BASAL SANDSTONE OF THE SILURIAN KAWAUCHI FORMATION IN THE KITAKAMI MASSIF, NORTHEAST JAPAN

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Introduction and Acknowledgements

The Silurian System, the oldest fossiliferous sediments known in the Japanese Islands, is due to the first discovery of Silurian fossils by ONUKI (1937) from the Kitakami Massif. Since then our knowledge on the stratigraphy and paleontology of the Silurian formations distributed sporadically in the Japanese Islands has progressed rapidly. While, many of the granitic and metamorphic rocks distributed in different localities have been emphasized to be pre-Silurian or pre-Cambrian in age by many authors on the basis of their petrographical characters and results of age dating. However, the stratigraphical relation between the Silurian sediments and pre-Silurian basement rocks is not known except for the contact by fault at some localities. Furthermore, the sediments which suggest derivation from the basement rocks have not been recorded from the Silurian formations.

Recently, MURATA *et al.* (1974) pointed out that the Hikami Granites in the Kitakami Massif are covered with distinct unconformity by the Silurian Kawauchi Formation. In the present article the writers described the results of petrographical and sedimentological observations on the basal sandstone of the Kawauchi Formation.

Before going further, the writers offer

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Hikami Granites

The Hikami Granites is a complex of granitic and metamorphic rocks, distributed around Mt. Hikami, north of Rikuzen-Takada City, Iwate Prefecture. It is unique among the granitic rocks of the Kitakami Massif, Northeast Japan, for the rich content of alkali-feldspars, distinct protoclastic texture, and having been intruded and metamorphosed by the Cretaceous (110—120 m.y.) granites.

The Hikami Granites was divided by ISHII *et al.* (1960) into two types of granite, *i.e.*, the Hinokami-yama Type and the Ono Type, and the Tsubonosawa Metamorphics. The Hinokami-yama Type Granite occupies the central and southern parts of the Hikami Granites and shows remarkable gneissosity, which indicates the character of late-kinematic intrusion under a stress condition. It consists chiefly of gneissic biotite-quartz diorite—grano diorite and biotite-adamellite—grano-diorite. The Ono Type Granite, distributed in the northern and eastern parts of the Hikami Granites, is distinguished from the former by having comparatively abundant

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potash-feldspars and lacking schistose structure. It consists of biotite-granodiorite and biotite-horn blende-granodiorite, that originated from a hydrous and low-temperature magma and intruded into the shallow zone during the post-kinematic stage. The Tsubonosawa Metamorphics occurs in the western part of the Hinokami-yama Type Granite mass, forming large irregular xenolithic lenses, and consist of mica schists and banded gneiss.

ISHII *et al.* (1960) considered that the Hinokami-yama Type granite was intruded by the post-Permian and pre-Cretaceous Ono Type Granite. Many authors accepted their view and the Hikami Granites had been assigned to the Late Permian or Triassic in age. While, the K-Ar ages of biotite, hornblende and orthoclase of the Hikami Granites were measured by KAWANO and UEDA (1964), SHIBATA (1973) and MURATA *et al.* (1974) with the results of the ages ranging from 114 m.y. to 355 m.y.. These data must be evaluated as the values influenced by the Cretaceous granite. Recently, MURATA *et al.* (1974) from stratigraphical and petrographical studies, concluded that the Hikami Granites may be a basement complex of the Silurian System in the Kitakami Massif.

Silurian Kawauchi Formation

The Kawauchi Formation was proposed by ONUKI (1937) based upon the sediments cropping out along the lower course of the Higuchizawa Valley and exposed in the vicinity of Kawauchi, Hikoroichi-machi, Ofunato City, Iwate Prefecture. The formation is also distributed along the northern margin of the Hikami Granites. The Kawauchi Formation was studied stratigraphically and paleontologically by SUGIYAMA (1940), who stated that it is composed of a thick alternation of gray to black limestone and dark green phyllitic slate that can be subdivided into five fossil horizons of the *Favosites*-limestone, *Clathrodiction*-limestone, *Halysites*-limestone, *Encrinurus*-bed and *Solenopora*-limestone in ascending order. SUGIYAMA (1940) correlated the Kawauchi Formation to the Middle Silurian

in age. However, HAMADA (1958, 1961) based upon his paleontological studies referred the *Halysites*-limestone and the *Encrinurus*-bed of SUGIYAMA (1940) to the Early and the Late Ludlovian respectively.

The stratigraphical succession of the Kawauchi Formation of SUGIYAMA (1940) reserved some problems, owing to the lateral change in lithofacies and to the misinterpretation of the geological structure. Besides, the lower limit of the Kawauchi Formation had not been known for a long time, because it was believed by many authors that the formation was intruded by the Hikami Granites. However, MURATA *et al.* (1974) pointed out that the Ono Type Granite of the Hikami Granites was covered with unconformity by the basal sandstone of the Kawauchi Formation. The result of a detailed stratigraphical study on the Kawauchi Formation is as follows in descending order:

4) Thin alternation of dark gray limestone and black slate, or black slate intercalated with thin lenses of dark gray limestone, less than 10 meters in thickness. This bed corresponds to the *Encrinurus*-bed of SUGIYAMA (1940).

3) Thick bedded dark gray to white micritic limestone with many corals, stromatoporoids and calcareous algae, 15—65 meters thick.

2) Black to dark gray slate with small lenses of limestone in the upper part, less than 11 meters in thickness.

1) Conglomeratic coarse arkose sandstone, about 5 meters thick; this is described in the present article.

Basal Sandstone of the Kawauchi Formation

The basal sandstone of the Kawauchi Formation outcrops conspicuously in the Hikoroichi Area, Ofunato City, Iwate Prefecture, at Higuchizawa, Kusayamizawa, Gyoninzawa and Ono (Text-figs. 1, 2). The sandstone covers the Ono Type Granite of the Hikami Granites with unconformity, and is succeeded upwards gradually by the black slate composing the lower part of the Kawauchi Formation. The thickness of the sand-

Fig. 1. Distribution of the Kawauchi Formation and Sample Localities of the Sandstone.

stone is about five meters at all of the localities mentioned above so far as observed.

The sandstone appears massive in the outcrops, white to gray in color, and consists of very coarse quartz and feldspars grains. At a casual glance, this rock has been mistaken from the exterior for mylonite or dyke of aplite or quartz-porphry exposed at granite margin. However, the rock can be proved to be sandstone from the following evidences:

The rock consists of detrital sand size grains of quartz, feldspars and rock fragments of granite and with rounded pebbles of granite-porphry, granodiorite and of quartz measuring 5 to 0.4 centimeters in diameter (Plate I, figs. 2—5). These grains are in close

contact with one another and are cemented by a little amount of clay minerals and secondary quartz. The clayey materials increase rapidly towards and at the top of the bed (Plate I, fig. 6), where the rock changes gradually upwards to the overlying black slate. The mineral grains of the rock are mainly of quartz and feldspars, and their ratio shows a high value of 4.2 in the basal part exposed at Kusayamizawa. This value differs distinctly from that of the Hikami Granites which is 0.6 according to SUZUKI (1952). The ellipsoidal grains are arranged with no regularity but at random and sporadically. The grain size distribution of the rock shows rather distinct graded bedding at

Fig. 2. Columnar Sections of the Kawauchi Formation.

Kusayamizawa and Higuchizawa, as mentioned later.

The localities and stratigraphical horizons of the specimens from the basal sandstone of the Kawauchi Formation are shown in Text-figs. 2 and 3 as follows:

G-7—G-9: Gyoninzawa, Hikoroichi-machi, Ofunato City.

H-2—H-5: Higuchizawa, Hikoroichi-machi, Ofunato City.

K-1—K-5: Kusayamizawa, Hikoroichi-machi, Ofunato City.

O-1: Ono, Ikawa-cho, Ofunato City.

The sedimentary petrographical descriptions of the basal sandstone of the Kawauchi Formation are as follows:—

a) Grain Size Distribution

The grain size distribution of the sandstone was analysed by the measurement of more than 300 grains in thin sections. The parameters of size distribution, as median, mean size, sorting, skewness and kurtosis, were calculated by INMAN's (1952) formula. The matrix is defined to be under 5ϕ , as defined by OKADA (1968).

The grain size distribution shows a poly-

modal distribution, because the sandstone is composed of very coarse grains and pebbles as shown in Table 1 and Text-fig 3.

Mean size:—The mean size grain of the sandstone was analysed to be very coarse grained, ranging from -1.0 to 0.3ϕ . The sandstone sequence seems to be a massive bed in the outcrops, however, their mean grain size shows rather distinct graded bedding. At Kusayamizawa, two cycles of grading were recognized in the basal sandstone of the Kawauchi Formation, viz., from K-1 to K-2 and K-3 to K-5 (Text-figs. 3, 7). In the same way, a single specimen (H-2), collected from Higuchizawa, shows a grading sequence between H-2c and H-2f (Table 1) of about 5 centimeters in thickness.

Sorting:—The majority of the collected and studied specimens of the sandstone are poorly sorted, ranging from 0.8 to 1.5 in values. However, the specimens collected at Kusayamizawa indicate sorting progressing toward the higher horizons. From the sorting values, the sandstone in the lower part of the sandstone bed seems to represent sediments that would be expected from abrasion.

Sample No.	Md ϕ	Mean Size ϕ	Sorting	Skewness	Kurtosis
K . 1	-0.84	-0.72	1.04	0.12	—
K . 2	-0.58	-0.32	1.05	0.21	0.86
K . 3	-0.50	-0.42	1.11	0.08	—
K . 4	-0.59	-0.09	1.06	0.47	0.86
K . 5	0.03	0.37	0.98	0.35	1.16
H . 2c	-0.85	-0.59	0.79	0.32	1.48
H . 2f	0.02	0.21	1.00	0.19	1.05
H . 3	-0.52	-0.08	0.85	0.52	0.82
H . 4	-0.70	-0.46	1.22	0.19	1.39
H . 5	-0.55	-0.27	1.26	0.22	0.86
G . 7	0.34	0.48	0.86	0.16	1.45
G . 8	-1.06	-0.89	1.46	0.12	—
O . 1	-0.55	0.28	1.66	0.51	—

Table 1. Grain Size Distribution of the Basal Sandstone of the Kawauchi Formation.

Fig. 3. Grain Size Distribution of the Sandstone of the Kawauchi Formation, exposed at Kusayamizawa, Ofunato City, showing Polymodal Distribution and Graded Sequences.

Skewness:—All of the specimens at hand give positive values, ranging from 0.1 to 0.5, thus pointing to the tailend of grain size distribution in the fine grained part and of fine skewed degree. These features are quite characteristic of abundant very coarse grains and pebbles.

Kurtosis:—The value of kurtosis ranges from 0.8 to 1.5, and shows a platy kurtic distribution. The low value of kurtosis may be due to the polymodal distribution of the grain size as would be expected from abrasion.

The relationship between sorting and skewness shows clearly that the sandstone of the Kawauchi Formation was deposited under non-marine environment (FRIEDMAN, 1962) (Text-fig. 4).

b) Grain Shape Distribution

The grain shape of about 100 quartz grains of 0—1.5 ϕ was classified based on the scale of POWERS (1953).

The grain shape of the sand in the basal sandstone of the Kawauchi Formation is angular in general, and only a few of the grains show slightly rounded shape. The subangular grains are most abundant, amounting to about 55 percent of the total measured, and the angular ones are next in abundance. The sandstone exposed at Kusayamizawa shows that the angular grains increase in quantity towards the upper sequences (Text-fig. 5).

c) Mineral Composition

The sand size grains of the basal sandstone of the Kawauchi Formation are composed of quartz, feldspars, mica, heavy minerals and rock fragments mostly of granite. This composition resembles that of granite.

Quartz:—The detrital quartz grains consist mainly of monocrystalline non-undulatory extinct quartz, and a small amount of monocrystalline slightly undulatory extinct quartz, polycrystalline (polygonized) non-undulatory extinct quartz and cataclastic monocrystalline weakly undulatory extinct quartz. Strongly undulatory extinct and stretched quartz, that can be considered to be of metamorphic rock

Fig. 4. Sorting and Skewness of the Sandstone of the Kawauchi Formation, and the Depositional Environments of Beach Sand and River Sand according to FRIEDMAN (1962).

Fig. 5. Sequences of the Grain Shape Distribution of the Sandstone exposed at Kusayamazawa.

SR : subrounded, SA : subangular, A : angular, VA : very angular

origin, could not be found.

A small amount of cataclastic quartz grains could be found sporadically with random orientation in some of the specimens collected from the upper part of the sandstone bed at Kusayamazawa and Higuchizawa. This kind of quartz grains may have been supplied from the sheared granite, because no cataclastic texture was observed in the sandstone at the mentioned localities. However, a sandstone specimen (G-7), collected from along a fault at Gyoninzawa, shows a distinct cataclastic texture due to the numerous sheared fractures (Plate I, fig. 7). The polycrystalline quartz may have originated from fissure filling quartz veins.

Feldspars:—Feldspars grains consist mainly of orthoclase (Perthitic K-feldspar, $2V_x = 64^\circ\text{--}69^\circ$) (Plate I, figs. 8, 9) and a small amount of albite (An 5) include “chess-board” albite (GILLULY, 1933) or “chequer” albite (BATTEY, 1955).

Mica:—Mica consists of biotite only, and the flakes are decolored and altered partly to chlorite. The flakes show shoe-string or folliar shape, and only a very small amount occurs.

Heavy Minerals:—A very small amount of heavy minerals are found in the sandstone of the Kawauchi Formation, they were identified as zircon, apatite and opaque minerals.

Clay Minerals:—The clay minerals were analysed by the X-ray powder diffraction method. The clay samples, which were crushed, decanted and dried for more than 24 hours in an oven of a temperature of 60°C were used for analysis.

The diffraction peaks of chlorite ($14.4 \text{ \AA}$ and $7.14 \text{ \AA}$) and sericite ($10.0 \text{ \AA}$) were both distinct.

d) Considerations and Discussion

As shown in Table 2, the basal sandstone of the Kawauchi Formation is composed mainly of quartz and feldspars attain about 70 to 80 percent of the whole composition, and about 15 percent of granite grains. The content ratio of quartz, feldspars and granite grains vary with horizon and locality, ranging from 70 to 28 percent in quartz, 45 to 18 per-

Sample No.	Quartz		Feldspars		Mica	Rock fragments	Unknown minerals	Heavy minerals	Over growth	Matrix
	I	II	Or	Pl						
K · 1	68.2	tr	16.3	tr	tr	13.0	—	tr	0.01	2.3
K · 2	30.3	tr	37.0	0.3	0.01	29.3	—	tr	0.02	3.0
K · 3	41.3	tr	41.5	1.5	tr	12.7	tr	tr	0.20	2.5
K · 4	38.2	tr	46.4	2.0	tr	10.8	tr	tr	0.10	2.5
K · 5	29.7	tr	31.3	10.2	tr	24.7	—	tr	0.01	4.0
H · 2c	37.8	3.4	35.8	tr	0.11	18.6	—	tr	tr	4.1
H · 2f	70.2	tr	14.8	tr	0.64	10.5	tr	0.2	tr	4.3
H · 3	46.3	tr	31.5	0.6	tr	19.1	tr	tr	tr	2.7
H · 4	51.8	0.1	34.5	0.2	0.13	8.1	—	tr	0.20	3.2
H · 5	55.9	0.2	35.4	0.2	0.12	4.1	—	tr	0.40	3.6
G · 7	67.6	0.4	25.3	1.3	0.10	1.6	tr	tr	0.70	3.0
G · 8	68.7	tr	16.6	0.1	0.40	15.2	—	tr	0.20	2.4
G · 9	33.8	tr	7.5	tr	tr	11.7	—	tr	tr	46.7
O · 1	43.1	1.2	17.7	0.1	tr	23.9	—	tr	2.40	11.1

Table 2. Mineral Composition of the Basal Sandstone of the Kawauchi Formation.

I : mono crystalline quartz, II : poly crystalline and cataclastic quartz,

Or : orthoclase, Pl : plagioclase

Fig. 6. Sorting and Content Ratio of the Sandstone of the Kawauchi Formation.

cent in feldspars and 29 to 1.5 percent in granite grains. The relationship between the grain size distribution and mineral com-

position is a negative correlation, as shown in Text-fig. 6, which is evidence of non-suffering from abrasion. The sandstone specimens which were collected in upward succession at Kusayamizawa show that the ratio of quartz attains 68 percent in the basal part of the formation, but decreases towards the upper horizon. While, the content ratio of granite fragments changes symmetrically with that of quartz. And, the stratigraphical change of the content ratio of quartz and granite fragments seem to have a close connection with the mean grain size of the grain size distribution which shows two cycles of grading, as presented in Text-fig. 7. It is considered that the products of deep weathering may have been supplied during the early depositional stage, thus the content ratio of the labile minerals shows very low values. And, the unweathered materials were supplied successively during the deposition of the higher horizons.

Based on the mineral composition, the basal sandstone of the Kawauchi Formation is plotted in the Q-F-M triangle diagram according to FOLK's (1965) classification. Most of the specimens at hand are classified into arkose sandstone; only one specimen (G·7) falls in the group of subarkose sandstone (Text-fig. 8). The compositional points of the sandstone are distributed along the

Fig. 7. Sequence of the Composition and Grain Size Distribution of the Sandstone exposed at Kusayamizawa.

Q-F line, because the sandstones have neither fragments of metamorphic rock nor abundant mica. However, the Q-F-M triangle diagram fails to show the true feature of the granite fragments bearing sandstone. Plotting the basal sandstone of the Kawauchi Formation on Q-F-R triangle diagram of FOLK *et al.* (1970) shows distinctly that the sandstone has not suffered deep weathering (Text-fig. 9).

Summary

From the textural characters, occurrence of the rounded pebbles of the granitic rocks and quartz, and the gradual change upwards to the black slate the clastic sediments at the basal part of the Kawauchi Formation are, with confidence, identified as sandstone. The mineral composition of the basal sandstone of the Kawauchi Formation characterize distinctly, arkose sandstone, that originated from granite, and the optical characters of the feldspars in the sandstone are of the Ono Type Granite of the Hikami Granites. The just mentioned granite is directly overlain by the basal sandstone of the Kawauchi Formation with unconformity, as already pointed

Fig. 8. Q-M-F Diagram (FOLK, 1965) of the Sandstone of the Kawauchi Formation. Open circle : collected at Kusayamizawa, Solid circle : other localities

out by MURATA *et al.* (1974). The relationship between the Ono Type Granite and the Silurian Kawauchi Formation may be a blinded unconformity originally.

The depositional condition of the basal sandstone of the Kawauchi Formation based

Fig. 9. Q-F-R Diagram (Folk *et al.*, 1970) of the Sandstone of the Kawauchi Formation.
Solid circle : collected at Kusayamizawa,
Open circle : other localities
I : quartz arenite V : lithic feldsarenite
II : subfeldsarenite VI : feldspathic lith-
arenite
III : sublitharenite
IV : feldsarenite VII : litharenite

upon the sorting and skewness may be considered to be non-marine (FRIEDMAN, 1962). The products of rather deep weathering were supplied during the early depositional stage, and the unweathered materials were supplied successively to the upper part of the sandstone. Thenafter, the basal sandstone of the Kawauchi Formation suffered marine transgression.

References

- BATTEY, M. H. (1956), Alkali metasomatism and the petrology of some Keratophyre. *Geol. Mag.*, vol. 93, p. 104—126.
- FOLK, R. L. (1965), Petrology of Sedimentary rocks. *Hemphill's*, Austin, 159p.
- , Andreus, P. B. and Lewis, D. W. (1970), Detrital sedimentary rock classification and nomenclature for use in New Zealand. *N.Z. Jour. Geol. Geophys.*, vol. 13, no. 4, p. 937—968.
- FRIEDMAN, G. M. (1962), On sorting, sorting coefficients, and lognormality of grain size distribution of sandstone. *Jour. Geol.*, vol. 70, no. 6, p. 736—753.
- GILLULY, J. (1933), Replacement origin of the albite granite, near Sparta, Oregon. *U.S. Geol. Surv., Prof. Paper*, no. 174-c, p. 65—81.
- HAMADA, T. (1958), Japanese Halysitidae. *Univ. Tokyo, Fac. Sci., Jour.*, Ser. 2, vol. 6, p. 91—114, pls. 6—10.
- (1961), The Middle Palaeozoic Group of Japan and its bearing on her geological history. *Ibid.*, vol. 8, p. 1—79.
- INMAN, D. L. (1952), Measures for describing the size distribution of sediments. *Sed. Petr., Jour.*, vol. 22, no. 3, p. 125—145.
- ISHII, K., SENDO, T., UEDA, Y. and YAMASHITA, Y. (1960), Granitic rocks of the Hinokamiyama district, northeastern Kitakami Massif. *Tohoku Univ., Sci. Rep., Ser. 3*, vol. 6, p. 439—485.
- KAWANO, Y. and UEDA, Y. (1964), K-Ar dating on the igneous rocks in Japan (I). *Japan. Assoc. Min. Petr. Econ. Geol., Jour.* vol. 51, no. 4, p. 127—148.
- MURATA, M., KANISAWA, S., UEDA, Y. and TAKEDA, N. (1974), Base of the Silurian System and Pre-Silurian Granites in the Kitakami Massif, Northeast Japan. *Geol. Soc. Japan, Jour.*, vol. 80, no. 10, p. 19—30.
- OKADA, H. (1968), Classification and nomenclature of sandstone. *Ibid.*, vol. 74, p. 371—384.
- ONUKE, Y. (1937), Discovery of the Gotlandian formation in the Kesen district, Iwate Prefecture, and stratigraphy of the Paleozoic formations. *Ibid.*, vol. 44, p. 600—604.
- POWERS, M. S. (1953), A new roundness scale for sedimentary particles. *Sed. Petr., Jour.*, vol. 23, no. 1, p. 117—119.
- SHIBATA, K. (1973), K-Ar ages of the Hikami granite and the Usuginu granitic clasts. *Geol. Soc. Japan, Jour.*, vol. 79, no. 10, p. 705—707.
- SUGIYAMA, T. (1940), Stratigraphical and palaeontological studies of the Gotlandian deposits of the Kitakami mountains. *Tohoku Imp. Univ., Sci. Rep., 2nd Ser.*, vol. 21, p. 81—146, pls. 13—33.
- SUZUKI, Y. (1952), On the structure of the granodioritic rocks in the Takata district of the Kitakami Mountailand. *Geol. Soc. Japan, Jour.*, vol. 58, no. 676, p. 1—16.

シルル系川内層の基底砂岩

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(要旨)

村田ら(1974)は、北上山地の氷上山花崗岩体中の大野型花崗岩が、シルル系川内層の基盤をなす先シルル系基盤岩であることを指摘した。その際、重要な根拠の1つとされた、川内層基底の“礫質アーコース砂岩”について、堆積岩岩石学的見地より考察した。

砂岩粒子は、石英・長石・花崗岩岩片からなり、0.4 5cm 大の花崗斑岩・花崗閃緑岩・石英の亜円〜角礫が散点的に含まれる。粒子は少量の粘土鉱物と2次石英により膠結され、粘土物質は砂岩層上部で急速に増加し、上位の黒色粘板岩に漸移する。鉱物組成より砂岩の多くは“アーコース”の領域に入る。石英・長石比は砂岩基

底部で著しく高く4.2に達する。この値は氷上山花崗岩の0.6との間に明らかな差異を示す。また、砂岩の初期堆積物がより風化の進んだ物質に由来することを示す。肉眼的には無層理に見える砂岩層も、粒度分布から明らかな級化成層が認められる。これらの特徴はこの岩石が堆積岩であることを明示する。砂岩中の長石類の光学性は、大野型花崗岩中の長石と一致する。分級度・歪度は、この砂岩が非海成で、源地性堆積物に近いことを示している。従って、大野型花崗岩とシルル系川内層の関係は、本来は“盲”不整合であろう。

Explanation of Plate I

- Fig. 1. Outcrop of the basal sandstone of the Silurian Kawauchi Formation at Kusayamizawa, Hikoroichi-machi, Ofunato City, Iwate Prefecture. The Ono Type Granite (gr) covered with unconformity (slightly displaced by a minor fault) by the conglomeratic arkose sandstone (ss) of the Kawauchi Formation.
- Figs. 2, 3, 5. Subrounded pebbles of quartz in the basal sandstone of the Kawauchi Formation. 2, 5: Polished specimen ($\times 0.8$) and thin section ($\times 2$) of a quartz pebble to show the details, cross nicols, collected at Kusayamizawa. 3: Another specimen ($\times 0.5$) collected at Ono, Ikawa-cho, Ofunato City, Iwate Prefecture.
- Fig. 4. Arkose sandstone with a granite-porphyry pebble(gp), cross nicols, $\times 18$, collected at Kusayamizawa.
- Fig. 6. Arkose sandstone with a large quantity of clayey matrix, cross nicols, $\times 5$, collected from the top of the basal sandstone of the Kawauchi Formation at Gyoninzawa, Hikoroichi-machi, Ofunato City, Iwate Prefecture.
- Fig. 7. Cataclastic texture of the arkose sandstone, cross nicols, $\times 5$, collected at Gyoninzawa.
- Figs. 8, 9. Arkose sandstone with perthitic K-feldspar (kf), cross nicols, $\times 55$, collected at Kusayamizawa.