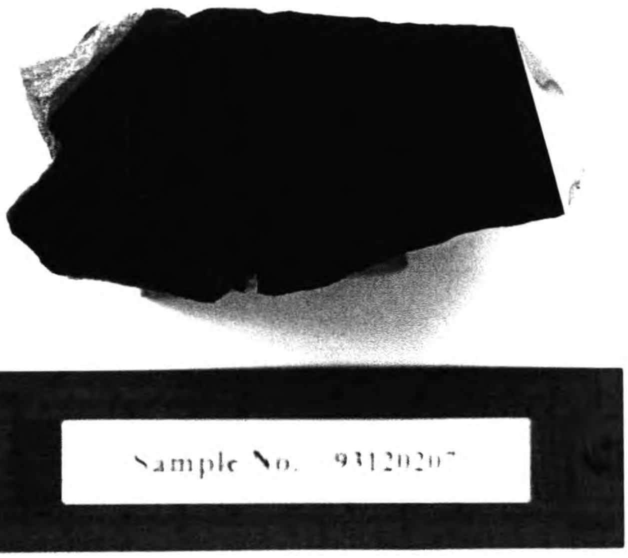

Figure 4.8 Light gray siltstone with some blackish gray bands alternating of Carboniferous Hikoroichi Formation.

Figure 4.9 Light gray siltstone with blackish gray bands alternating of Carboniferous Hikoroichi Formation.

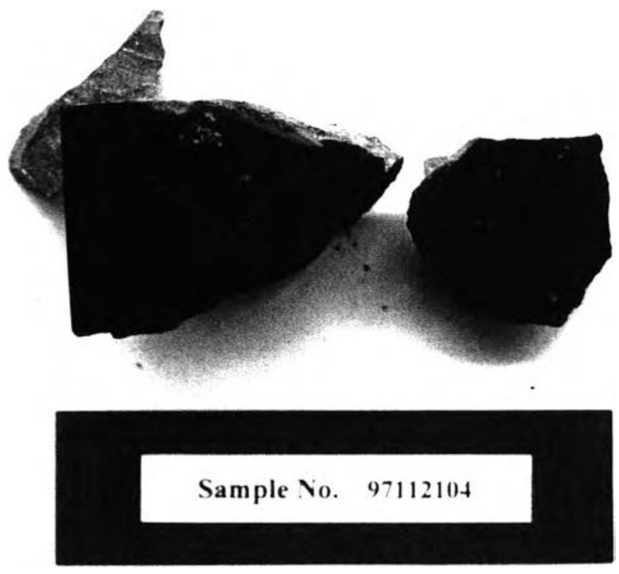

Figure 4.10 Dark green porphyritic basalt of Carboniferous Karosawa Formation.

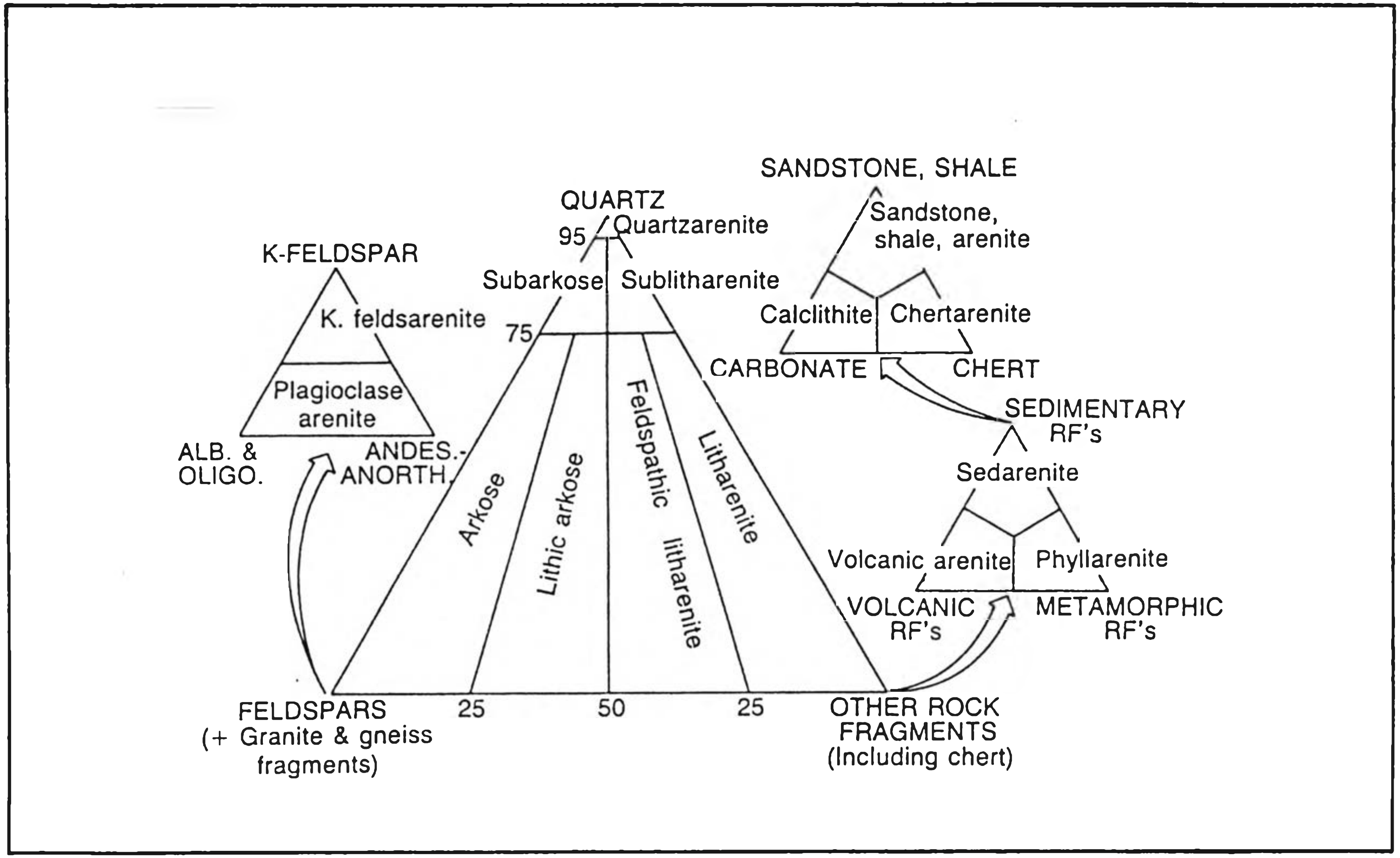

Figure 4.11 Sandstone classification of Folk (1974).

4.2.1 Litharenite

Litharenite is characterized by very high rock fragment content. Many Carboniferous sandstones of the Southern Kitakami area are of this type. Their phenoclasts comprise dominantly of rock fragments, with some, less than 25 %, feldspar. More than 80 % of rock fragments are observed in specimens from Carboniferous strata (see Table 4.1). Quartz was rarely found, not more than 10 %, within these rocks. Rock fragments of this rock type are chiefly volcanic, and/or carbonate fragments (Figs. 4.12 to 4.15). Volcanic arenite is named for litharenite that rock fragments are volcanic (see Fig. 4.11) while the litharenite that rock fragments are carbonate (Fig. 4.11) is called calclithite (Folk, 1974). The calclithite sometimes contain fossil fragments, such as crinoid stems (Fig. 4.14). Other components are plagioclases and some flakes of mica, changing from the higher temperature mafic minerals. Detrital chromian spinels were observed in five samples, four from volcanic arenite, and one from calclithite. Each sample contains only a few grains of detrital chromian spinels. Sizes of phenoclasts from these rocks vary from very fine sand to larger than very coarse sand. The rock fragments are mostly very poorly sorted. They exhibit low sphericity, with very angular to sub rounded nature. These characteristics indicate both textural and mineral immaturities of the rocks. Cementing materials of these rocks are mixed silicate and calcareous, and matrix and mostly microcrystalline plagioclases and/or carbonates.

4.2.2 Feldspathic litharenite

Feldspathic lithalenites in the Southern Kitakami area are of Carboniferous and Devonian. They comprise mostly rock fragments and feldspar, but rock fragments are more abundant (Figs. 4.16 and 4.17). Rock fragments are, to some extent, similar to those of the above lithalenite, i.e., composed mainly of volcanic rock fragments.

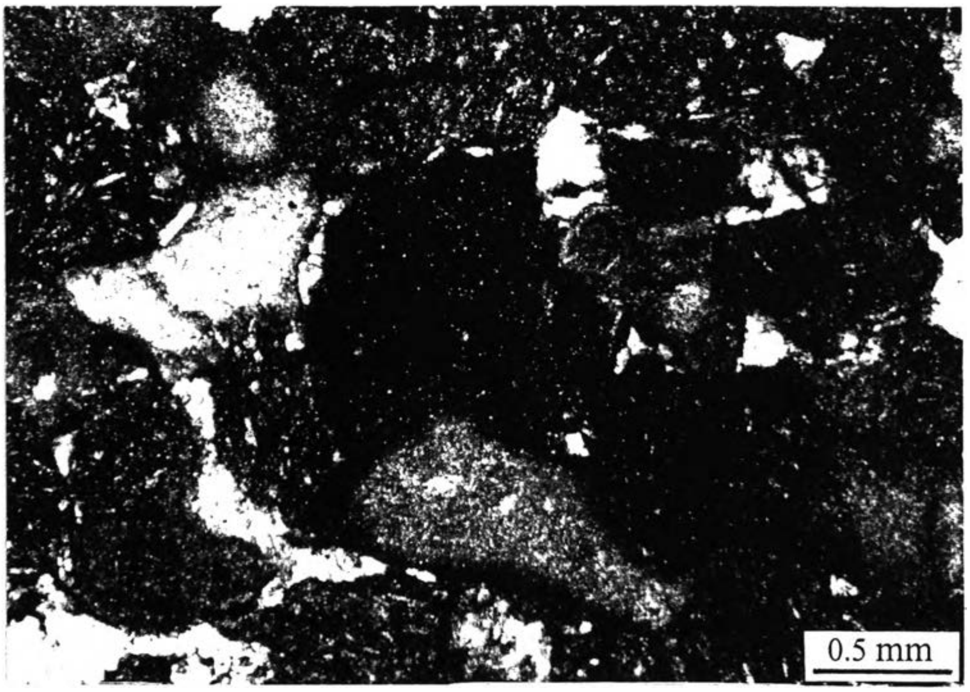

Figure 4.12 Moderately sorted volcanic arenite of sample no. 97112205 from Carboniferous Hikoroichi Formation containing wholely irregular felsic to mafic volcanic fragments.

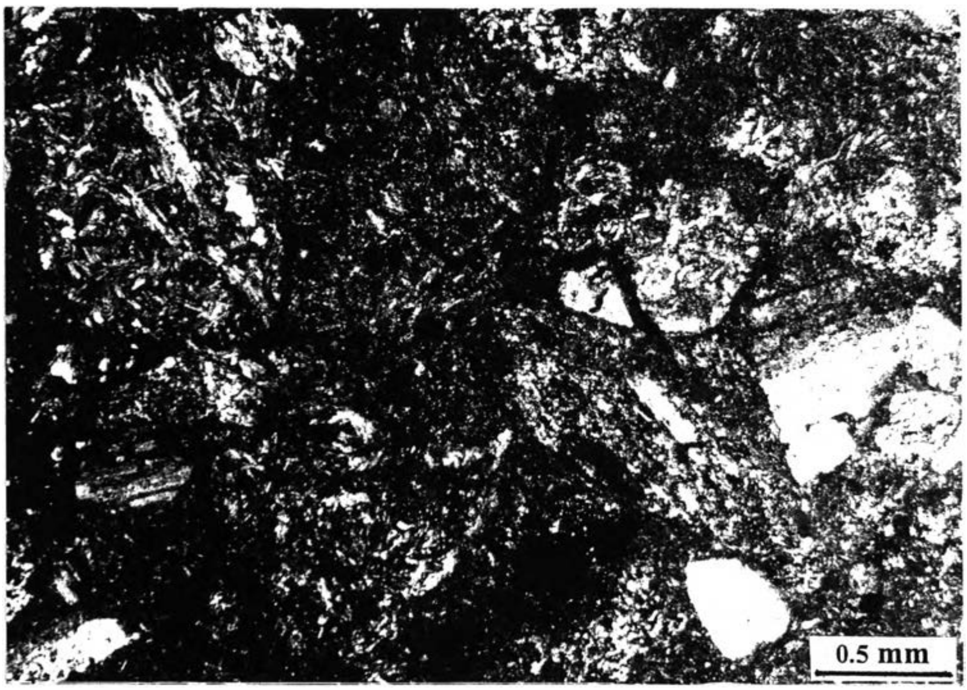

Figure 4.13 Moderately sorted volcanic arenite of sample no. 97031605-5 from Carboniferous Hikoroichi Formation containing mostly volcanic clasts with small amount of feldspar grains.

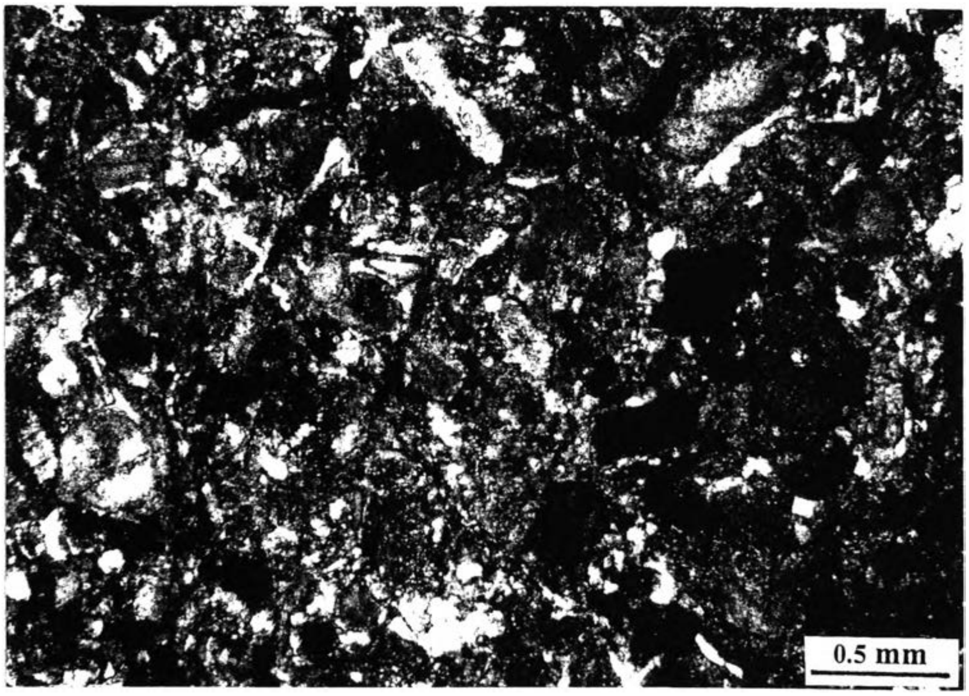

Figure 4.14 Moderate-sorted Calclithite of sample no. 97112217 from Carboniferous Odaira Formation containing wholely carbonate fragments with some crinoid stems.

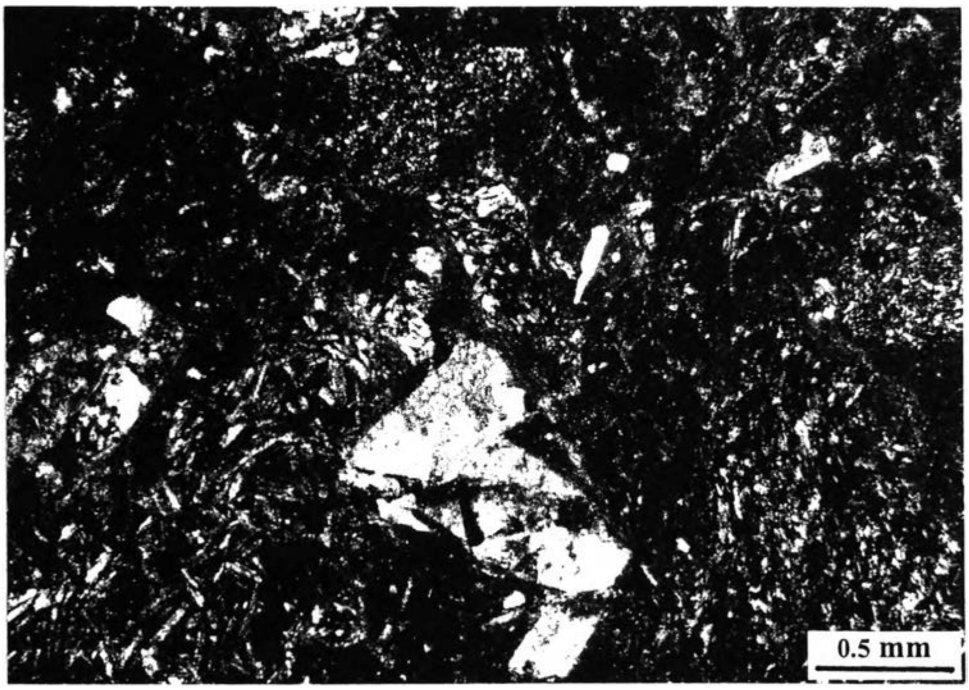

Figure 4.15 Poor-sorted volcanic arenite of sample no. 97112302 from Carboniferous Hikoroichi Formation containing mostly volcanic fragments from various source rocks with a few feldspar grains.

Figure 4.16 Very poorly sorted feldsparthic litharenite of sample no. 97031603 from Devonian Ono Formation.

Figure 4.17 Poorly sorted feldsparthic litharenite of sample no. 97112204 from Carboniferous Hikoroichi Formation.

Prismatic and short-tabular plagioclases are the chief feldspar of these rocks. Other components, rarely found, are some mafic or mafic derived minerals, such as hornblende and biotite which exist as the matrices. Detrital chromian spinel has not been detected in this rock type yet. Sorting of the rocks are very poor, grain sizes vary from silt up to coarse sand. They are low sphericity, with almost angular shapes. These characteristics suggest the immature stage of maturity both mineralogy and textural features. Essential matrices are microcrystalline plagioclases, and precipitated cements are mostly of carbonates.

4.2.3 Lithic arkose

The other type of Devonian and Carboniferous sandstones is lithic arkose, but not so common and occur in limited areas. This lithic arkose consists principally of feldspars and rock fragments. Unlike feldspathic lithalenite, feldspars are more abundant than rock fragments in lithic arkose (Figs. 4.18 and 4.19). Feldspar and rock fragments of this rock type are, however, similar to those of feldspathic lithalenite. Base on petrographic investigation, plagioclases are the chief feldspar while volcanics are the general rock fragments of this rock type. Plagioclases are often prismatic and stout characters. Abundant detrital chromian spinels (average 20 grains per a 2x3 cm thin-section) were detected in one sandstone of Devonian age. Other components of lithic arkose are mafic and their derivative minerals, and carbonates which are occurred normally as precipitated cementing materials. Its sorting is also very poor, grain sizes vary from fine to coarse sand. Many of them, especially plagioclase grains, show very low sphericity, but generally are sub angular to sub rounded shapes. From the mineralogies and textural features, maturity of this rock type is also in the immature stage.

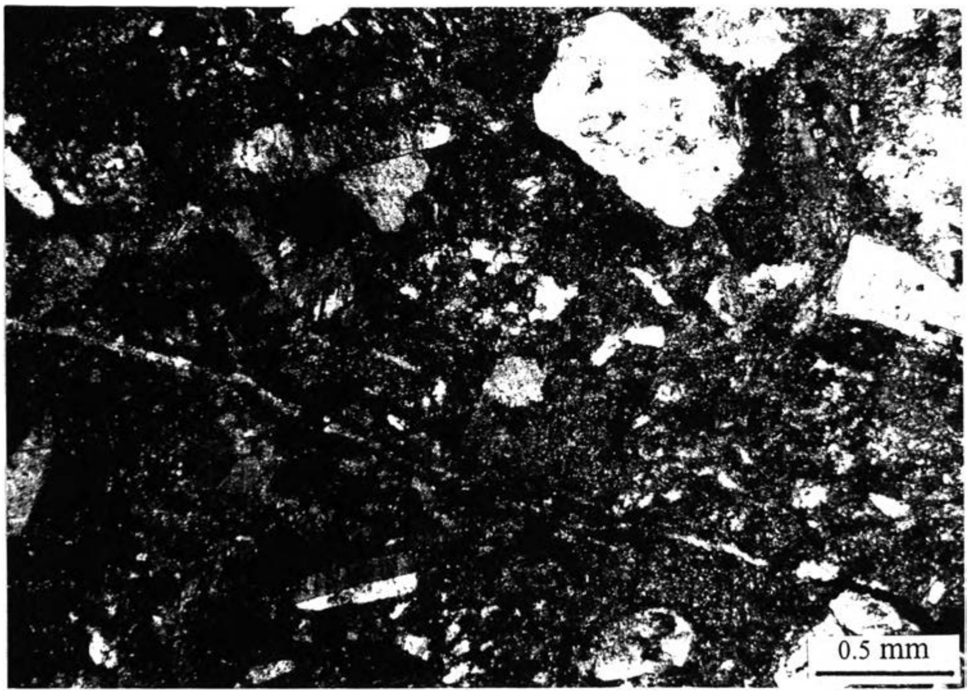

Figure 4.18 Very poorly sorted lithic arkose of sample no. 97031606 from Carboniferous Odaira Formation.

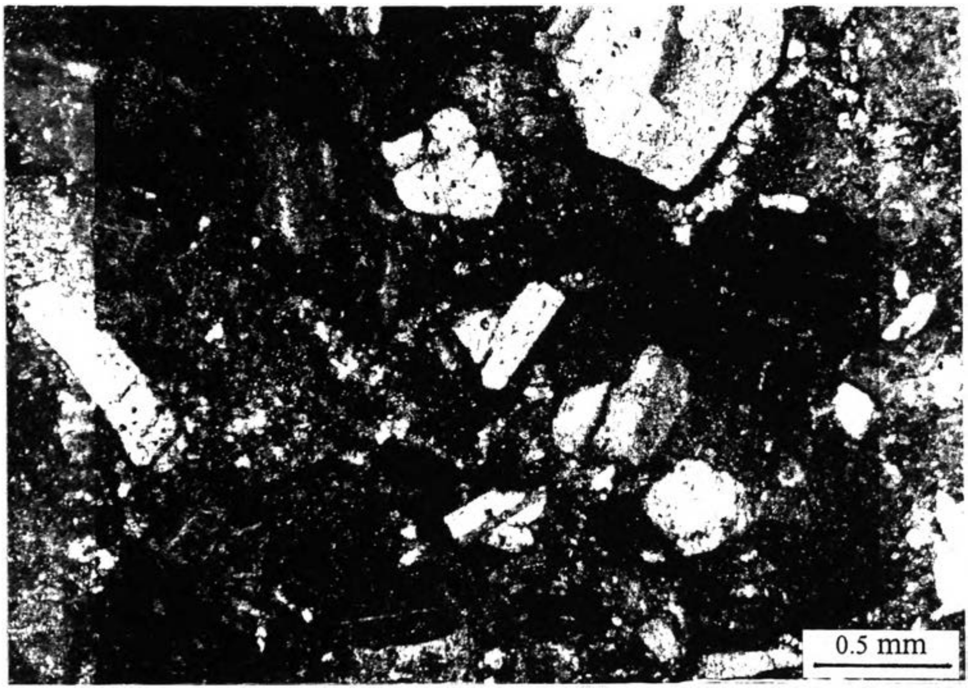

Figure 4.19 Very poorly sorted lithic arkose of sample no. 97112204 from Carboniferous Hikoroichi Formation.

4.2.4 Arkose

Arkose is the major type of Permian to Cretaceous sandstones in the Southern Kitakami area consisting mostly of feldspar, with small amount of rock frackments and less than 9 % quartz. Detrital micas are also present as the fine-grained matrix. A few detrital chromian spinel grains were detected only in Triassic arkose. The feldspar is chiefly plagioclase (Figs. 4.20 to 4.23), especially Na-rich plagioclase. More than 90 % of plagioclases are observed in Permian and Jurassic rocks (Table 4.1). This rock type can be named more perfectly as plagioclase arenite (Fig. 4.11) based on Folk (1974). These plagioclases are usually fresh, only small amount are altered to kaolinite and sericite. Grain sizes of the rock are mainly fine sand, some are very fine sand, and rarity are medium sand. All of them have a well-sorted particles, which show moderate to high sphericity and are angular to sub rounded. Both mineralogical and textural natures of this rock point to the mature stage of maturity. The cementing materials of these arkoses are carbonates or iron oxides or sometimes, in the grain-supported arkoses, are the altered matrix and precipitated cements, composing mostly of clay mineral.

4.2.5 Siltstone

Though siltstones are exposed in several strata of different ages, they were collected only from Carboniferous strata. Their grains are composed mostly of plagioclase with some quartz, and cemented by carbonates (Figs. 4.24 and 4.25). Detrital chromian spinels were found in three samples, only one to two grains from each thin-section. The particles of siltstone usually arrange themselves linearly. Sandy texture was also found in some silstones, their sand grains are mostly of elongated shapes. The most common sand grains include feldspar and volcanic rock-fragments (Fig. 4.25). Most of feldspars are K-feldspar which are moderately altered to kaolinite

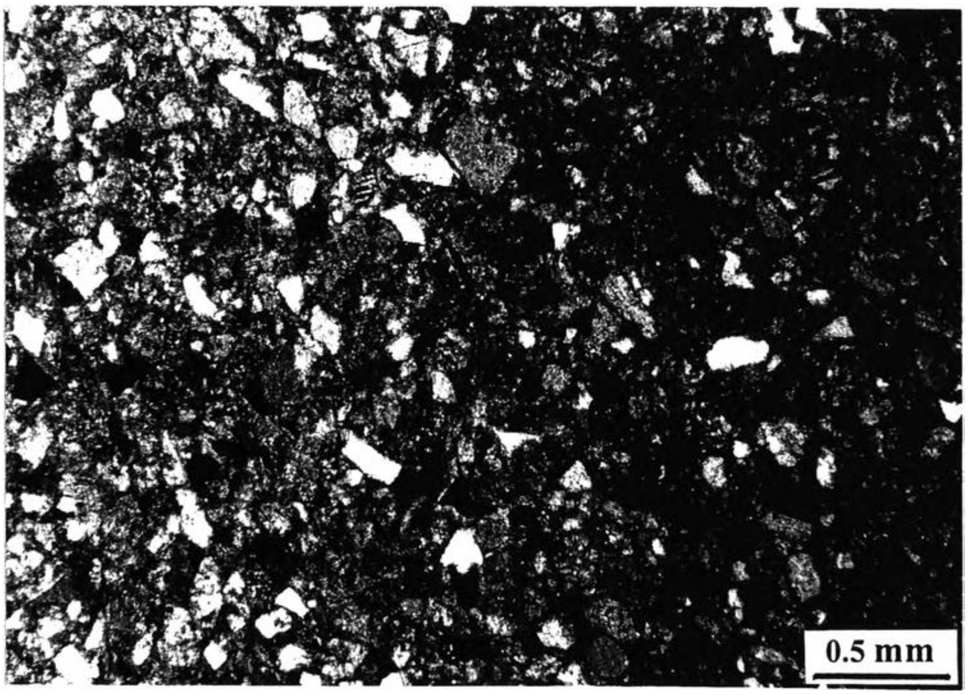

Figure 4.20 Well-sorted ferrogeneous arkose of sample no. 97031707 from Permian Toyoma Formation.

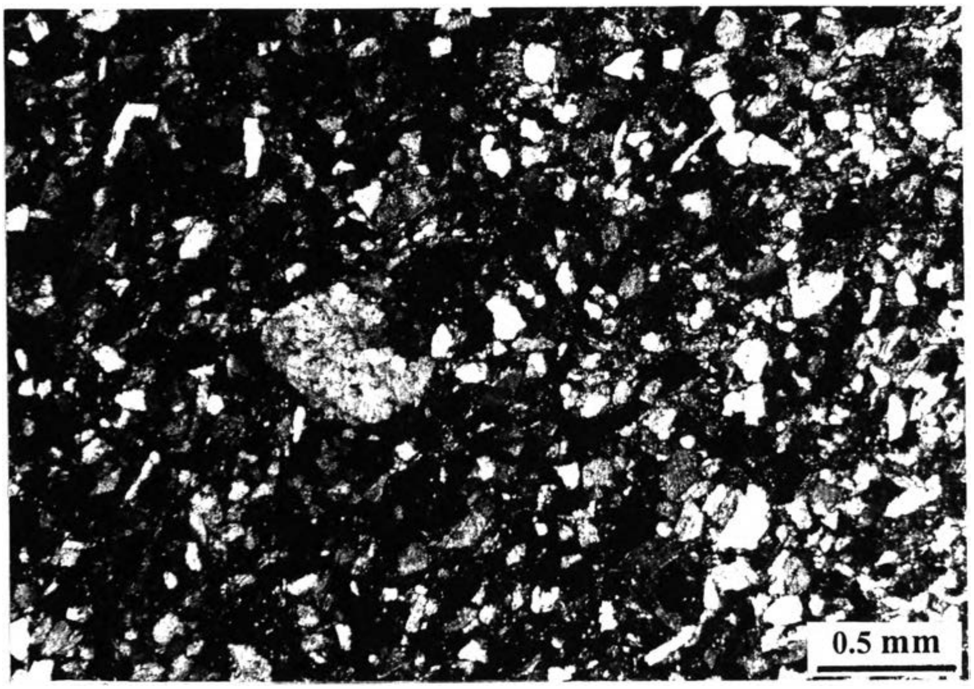

Figure 4.21 Well-sorted siliceous arkose of sample no. 97031703 from Triassic Osawa Formation.

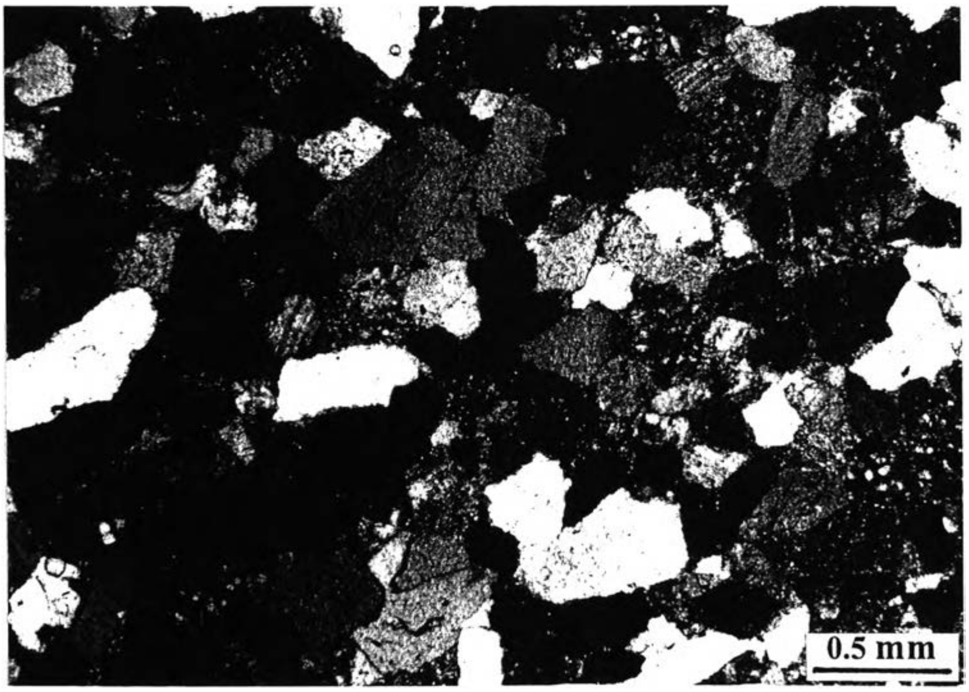

Figure 4.22 Well sorted medium-grained siliceous arkose of sample no. 97031704 from Jurassic Niranohama Formation.

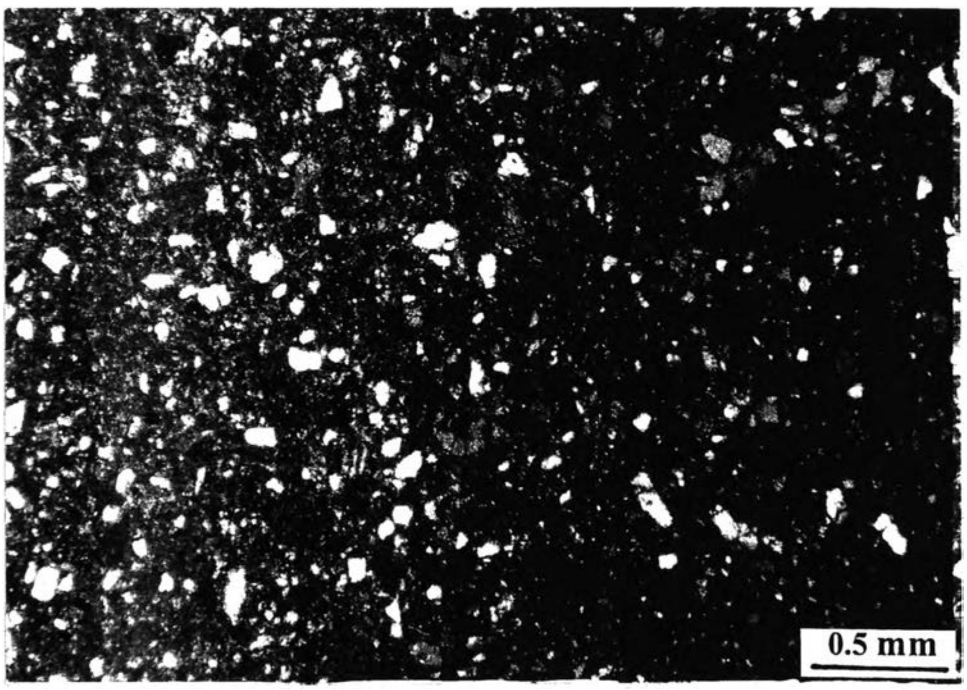

Figure 4.23 Moderately sorted very fine- to fine-grains ferrogeneous arkose of sample no. 97031502 from Cretaceous Ofunato Group.

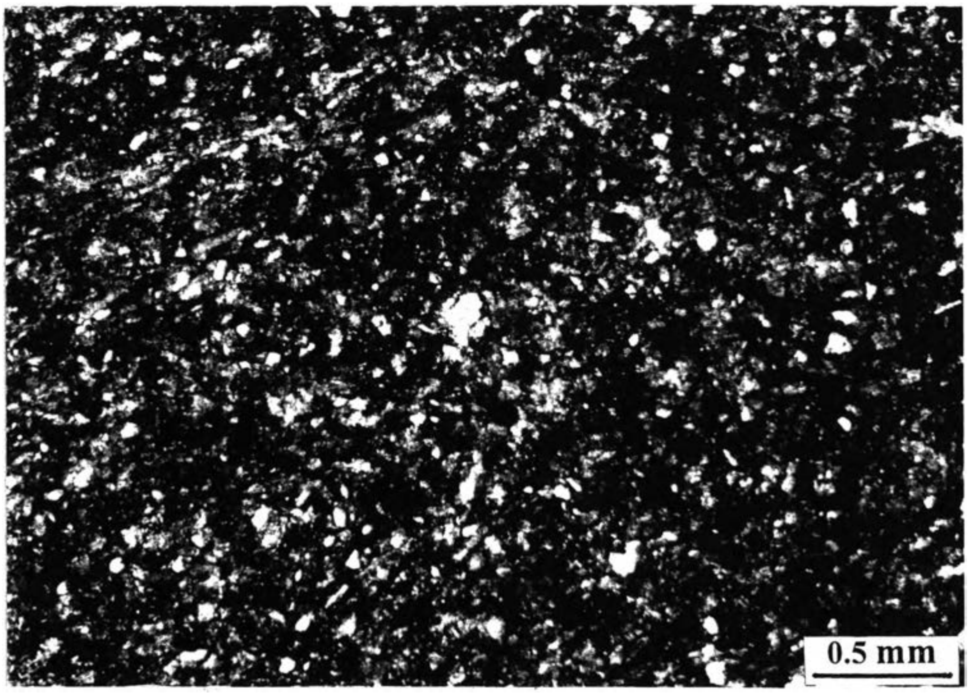

Figure 4.24 Strong calcareous siltstone from sample no. 93120207 of Carboniferous Hikoroichi Formation.

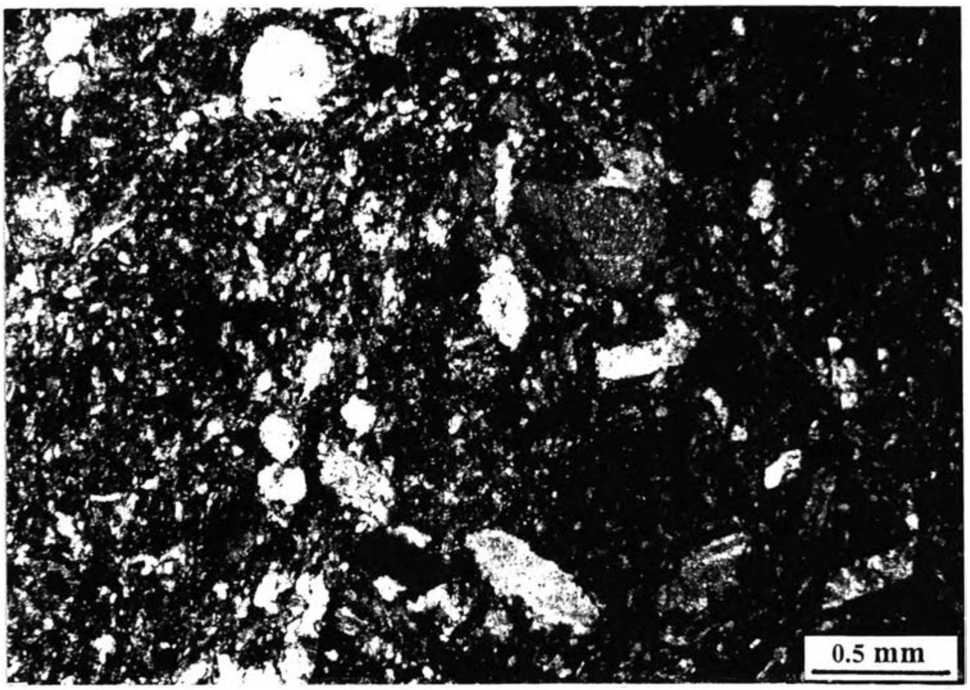

Figure 4.25 Calcareous sandy siltstone from sample no. 93120208 of Carboniferous Hikoroichi Formation. Sand grains are mostly feldspar and volcanic fragments.

and sericite. Rock fragments in this siltstone are derived from volcanic rocks, however their abundance is not much as compared to K-feldspar.

4.2.6 Basalt

Carboniferous basalts are composed of plagioclase, pigionite, olivine, and hornblende. They often show porphylitic and flow textures (Figs. 4.26 and 4.27). Plagioclase, olivine, and hornblende are generally crystallized as the phenocrysts. These phenocryst sizes vary from 0.5 to 1.5 mm, plagioclases are presented as prismatic crystals, olivine and hornblende are generally occurred as euhedral or subhedral crystals. In some specimens, olivine is partly altered to serpentine mineral through the serpentinization (Fig. 4.27), and often found with chromian spinels. Groundmass is composed mostly of microcrystalline plagioclase and pigionite.

4.3 Modal composition of sandstones

Selected 35 sandstone samples of the Southern Kitakami area were counted using point-counter. Quartz, feldspar, and lithic fragment are the major minerals in almost all specimens. For counting, Quartz is the total quartzose grain (Q), including polycrystalline lithic fragments such as chert and quartzite; feldspar (F) is the monocrystalline feldspar grain; and lithic fragment (L) is the unstable polycrystalline lithic fragment of either igneous or sedimentary parentage, including metamorphic varieties. 300-time counting of each sample is regarding to attain the reliable results. Modal compositions of sandstones in the study area are displayed on Table 4.1.

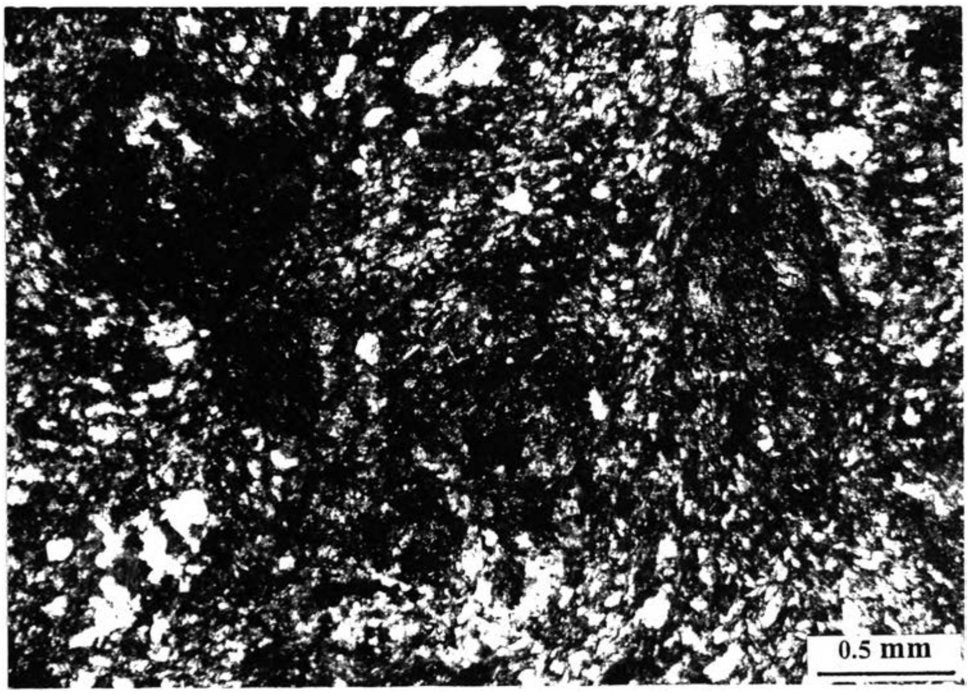

Figure 4.26 Porphyritic basalt from sample no. 97112201-2 of Carboniferous Hikoroichi Formation. Altered subhedral olivine (up right) is phenocrysts surrounding by the flow of microcrystalline feldspar.

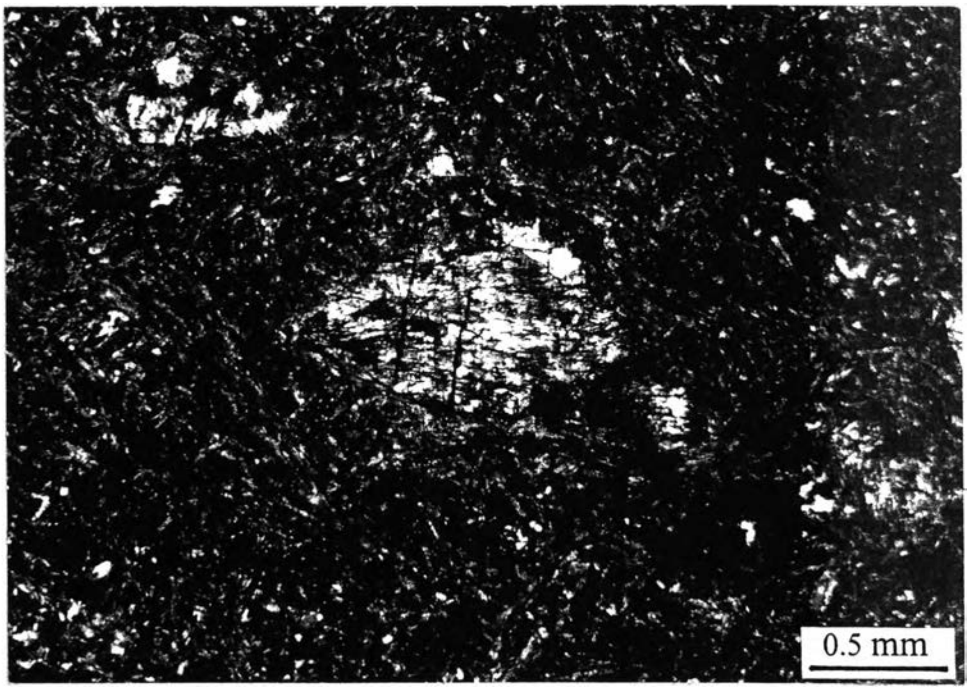

Figure 4.27 Porphyritic basalt from sample no. 97112104 of Carboniferous Karosawa Formation. Serpentinized-olivine phenocrysts always found in association with chromian spinels and are surrounding by the flow of microcrystalline feldspar and pigionte.

Table 4.1 Modal composition of sandstones of the Southern Kitakami area.

Sample No.	Age	QFL (%)			Type of Sandstone
		Q	F	L	
97031603	Devonian	0	42	58	Feldspathic litharenite
93120205	Carboniferous	0	24	76	Volcanic arenite
93120206	Carboniferous	0	25	75	Volcanic arenite
93120209	Carboniferous	9	39	52	Feldspathic litharenite
97031605-5	Carboniferous	0	13	87	Volcanic arenite
97031606	Carboniferous	0	77	23	Plagioclase arenite
97112101-4	Carboniferous	0	19	81	Volcanic arenite
97112103	Carboniferous	4	3	93	Volcanic arenite
97112105-2	Carboniferous	0	16	84	Volcanic arenite
97112105-3	Carboniferous	0	40	60	Feldspathic litharenite
97112106	Carboniferous	0	18	82	Volcanic arenite
97112203	Carboniferous	0	36	64	Feldspathic litharenite
97112204	Carboniferous	0	59	41	Lithic arkose
97112205	Carboniferous	0	33	67	Feldspathic litharenite
97112206	Carboniferous	0	29	71	Feldspathic litharenite
97112211	Carboniferous	1	15	84	Volcanic arenite
97112212	Carboniferous	3	12	85	Volcanic arenite
97112219	Carboniferous	9	13	78	Volcanic arenite

Table 4.1 Continued.

Sample No.	Age	QFL (%)			Type of Sandstone
		Q	F	L	
97112301	Carboniferous	3	35	62	Feldspathic litharenite
97112302	Carboniferous	4	25	71	Feldspathic litharenite
97112304	Carboniferous	9	54	37	Lithic arkose
97112305	Carboniferous	0	76	24	Plagioclase arenite
97112315	Carboniferous	0	47	53	Feldspathic litharenite
97112317	Carboniferous	4	45	51	Feldspathic litharenite
97112318	Carboniferous	4	60	36	Lithic arkose
97031701	Permian	0	98	2	Plagioclase arenite
97031702	Permian	0	93	7	Plagioclase arenite
97031703	Triassic	8	89	3	Plagioclase arenite
97031708	Triassic	9	81	10	Plagioclase arenite
97031704	Jurassic	6	91	3	Plagioclase arenite
97031705	Jurassic	0	85	15	Plagioclase arenite
97031706	Jurassic	0	91	9	Plagioclase arenite
97031709	Jurassic	4	96	0	Plagioclase arenite
97031710	Jurassic	0	95	5	Plagioclase arenite
97031601	Cretaceous	0	81	19	Plagioclase arenite

The compositional results of Southern Kitakami sandstone samples were then plotted in QFL diagram as shown in figure 4.28.

From the QFL plot, all sandstone samples from the Southern Kitakami area contains low amount or mostly lack of quartz, less than 10 %. In Carboniferous sandstones, percents of lithic fragments vary considerably from 23 to 93 % and feldspar from 3 up to 77%. A composition of Devonian sandstone was plotted within the similar range of Carboniferous sandstones. Permian to Cretaceous sandstones contain dominantly feldspar which vary from 81 to 98 %, percents of lithic fragments of these rocks are low (0-19 %).

Comparing this plot with the sandstone classification diagram of Folk (1974) in figure 4.11, Carboniferous and also Devonian sandstones of the Southern Kitakami area are composed of lithic arkose, feldspathic litharenite, and litharenite whereas Permian to Cretaceous sandstones comprise only arkose. These conform with the detailed petrographic description of the rocks mentioned earlier. Triassic sandstones seem to contain averagely the higher amount of quartz.

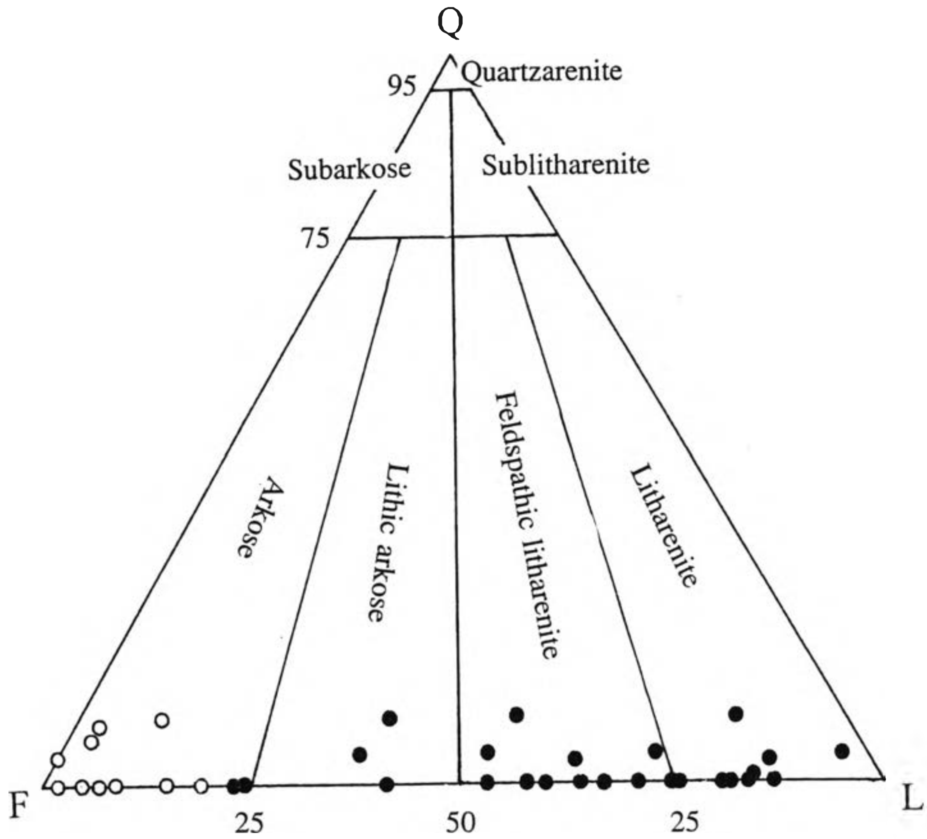

Figure 4.28 QFL diagram showing modal composition of sandstones in the Southern Kitakami area. Note: open circles are sandstones from Permian to Cretaceous, closed circles are Devonian and Carboniferous sandstones.