

Sedimentology of the Cretaceous Mikasa Formation

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<https://doi.org/10.5109/1543625>

出版情報 : 九州大学理学部紀要 : Series D, Geology. 16 (1), pp.81-111, 1965-03-25. Faculty of Science, Kyushu University

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By

Hakuyu OKADA

Abstract

The Cretaceous Mikasa Formation is typically exposed in the Ikushumbets area, central Hokkaido, which is one of the type areas of the Cretaceous System in Japan. This paper contains the results of the petrological study of the sandstone of the Mikasa Formation.

Two types of sandstone, graywackes and subgraywackes, are developed in harmony with a number of geological facts. On each rock type textural and mineralogical features have been examined, and its depositional conditions are discussed. Further comments are extended to some characteristics of heavy minerals. Comparison of the Mikasa Formation with that of other related stratigraphic units are also described.

Detritus of the sediments came mainly from western uplands, where source rocks were chiefly composed of older sedimentaries and subordinately of acid to ultrabasic igneous rocks.

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I. Introduction

The Ikushumbets area in Hokkaido, which occupies the middle part of the western periphery of the Cretaceous outcrops in and along the backbone of Hokkaido (Fig. 1), is one of the type areas of the Cretaceous System in Japan. Since YABE's

* Manuscript received September 30, 1964.

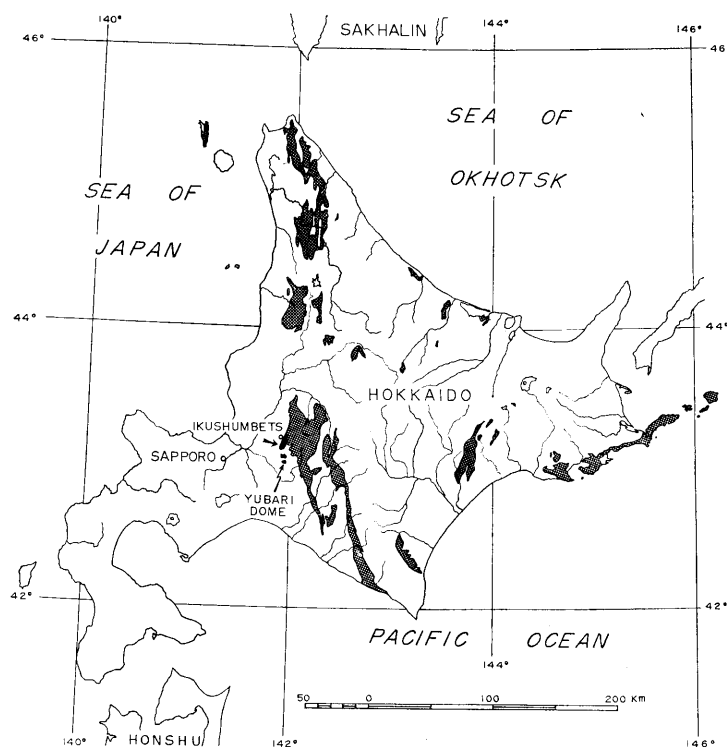


Fig. 1. Index map of Hokkaido showing distribution of the Cretaceous deposits.
The investigated area is indicated by a black spot with an arrow.

pioneer researches (YABE, 1903, 1909, 1926a and b, 1927), therefore, many geological and palaeontological studies have been undertaken and are being carried on. Especially, an up-to-date stratigraphic scheme has been established by MATSUMOTO (1959, etc.; see Fig. 5) for the classical section along the Ikushumbets Valley.

Of the marine Cretaceous in this area, I have undertaken a sedimentological study, especially petrological study of the Mikasa Formation (Cenomanian to Turonian) of the Middle Yezo Group (Albian to Turonian), succeeding to a pioneer approach to this study by FUJII (1958). The Mikasa Formation, which has been accustomed to be called the "*Trigonia* Sandstone" since YABE (1903) denominated so, is not only important for the subject of palaeontologic studies but also interesting for the sedimentological viewpoint. It is characterized for the most part by coarse clastics such as sandstones and conglomerates.

Unlike the flat-lying or gently inclined beds on the well-known shelf areas in Europe and North America, the Cretaceous strata of Hokkaido are intensely folded. Therefore there is some difficulty in the study of the lithological change. The Mikasa Formation displays an anticlinal structure of NNE-SSW trend (Fig. 2). Fortunately there are a number of streams cutting across the formation which generally exhibit good exposures. This gives us the situation as if a number of borings were drilled at certain intervals.

The purpose of this paper is to describe the petrologic characters of the Mikasa sandstone, to make clear the geological and sedimentological environments at the time of deposition and also to elucidate palaeogeographic conditions. In connection with this, comparison is attempted between the sandstone of the Mikasa Formation and that of the overlying and underlying stratigraphic units as well as the contemporary deposits in the Yubari dome (Fig. 1).

II. Acknowledgements

It is a great pleasure to record here a debt of gratitude to Professor Tatsuro MATSUMOTO of Kyushu University, who has suggested this study, freely given me necessary information of stratigraphy, provided me with various facilities for study and read the manuscript with invaluable criticism.

Further, I wish to acknowledge several companies and persons: My gratitude is due to the Japan Petroleum Exploration Co., Ltd., the Sumitomo Coal Mining Co., Ltd., the Hokkaido Colliery and Steamship Co., Ltd. and the Higashihoronai Coal Mining Co., Ltd. for their help in accommodation and transportation in my field works. I am also greatly indebted to Drs. Koji KINOSHITA and Yuzuru AGATSUMA of the Japan Petroleum Exploration Co., Ltd., Drs. Kametoshi KANMERA, Jyonosuke OHARA and Akira MOMOI and Mr. Sadanori MIYACHI of Kyushu University, Dr. Hisao SHIMOGAWARA of the Hokkaido Colliery and Steamship Co., Ltd. and Mr. Ichiro HAYASHI of the Sumitomo Coal Mining Co., Ltd., for their help in many ways. Furthermore, I wish to express my gratitude to Messrs. Tatsuo MURAMOTO and Kikuo MURAMOTO for their kind assistance in collecting some sandstone samples. Miss Misako KIDO has kindly assisted me in draughting and my wife has helped me in typing the manuscript.

This study was partly carried out in aid of a grant through Professor Tatsuro MATSUMOTO from the Ministry of Education.

III. Geologic Setting

A. *General remarks*

The Cretaceous System in the Ikushumbets area, the type section of which is along the Ikushumbets Valley, makes up an anticlinal structure of north-northeast trend that stretches over 40 km from Utashinai City to Miruto, Kurisawa-machi, Sorachi-gun, and constitutes a basement of the coal-bearing Palaeogene of the Ishikari coal field. The northern half of this structure is named the Sorachi anticline and the southern half the Ikushumbets anticline (Fig. 2). This study is focussed on the Mikasa Formation in the Ikushumbets anticlinal area.

The Cretaceous sequence in the Ikushumbets anticlinal area is subdivisible into the Middle Yezo Group and the Upper Yezo Group. The Middle Yezo Group, ranging from Albian to Turonian in age, occupies the axial part of the anticline in distribution. Although the basal part is unknown in this area, the Group consists generally of muddy facies in the lower part and sandy facies in the upper part. The latter is

denominated the Mikasa Formation (or the Mikasa Sandstone Formation) (MATSUMOTO, 1951), that was formerly called the *Trigonia* Sandstone (YABE, 1903, 1909, 1926a and b, 1927). This formation grades into the overlying Upper Yezo Group.

The Upper Yezo Group, which is distributed mainly on the eastern wing of the anticline, consists in general of mudstones frequently with fossiliferous nodules, being accompanied with a few glauconitic sandstone beds and layers of tuff. This Group ranges from Upper Turonian to Santonian in age.

As characteristic features of major geological structures, the western flank of the anticline is very steeply inclined: in many places vertical or even overturned, while the eastern one shows as moderate inclination as 30 to 40 degrees. The axial

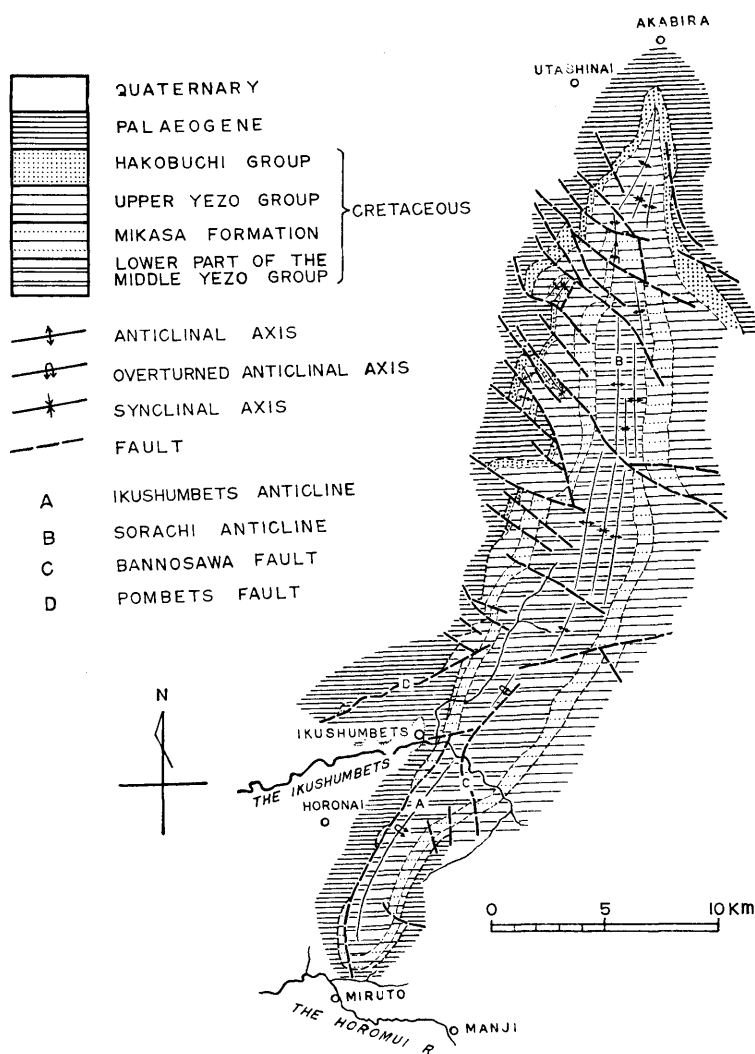


Fig. 2. Compiled geologic map of the outcrop areas of the Mikasa Formation in the Ishikari coal field.

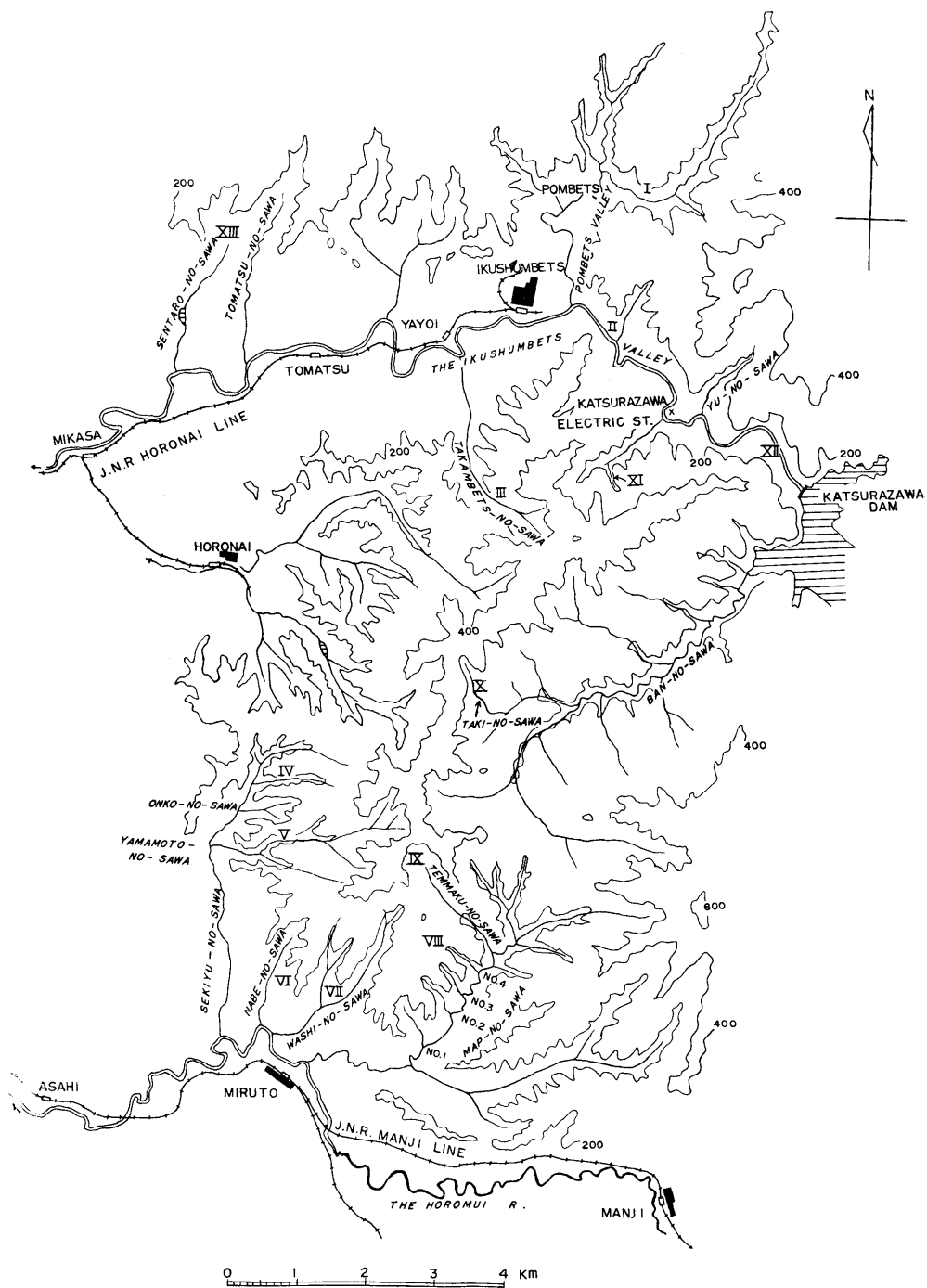


Fig. 3. Drainage system in the Ikushumbets area.

plane is overturned northwest by 40 degrees at one place (*e.g.* observed at loc. 206 in the Yamamoto-no-sawa [V]. see Figs. 3 and 4). Transverse faults of a northwest trend are prominent over the whole anticlinal area besides a thrust on a considerable

scale across the Ikushumbets Valley [Bannosawa thrust (OTATUME, 1940-'41) (c) in Fig. 2].

The outline of stratigraphy and palaeontology of certain groups of mollusca of the Cretaceous in this area have been published by Prof. Tatsuro MATSUMOTO sometimes with his coworkers.

B. Notes on the stratigraphy of the Mikasa Formation

(1) *Type area.* MATSUMOTO (1951) introduced the name of the Mikasa Formation for a unit of the sandy facies of the Gylia-kian (approximately Cenomanian to Turo-nian) sequence, which was called the *Trigonia* Sandstone by YABE (1903, 1926a and b, 1927). Its type is in the Ikushumbets Valley area near the Ishikari coal field (Figs. 3, 4 and 5). It is exposed in other areas of the Ishikari coalfield, such as Bibai, Miruto, Yubari, etc. The outcropping area represents the western part of the Cretaceous terrain in the meridional belt of Hokkaido (see MATSUMOTO, 1943, P. 176).

(2) *Subdivision.* According to MATSUMOTO (1954, 1959) and MATSUMOTO et al. (1960), the Mikasa Formation in the section along the Ikushumbets Valley on the eastern wing of the anticline is subdivided into the following four members; Basal [IIa], Lower [IIb], Middle [IIc] and Upper [IId] (Fig. 5).

(a) Basal Member [IIa], 40 m thick, is mainly composed of dark greenish grey and

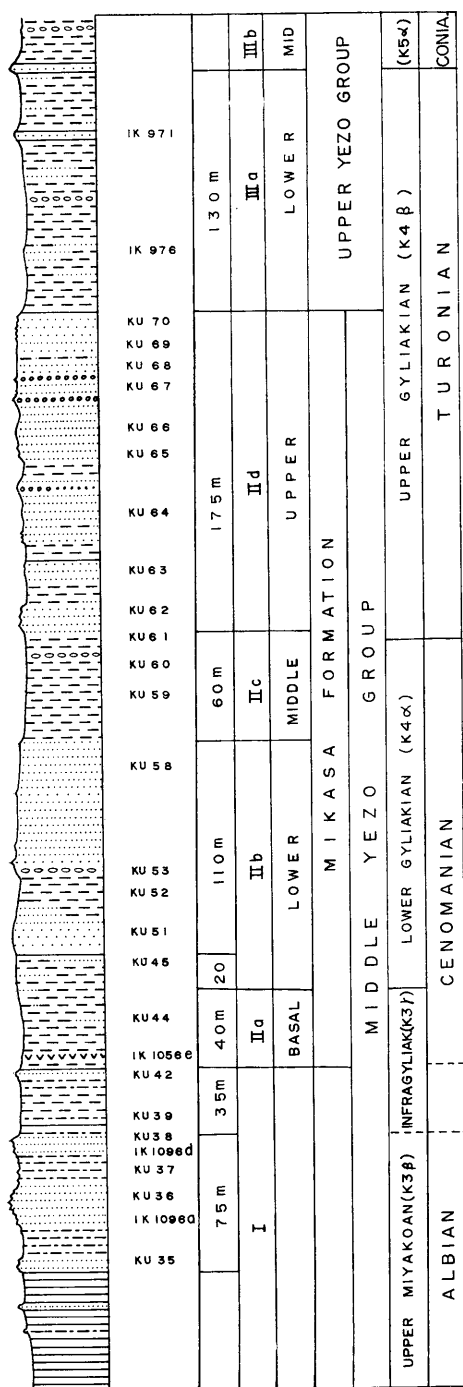


Fig. 5. Standard stratigraphic section along the Ikushumbets Valley (on the eastern wing) prepared by MATSUMOTO (1959), and positions of the rock samples.

Explanation of lithology in the columnar section is shown in Fig. 6.

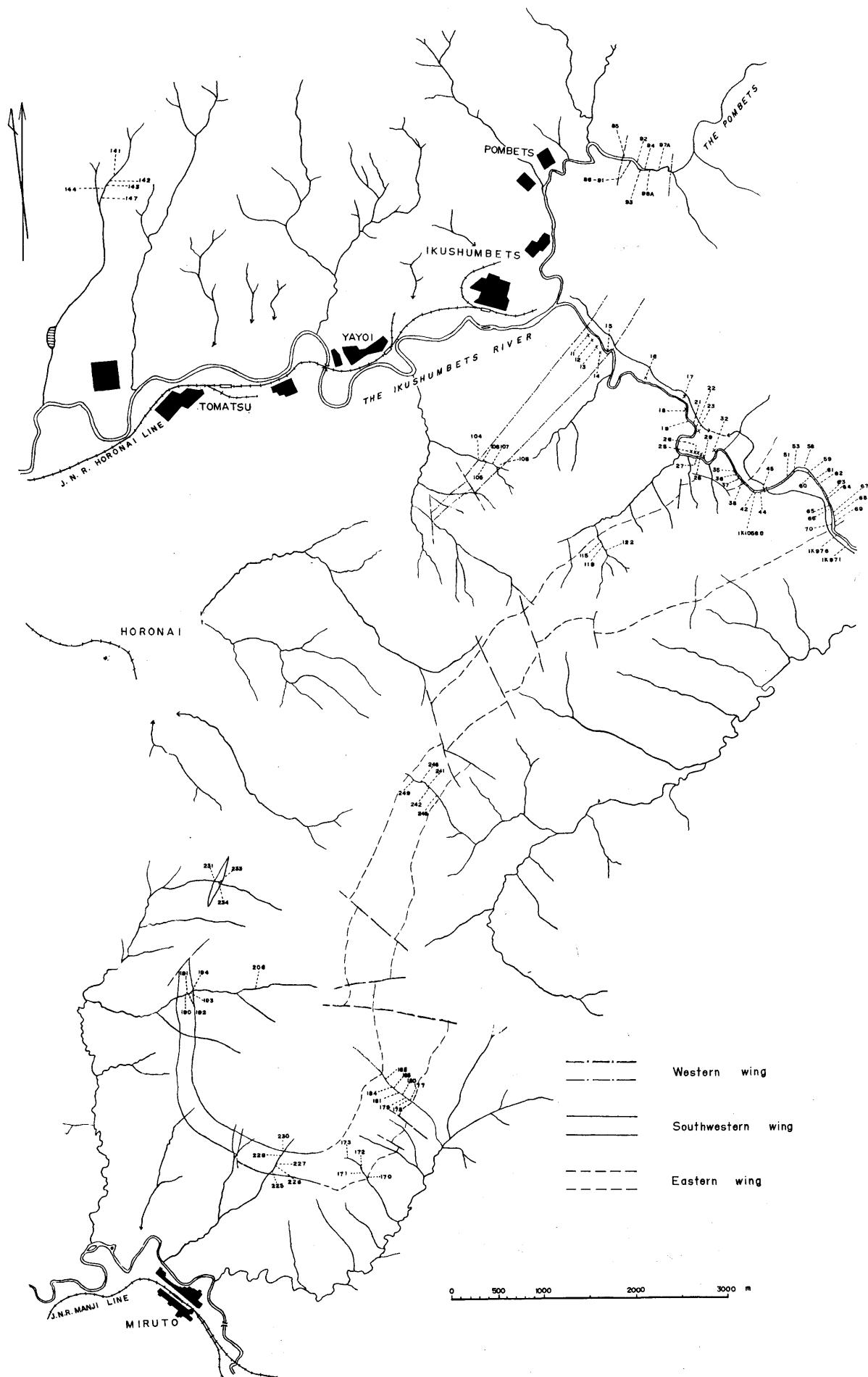


Fig. 4. Map showing distribution of the Mikasa Formation in the Ikushumbets anticlinal area and the localities where the examined specimens were collected.

massive sandy-siltstone intercalated rarely with thin beds of very fine-grained sandstone. The siltstone is rich in calcareous nodules of various sizes which commonly contain *Desmoceras kossmati*.

(b) Lower Member [IIb], about 130 m thick, consists of muddy fine-grained sandstones with numerous calcareous nodules. As leading fossils are abundant *Desmoceras* (*Pseudouhligella*) *japonicum*, *Mantelliceras* n. sp. (Lower part only), *Calycoceras orientale*, *C. asiaticum* (these two species upper part only) and *Inoceramus concentricus nipponicus*. In addition to them, pelecypods of *Acanthotrighonia pustulosa*, *Ac. longiloba*, *Pterotrighonia hokkaidoana*, *Pt. brevicula*, *Cucullaea ezoana*, *Anthonia japonica*, *Callista pseudoplana*, *Crenella gyliakiana*, etc. are commonly found especially in the lower part.

(c) Middle Member [IIc], 60 m thick, comprises massive siltstones which frequently contain large and small calcareous nodules. *Calycoceras naviculare*, *Desmoceras* (*Pseudouhligella*) *japonicum* and *Inoceramus concentricus nipponicus* occur at the lower and middle parts. In addition, *Kanabicerias septemseriatum*, *Sciponoceras kossmati* and *Inoceramus* cf. *labiatus* are found at the uppermost part.

(d) Upper Member [IId] is made up of coarse- to fine-grained graywackes. Calcareous nodules are commonly contained in some beds. Glauconitic sandstone beds are sometimes intercalated in addition to some thin beds of pebble conglomerate and layers of pebbles. As a sedimentary feature lobal ripple mark is occasionally observed on sandstone beds. *Inoceramus hobetsensis* and *Tragodesmocerooides subcostatus*, pelecypods of *Heterotrighonia subovalis*, *Steinmanella* (*Yeharella*) *ainuana*, *Glycymeris hokkaidoensis*, *Cucullaea ezoana*, *Callista pseudoplana*, etc. are commonly found although they occur in certain particular beds. Especially, glycymerids, cucullaeids and *Callista* are abundant in conglomeratic parts, together with shell fragments of inocerami.

(3) *Distribution*. The outcrop of the Mikasa Formation in the Ikushumbets anticline is schematically shown in Fig. 2. The outcrop belt of the Mikasa Formation in the studied area is for convenience divided into the three parts: western wing, south-western wing and eastern wing (Fig. 4).

(4) *Lithofacies*. Vertical and lateral variations of lithofacies of the Mikasa Formation in the studied area are concisely described in the following:

(a) Vertical variation: In the section along the Ikushumbets Valley (eastern wing) (Fig. 5, adopted from MATSUMOTO, 1959, pl. 7) the Upper Member IId is mainly composed of sandstone and conglomerate, whereas the whole of the rest Members IIa to IIc is predominated by siltstone. In term of the sandstone plus conglomerate/siltstone ratio which is replaced by the coarse clastics/silt ratio in other places of the paper, it is about 3 in the former member, while in the latter about 0.9.

(b) Lateral variation: A remarkable change of lithofacies is recognized laterally in the Mikasa Formation, as is concisely shown in the serial columnar sections in Figs. 5 and 6.

So far as the exposed strata are concerned, the coarse clastics/silt ratio in each of the examined sections (Figs. 3 and 5) is estimated as follows:

- Western wing—Pombets Valley [I] : 8
 Ikushumbets Valley [Western wing] [II] : 17
 Takambets-no-sawa [III] : 19
- Southwestern wing—[IV] : 62
 Yamamoto-no-sawa : 98
 Nabe-no-sawa [VI] : 55
 Washi-no-sawa [VII] : 120
- Eastern wing—No. 4 Map-no-sawa [VIII] : 6
 Temmaku-no-sawa [IX] : 3
 Taki-no-sawa [X] : 6
 Ikushumbets Valley [eastern wing] [XII] : 1.5

Another fact to be noted is that in the Mikasa Formation on the western wing thin coal seams are contained, bearing tiny lumps of amber, and especially redbeds are intercalated at a few horizons in the sequence along the Pombets Valley (Fig. 6).

In brief, there is a considerable difference in lithological constituents between the eastern and the western to southwestern wings of the Ikushumbets anticline. Namely, on the former wing the mudstone or siltstone occupies a considerable part, whereas on the latter the conglomerate and sandstone are much predominant, being sometimes accompanied by coal seams and redbeds.

(5) *Sedimentary features.* Noteworthy sedimentary features are as follows: For one thing, conglomeratic parts contain in general molluscan fossils of such shallow-sea elements as "*Trigonia*", *Glycymeris*, *Callista*, *Ostrea*, etc. Conglomerates are as a rule made up of well-abraded pebbles and cobbles which consist mainly of red and milky white cherts, fine- to medium-grained sandstones and hornfelsic shale, and subordinately of andesite, liparite, porphyrite, diabase, granitic rocks and aplite.

Calcareous nodules are abundant in siltstone facies, measuring some 10 cm to 1 m, and most of them bear fossils of ammonoids, inocerami and other molluscs, usually together with plant drifts. Sandstone also includes calcareous nodulous parts which look umber when weathered, but it is mostly barren of fossils.

Lobal ripple marks are not uncommonly observed on the bedding planes of sandstones.

Petrology

A. *Method of study*

(1) *Material.* Sampling of sandstone specimens was made to ensure adequate geographic and stratigraphic coverage as effectively as possible from outcrops according to the following scheme: to collect one specimen from one bed and at least two samples either in the case the sandstone bed is very thick or lithologic variation is distinct with one bed. Especially, sampling was confined to the parts free from calcareous nodules. In addition to sandstone specimens, sandy siltstones and pebbles of conglomerates were collected as supplementaries. Geographical and stratigraphical positions from which the examined specimens came are tabulated on Table 1 and

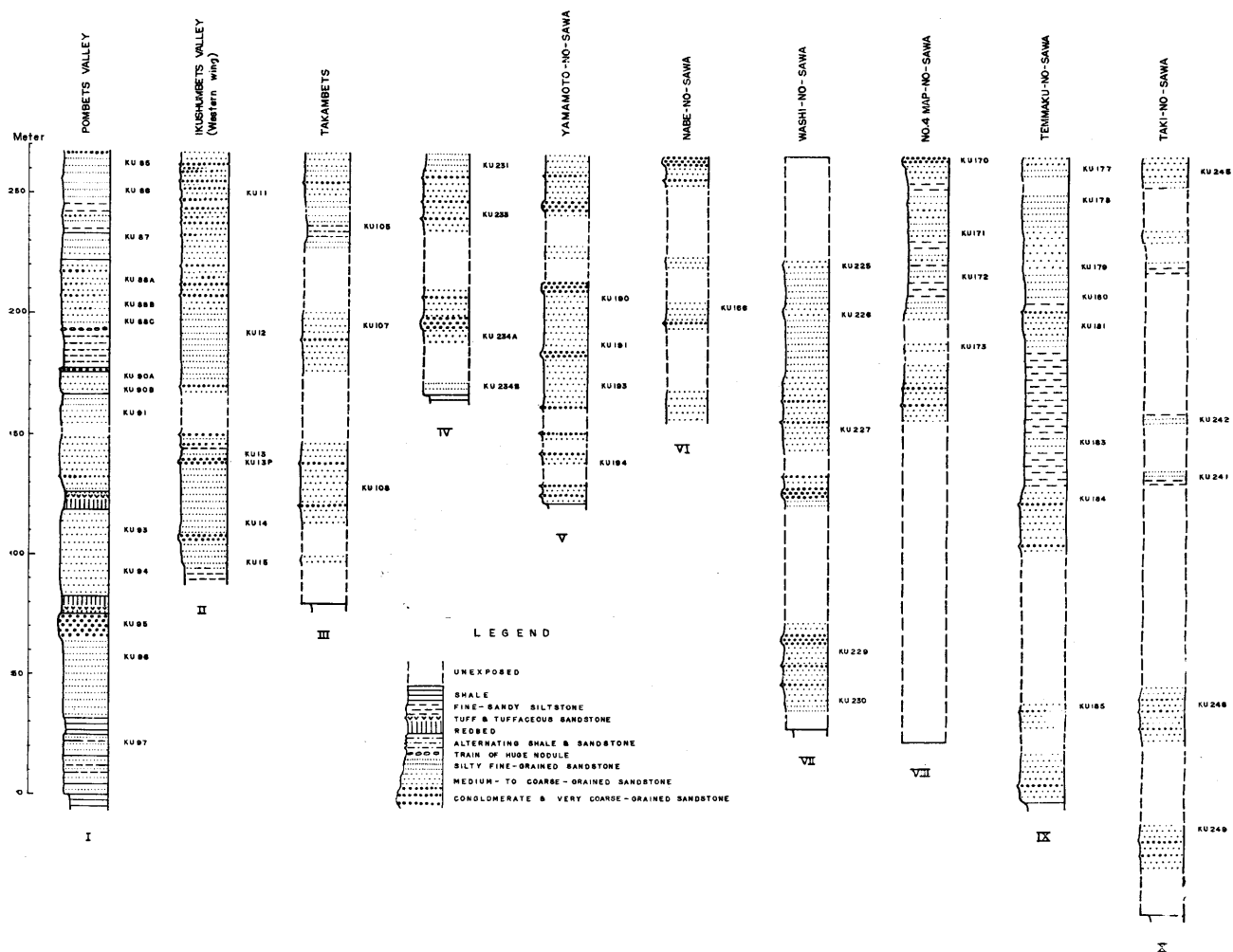


Fig. 6. Columnar sections of the Mikasa Formation along the selected routes in the Ikushumbetsu anticlinal area, showing positions of the rock samples. (The columnar section I along the Pombets Valley is drawn after MATSUMOTO's unpublished data by his courtesy).

Sections I to III: western wing, sections IV to VII: southwestern wing, sections VIII to X: eastern wing.

Explanation of lithology in the columnar section: 1: mudstone, 2: tuff and tuffaceous sandstone, 3: fine-sandy siltstone, 4: silty fine-grained sandstone, 5: medium- to coarse-grained sandstone, 6: conglomerate and very coarse-grained sandstone, 7: alternating shale and sandstone, and 8: shale.

Table 1. List of specimens used.

Specimen No.	Stratigraphic positions*	Locality	Remarks (colour; grain size; others)	Collectors
KU11	II	Ikushumbets Valley, Mikasa City [Western wing] (三笠市幾春別川) [II]	10 GY 5/2; c.	H. OKADA
KU12	II	Do.	5 GY 5/2; f.	—
KU13	II	Do.	5 GY 5/2; c.	—
KU13p	II	Do.	Rounded sandstone pebble	—
KU14	II	Do.	5 GY 5/2; c.	—
KU15	II	Do.	10 GY 3/2; v. f.	—
KU16	I	Do.	—	—
KU17	I (Yunosawa Sandstone)	Ikushumbets Valley [Eastern wing] [XII]	5 B 6/2; f.	—
KU18	I (Do.)	Do.	10 GY 5/2; m.	—
KU19	I (Do.)	Do.	5 BG 5/2; m.	—
KU21	I (Do.)	Do.	5 B 6/2; m.	—
KU22	I (Do.)	Do.	5 B 6/2; m.	—
KU23	I (Do.)	Do.	5 B 6/2; m.	—
KU25	I (Do.)	Do.	5 BG 6/2; m.	—
KU26	I (Do.)	Do.	5 BG 6/2; m.	—
KU27	I (Do.)	Do.	5 B 6/2; m.	—
KU28	I (Do.)	Do.	5 BG 5/2; m.	—
KU29	I (Do.)	Do.	5 B 6/2; m.	—
KU31	I (Do.)	Do.	—	—
KU32	I (Do.)	Do.	5 BG 5/2; c.	—
KU35	I	Do.	N 3; v. f.	T. MATSUMOTO & H. OKADA
IK1096a	I	Do.	5 BG 5/2; f.	T. MATSUMOTO
KU36	I	Do.	5 G 5/2; f.	T. MATSUMOTO & H. OKADA
KU37	I	Do.	10 GY 5/2; f.	—, —
IK1096d	I	Do.	10 GY 5/2; m.	T. MATSUMOTO
KU38	I	Do.	5 GY 5/2; m.	T. MATSUMOTO & H. OKADA
KU39	I	Do.	10 GY 5/2; f.	—, —
KU42	I	Do.	5 G 4/1; v. f.	—, —
IK1056e	IIa	Do.	5 BG 5/2; m. tuffaceous	T. MATSUMOTO
KU44	IIa	Do.	5 G 4/1; f.; bearing gastropods	T. MATSUMOTO & H. OKADA
KU45	IIb	Do.	N 3; v. f.; bearing drifts	—, —
KU51	IIb	Do.	5 G 4/1; f.	—, —
KU52	IIb	Do.	5 G 4/1; f.; bearing gastropods	—, —

* Regarding stratigraphic divisions, Fig. 5 should be referred to.

Continued Table 1.

KU53	IIb	Do.	5 G 4/1; v. f.; bearing drifts and pelecypods	—, —
KU58	IIb	Do.	5 G 4/1; f.	—, —
KU59	IIId	Do.	10 GY 6/2; m.; pyritiferous	—, —
KU60	IIId	Do.	5 G 4/1; v. f.	—, —
KU61	IIId	Do.	5 G 4/1; f.	—, —
KU62	IIId	Do.	5 G 4/1; m.	—, —
KU63	IIId	Do.	5 G 4/1; f.	—, —
KU64	IIId	Do.	5 G 4/1; v. f.	—, —
KU65	IIId	Do.	N 3; v. f.	—, —
KU66	IIId	Do.	5 G 4/1; m.	—, —
KU67	IIId	Do.	5 G 5/2; m.	—, —
KU68	IIId	Do.	10 GY 5/2; m.	—, —
KU69	IIId	Do.	10 GY 5/2; m.	—, —
KU70	IIId	Do.	5 B 5/1; m.	—, —
IK971	IIIa	Do.	m.; glauconitic	T. MATSUMOTO
IK976	IIIa	Do.	m.	—
IK1263	III	Kikumen-zawa, a tributary of the upper course of the Ikushum- bets (Valley) (菊面沢)	m.	—
IK1121	III	Ban-no-sawa, ditto (盤ノ沢)	m.	—
KU85	II	Pombets Valley, Mikasa City (奔別川) [I]	10 GY 5/2; f.	T. MATSUMOTO & H. OKADA
KU86	II	Do.	5 GY 5/2; f.	—, —
KU87	II	Do.	10 GY 5/2; f.	—, —
KU88A	II	Do.	5 G 5/2; v. f.; bearing drifts	—, —
KU88B	II	Do.	5 G 5/2; f.	—, —
KU88C	II	Do.	5 G 5/2; f.	—, —
KU90A	II	Do.	5 G 5/2; m.	—, —
KU90B	II	Do.	5 G 5/2; m.	—, —
KU91	II	Do.	5 G 5/2; m.	—, —
KU93	II	Do.	5 Y 5/6; m.; weathered	—, —
KU94	II	Do.	5 GY 5/2; m.	—, —
KU96	II	Do.	5 GY 5/2; v. f.	—, —
KU97	II	Do.	5 G 5/2; f.	—, —
KU105	II	Takambets, Mikasa City (多寒別) [III]	m.	—, —
KU107	II	Do.	m.	—, —
KU108	II	Do.	m.	—, —
KU119	II	A small branch of the Ikushumbets Valley, south of the Katsura- zawa Electric Station (桂沢発電所) [XI]	m.	—, —

Continued Table 1.

KU141	II	Sentaro-no-sawa, northwest of Tomatsu, Mikasa City (仙太郎ノ 沢, 唐松) [XIII]	5 G 6/1; f.	H. OKADA
KU142	II	Do.	5 G 6/1; f.	_____
KU143	II	Do.	5 G 6/1; f.	_____
KU144	II	Do.	5 G 6/1; f.	_____
KU147	II	Do.	5 G 6/1; f.	_____
KU166	II	Nabe-no-sawa, north of Miruto, Kurisawa- machi, Sorachi-gun (空知郡栗沢町美流渡, 鍋ノ沢) [VI]	5 BG 5/2; m.	_____
KU170	II	No. 4 Map-no-sawa, east of Miruto (マップノ沢) [VIII]	10 GY 5/2; v. f.; bearing pelecypods	_____
KU171	II	Do.	10 GY 5/2; f.	_____
KU172	II	Do.	5 Y 5/6; m.; weathered	_____
KU173	II	Do.	10 GY 5/2; f.; bearing pelecypods	_____
KU177	II	Temmaku-no-sawa, northeast of Miruto (テンマクノ沢) [IX]	5 BG 5/2; m.	_____
KU178	II	Do.	10 GY 5/2; f.	_____
KU179	II	Do.	5 G 5/2; v. f.; bearing drifts	_____
KU180	II	Do.	10 GY 5/2; v. f.	_____
KU181	II	Do.	10 GY 5/2; v. f.	_____
KU183	II	Do.	_____	_____
KU184	II	Do.	10 GY 5/2; f.	_____
KU185	II	Do.	5 B 5/1; m.	_____
KU189	II	Yamamoto-no-sawa, about 3.4 km north of Miruto (山本ノ沢) [V]	10 G 6/2; m.	_____
KU190	II	Do.	10 G 6/2; f.	_____
KU191	II	Do.	10 G 6/2; f.	_____
KU192	II	Do.	5 B 6/2; m.	_____
KU193	II	Do.	_____	_____
KU194	II	Do.	10 G 6/2; m.	_____
KU225	II	Washi-no-sawa, Miruto (鷺ノ沢) [VII]	5 G 5/2; f.; bearing pelecypods	_____
KU226	II	Do.	5 GY 7/2; m.	_____
KU227	II	Do.	5 G 5/2; m.	_____
KU228	II	Do.	10 G 6/2; m.	_____
KU229	II	Do.	10 G 6/2; f.	_____
KU230	II	Do.	5 GY 7/2; m.	_____
KU231	II	A valley, north of Onko- no-sawa, ca. 4.7 km north of Miruto (オン コノ沢) [IV]	5 GY 7/2; m.	_____
KU233	II	Do.	5 GY 7/2; m.	_____

Continued Table 1.

KU234A	II	Do.	5 G 7/2; v. f.	_____
KU234B	II	Do.	5 G 7/2; m.	_____
KU241	II	Taki-no-sawa, ca. 5.8km south of Ikushumbets, Mikasa City (滝ノ沢) [X]		_____
KU242	II	Do.	10 GY 5/2; f.	_____
KU245	II	Do.	10 G 6/2; m.	_____
KU248	II	Do.		_____
KU249	II	Do.	10 G 6/2; m.	_____

- Notes: 1) Specimen number has a prefix KU except for the specimen with a prefix IK which is Professor Tatsuro MATSUMOTO's locality number.
 2) Stratigraphic position of the examined specimen is shown by the Roman numerals after the scheme proposed by MATSUMOTO (1959) (see Fig. 5).
 3) Locations of valley and *sawa* (or *zawa*) [Jap.: small valley] should be referred to Fig. 3.
 4) Rock colour is after GODDARD [Chairman] (1951).

illustrated in Figs. 4, 5 and 6.

The material used in this study is all preserved in the Department of Geology, Kyushu University, Fukuoka.

(2) *Procedure.* Standard methods of petrologic analyses (see OKADA, 1960b) are applied for each sample.

B. Sandstone types

The examined sandstones are represented by the graywacke and the subgraywacke clans on the basis of PETTIJOHN's scheme of classification (PETTIJOHN, 1957, Table 48) (see Fig. 10 and Table 2 and 3).

The graywacke sandstones with clay matrix of more than 15 percent are developed on the eastern wing of the Ikushumbets anticlinal area. The subgraywacke is characteristic of the western to southwestern wing.

This type may be also regarded as washed graywacke, a product of current agitation at or near the site of sedimentation.

The significance of these two types of sandstones is discussed in Chapter V in more detail.

C. Texture and maturity

(1) *Grain-size distribution.* The graywacke sandstones are characterized by bimodal to polymodal distribution of grain size, as is shown by a specimen KU91 in Fig. 7. In a striking contrast to the above, the subgraywacke sandstones show a unimodal distribution, as is shown by specimens KU 185 and KU 233 in Fig. 7. Sorting values of the measured subgraywackes are 1.10 to 1.22 and are thus comparable to beach sands. This fact suggests that they were to a great extent subject to wave agitation. Some well sorted examples are exhibited in Fig. 8.

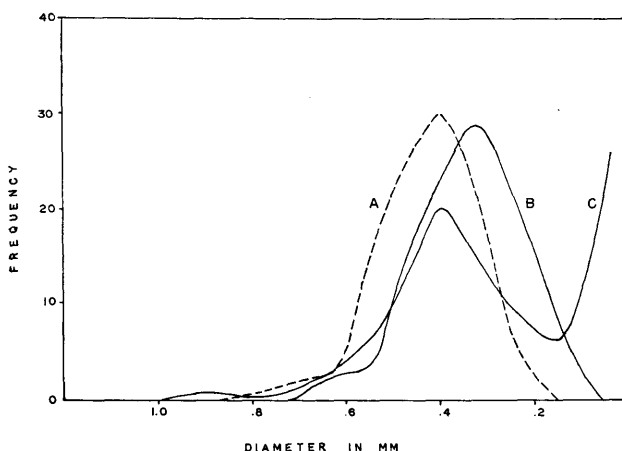


Fig. 7. Representative examples of grain-size distribution of sandstones.
A: Sp. No. KU 185, B: Sp. No. KU 233, C: Sp. No. KU 91.

(2) *Roundness*. The average roundness of sand-grains of each specimen is subdivided into the five classes, according to PETTIJOHN's scale (1957, pp. 58-59): A-angular, B-sub-angular, C-subrounded, D-rounded, E-well rounded. It is interesting that sandstones on the eastern wing show the average roundness of B, whereas those on the western and the southwestern wings show that of C to D (see Tables 2 and 3).

(3) *Maturity*. The maturity of sediments is expressed in terms of mineralogical and textural characters, and these two characters are as a rule interrelated, although a peculiar case is exceptionally known that even texturally mature sediments are mineralogically immature.*

The textural maturity of sediments is defined by the three factors, *i.e.* clay content, sorting and roundness (FOLK, 1951), each of which is concisely described in the preceding pages.

The mineralogical maturity is in general measured by the ratio of quartz/feldspar or quartz plus chert/feldspar plus rock fragments (PETTIJOHN, 1957, pp. 509-510). Even from a rough estimation the coarse clastics in the investigated area are evidently prevailed by older sedimentary rock fragments. That is to say, the sediments are mainly derived from a supracrustal complex poor in feldspar. Therefore, it seems to

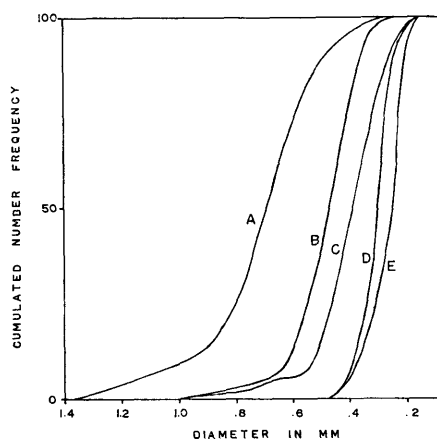


Fig. 8. Cumulative curves showing some well-sorted examples. A: Sp. No. KU 166, B: Sp. No. KU 185, C: Sp. No. KU 233, D: Sp. No. KU 190, E: Sp. No. KU 177.

* For instance, serpentine sandstones of the Miocene sediments in Hokkaido (MATSUMOTO et al., 1963; OKADA, 1964).

be appropriate in the present case to introduce the ratio of quartz plus chert/feldspar plus rock fragments as a mineralogical maturity index rather than the ratio of quartz/feldspar.

On the eastern wing the ratio in the examined specimens is estimated as about 1.9, although it varies between 0.71 and 4.35. To the contrary, on the western wing the average value is about 3.3 and on the southwestern about 2.4. Therefore, the sandstones on the western to southwestern wing are more mature than those on the eastern. This fact agrees well with the natures shown by sorting and roundness.

D. Mineral composition

1. Major constituents

Six components are taken as the major constituents of sandstones; quartz, chert, feldspar, non-cherty rock fragments, clay matrix and calcite cement. Their frequency in occurrence is tabulated in Tables 2 and 3, and compositional tendency of sandstones is shown in Fig. 9 and 10.

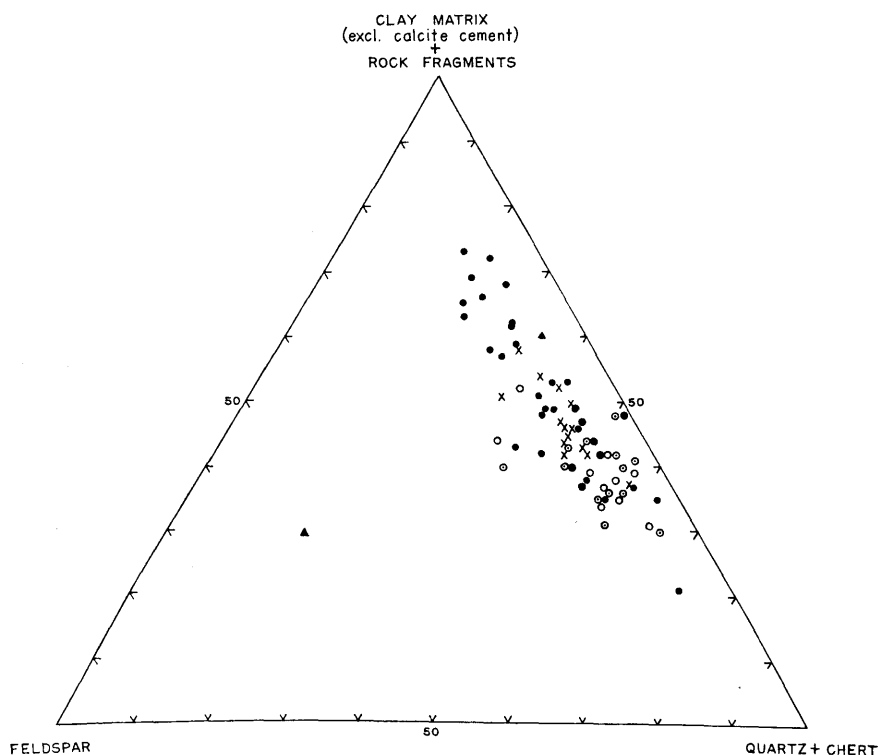


Fig. 9. Compositional diagram of the Cretaceous sandstones.

- Sandstones of the Mikasa Formation on the eastern wing.
- ⊙—Sandstones of the Mikasa Formation on the western wing.
- Sandstones of the Mikasa Formation on the southwestern wing.
- ×—Sandstones of the lower part [1] of the Middle Yezo Group.
- ▲—Sandstones of the Upper Yezo Group.

Following is a brief note on each of the major constituents:

(1) *Quartz*. Quartz is one of the most important constituents of sandstones in the studied area. In an exceptional case where the quartz content is only 7 percent of the bulk (*e.g.* KU 166), chert serves as complementary of quartz in amount.

In general quartz is subdivisible into the following varieties: igneous quartz, metamorphic quartz, vein quartz and microcrystalline quartz. Among these varieties, igneous quartz is predominant, many grains of which are considered to be of plutonic origin, although high-quartz of volcanic origin is not uncommon in occurrence. Metamorphic quartz is readily identified when each part of the grains bounded with complicate sutures displays intense undulose extinction. Its occurrence is not significant. Vein quartz is also rarely met with.

(2) *Chert or microcrystalline quartz*. Chert fragments occur with a considerable high percentage (Pl. 1, Figs. 1, 2, 4-7; Pl. 2). Generally chert grains are somewhat more rounded than other mineral grains. They consist of milky white, dark grey and reddish varieties. Many of the grains are crossed by veinlets which seem to suggest fracturing in the mother rock. Radiolarian remains are commonly met with (Pl. 2, Fig. 1c).

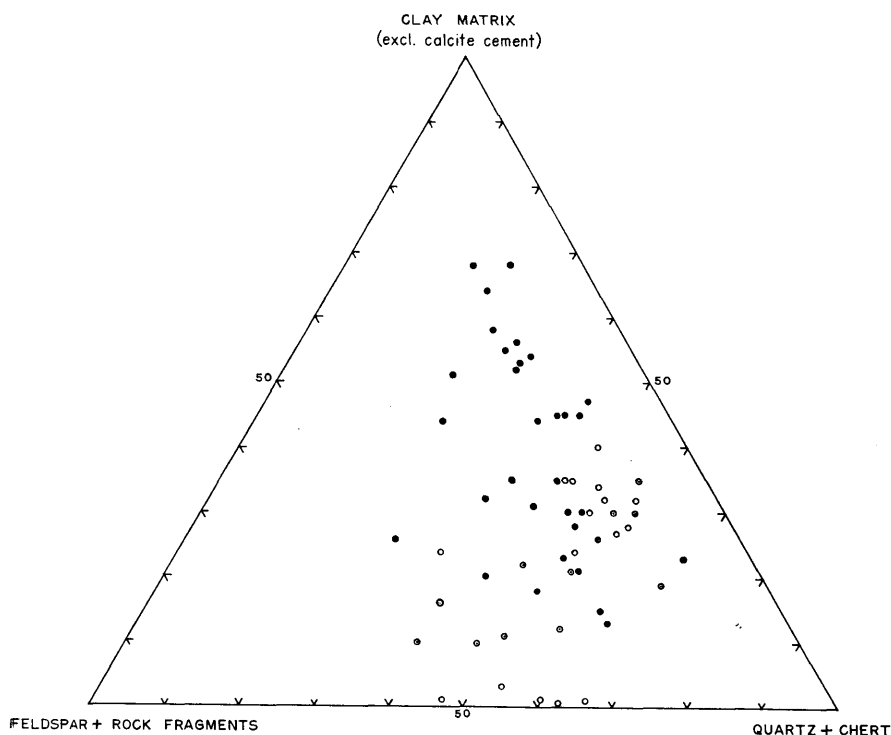


Fig. 10. Diagram showing differentiation of the Mikasa sandstone between the eastern and the western to southwestern wing.

- Sandstones from the eastern wing.
- ⊙—Sandstones from the western wing.
- Sandstones from the southwestern wing.

(3) *Feldspar*. Potassic feldspar and plagioclase mainly of andesine are predominant, of which the former is a little commoner than the latter, being accompanied with microcline.

A specimen of the Upper Yezo Group [IK 1263] differs from those of the Mikasa Formation (Fig. 9; Pl. 1, Fig. 3).

(4) *Rock fragments*. They are rather variable in frequency. They consist of andesite, spherulitic acid to intermediate tuff, porphyrite, sandstone, slate, etc.

(5) *Clay matrix*. It is mostly altered into chlorite and/or sericite.

(6) *Calcite*. Sediments in the studied area are more or less calcareous. Sandstone is not exceptional, either. Sandstone of the subgraywacke clan is generally cemented with sparry calcite instead of clay matrix (Pl. 1, Figs. 5, 7; Pl. 2, Figs. 1, 2, 4, 6). In addition, small parts of feldspars, rock fragments and clay matrix are replaced by calcite.

2. Heavy minerals

a. Heavy mineral content

Although heavy mineral contents of the examined specimens range from 0.06 to 3.36 percent, most of them are rather insistent in heavy mineral content, showing less than 1 percent. On the eastern wing the content is somewhat lesser than that on the western and the southwestern wings.

b. Identified mineral species

The identified fifteen transparent minerals and six iron minerals are listed on Tables 4 and 5, with their abundance in the examined samples. Some brief notes are given below on each of them:

(1) *Zircon*. Euhedral zircon is almost equal with or lesser than abraded one in frequency. In both cases zircon is divisible into colourless, pale pink and purple varieties according to colours, of which egg-shaped purple variety shows a particular pattern of distribution. Namely it horizontally occurs more abundantly in the

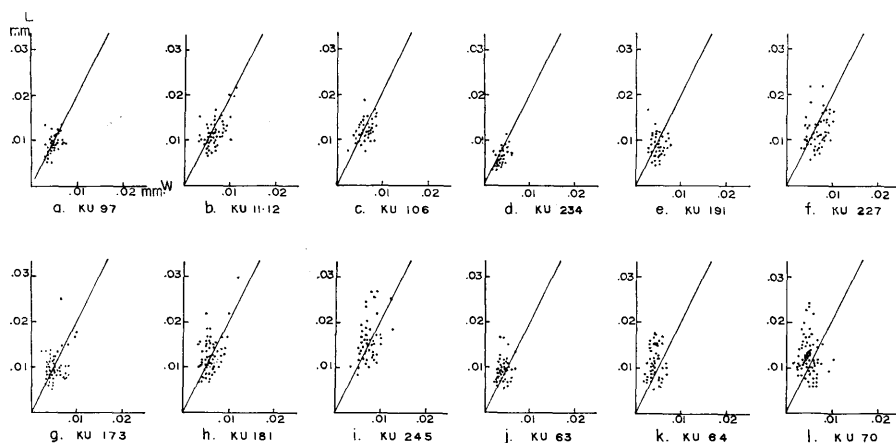


Fig. 11. Elongation ratio of zircons from some selected sandstones. Note the difference between the eastern and the western to southwestern wing. Zircons from the former (i-l) are slenderer than those of the latter (a-h).

Table 2. Major constituents of the sandstones of the Cretaceous exposed along the Ikushumbets Valley.

Stratigraphic division		Middle Yezo Group																																	Upper Yezo Group																																																																																																																		
		Western wing				Eastrn wing																																																																																																																																															
		Mikasa Form.			I	I												Mikasa Formation																		III																																																																																																																	
						Yunosawa Sandstone												IIa																					IIb						IId																																																																																																								
II			Alternating part				massive part								IK1096a						IK1096d						IK1056e						44						45						51						52						53						58						59						60						61						62						63						64						65						66						67						68						69						70						IK971			IK1263			IK1121		
Specimen Number		11	13	14	16	17	19	21	22	23	26	29	31	32	IK1096a	36	37	IK1096d	39	42	IK1056e	44	45	51	52	53	58	59	60	61	62	63	64	65	66	67	68	69	70	IK971	IK1263	IK1121																																																																																																											
Major constituents	Quartz	16	18	45	28	32	21	33	27	44	36	29	30	24	32	26	36	19	21	23	9	16	21	14	14	17	17	14	23	16	24	23	31	19	33	18	27	32	31	15	8	+																																																																																																											
	Chert	34	21	12	8	+	8	16	12	10	15	17	9	18	12	17	9	18	13	17	16	7	9	6	3	6	5	7	6	5	4	5	10	7	7	7	9	8	10	19	3																																																																																																												
	Feldspar	2	21	73	20	8	9	9	7	5	11	9	8	11	10	10	10	9	16	7	7	24	13	11	10	11	15	7	9	14	14	9	6	8	11	7	8	12	10	6	31	77																																																																																																											
	Rock fragments	37	30	5	25	30	43	27	40	26	23	29	37	32	31	13	5	36	15	10	39	7	12	4	5	6	11	3	6	3	2	4	4	6	4	13	9	2	2	25	18	5																																																																																																											
	Clay matrix	11	10	30	16	3	11	14	11	7	14	12	2	7	14	31	37	17	35	36	26	44	23	64	68	58	51	68	56	55	53	54	47	43	45	21	41	45	45	29		16 ^(partly glass)																																																																																																											
	Calcite cement				3	27	8	1	3	8	1	4	14	8	1	3	3	1		7			22	1	+	2	1	1		7	3	5	2	17		34	6	1	1		37	+																																																																																																											
Glauconite															3	2						+	+	+			1						+				+	1		6	3	2																																																																																																											
Grain size		c.	c.	c.		f.	m.	m.	m.	m.	m.	m.	c.		f.	f.	f.	m.	f.	v.f.	m.	f.	v.f.	f.	f.	v.f.	f.	m.	v.f.	f.	m.	f.	v.f.	v.f.	m.	m.	m.	m.	m.																																																																																																														
Roundness		C	B	C	B	A	A	B	B	B	B	B	B		A	B	B	B	B	B	C	B	B	B	B	B	C	C	B	B	B	C	B	B	B	B	B	B	B	B	A	A																																																																																																											
Q+Ch/F+RF		1.28	.77	4.75	.80	.84	.56	1.36	.83	1.74	1.50	1.21	.71	.98	1.07	1.82	2.97	.82	1.06	1.91		.71	1.12	1.31	1.17	1.28	.82	2.09	1.90	1.23	1.77	2.30	4.35	1.97	2.66	1.20	2.20	2.80	3.65																																																																																																														

N.B. Sign + less than 1 percent.
From the Specimen Number a prefix KU is omitted except for in the specimen with IK.

Table 3. Major constituents of the Mikasa sandstones.

Locality		Western wing									Southern wing										Eastern wing														
		Pombets Valley [I]						Takambets [III]			[IV]			Yamamoto-no-sawa [V]			[VI]	Washi-no-sawa [VII]				Map-no-sawa [VIII]		Temmaku-no-sawa [IX]								Taki-no-sawa [X]			
Specimen Number		87	90A	90B	91	93	94	105	107	108	231	233	234B	190	193	194	166	225	226	227	229	172	173	177	178	179	181	183	184	185	242	245	248	249	119
Major constituents	Quartz	33	47	35	31	36	26	47	29	40	20	20	31	38	34	30	29	42	41	29	25	38	38	25	36	44	44	34	42	16	41	37	20	34	34
	Chert	24	19	20	24	18	20	9	24	8	8	19	21	19	23	25	19	5	10	6	12	7	7	11	8	7	7	5	7	29	5	14	42	+	21
	Feldspar	12	5	9	5	11	11	3	5	8	10	4	6	7	4	8	4	13	10	6	6	11	7	9	7	12	7	8	7	1	8	11	3	12	10
	Rock fragments	19	9	6	14	14	20	6	18	4	22	19	12	9	7	6	21	5	5	22	29	8	13	30	18	7	14	18	11	28	11	20	21	17	14
	Clay matrix	12	19	30	26	21	22	35	24	40	19	+	30	27	32	27	1	35	34	2	8	35	35	1	31	30	23	35	30		35	18	15	16	21
	Calcite cement			1			1	+			21	38	+		+	4	26		1	35	20			24			+		3	26				21	
Grain size		f.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	f.		m.	m.	f.	m.	m.	m.	m.	f.	m.	m.	f.	v.f.	v.f.	f.	f.	m.	f.	m.		m.
Roundness		C	C	D	C	D	C	C	D	C	D	D	B	D	D	C	D	C	C	D	C			C	C	C	C	B	C	D	C	B	C	B	B
Q+Ch/F+RF		1.84	4.71	3.67	2.90	2.16	1.48	6.22	2.31	4.00	0.86	1.72	3.02	3.54	4.77	2.20	1.93	2.67	3.47	1.23	1.03	2.37	2.29	0.94	1.79	2.54	2.55	1.56	2.72	1.59	2.50	1.59	2.54	1.19	2.29

N.B. Sign + less than 1 percent.
For every Specimen Number a prefix KU is to put.
Roman numeral with square brackets indicating locality is a guide index shown in Fig. 3.

Table 4. Heavy mineral frequencies of the sandstones of the Cretaceous exposed along the Ikushumbets.

Stratigraphic division		Middle Yezo G. (Western wing)					Middle Yezo Group (Eastern wing)																														Up. Yezo G.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
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Opaques	Pyrite	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

Explanation of signs: ● abundant, ○ common, × rare, + less than 1 percent.
N.B. For every Specimen Number the prefix KU is to be put, unless the number has the prefix IK.

Table 5. Heavy minerals of the Mikasa sandstones.

Locality		Western wing												Southwestern wing										Eastern wing																												
		Pombets Valley [I]												Takambets [III]					Yamamoto-no-sawa [V]					Washi-no-swaa [VII]					No. 4 Map-no-sawa [VIII]				Temmaku-no-sawa [IX]								Tak-no-sawa [X]											
Specimen Number		85	86	87	88A	88B	88C	90A	90B	91	93	94	96	97	105	107	108	234A	234B	190	191	192	193	194	225	226	227	229	230	170	171	172	173	177	178	179	180	181	183	184	185	241	242	245	248	249	141	142	143	147		
Opagues	Pyrite	○	○	●	●	●	●	●	●	○	●	●	●		●	●	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●			
	Magnetite or ilmenite	×	×	○	○	○	○	+	×	×	×	×	○	○	×	×	×	×	○	×	○	×	×	○	×	×	×	×	×	○	×	×	×	○	×	×	×	×	×	×	×	×	×	×	×	×	×	×				
	Leucoxene	○	○	○	○	○	○	○	○	×	○	●	○	●	×	○	●	○	○	○	○	○	○	○	○	○	×	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	
	Hematite		×	×	○	×	×					×	×	×	×	×	×	×	○	×					×	×	×	×		×	○	×		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×		
	total	60	61	47	56	64	54	79	74	70	61	61	59	59	84	91	76	50	66	53	49	20	77	53	51	52	76	53	56	57	41	58	40	47	61	53	45	51	39	58	79	47	54	26	17	23	27	56	43	31		
Non-opagues		40	39	53	44	36	46	21	26	30	39	39	41	41	16	9	24	50	34	47	51	80	23	47	49	48	24	47	44	43	59	42	60	53	39	47	55	49	61	42	21	53	46	74	83	77	73	44	57	69		
Zircon	colourless	euohedral	1	1	1	2	3	3	1	1			1	3	3	2	10	6	4	4	1	4	2	6	4	1	6	4	4	2	5	2	1	4	3	1	1	2	2	4	3	3	2	5	3	2	+	12	6	4	5	
		rounded	1	1	1		1	5	1					2	1	5		1				2	1	1		1	1			1	1	1	1		1	1	+	1	3	1	1	+	+	+	+	+	+	+	+			
	pale pink	euohedral	8	3	8	9	3	8	1	1	2	1	1	17	9	17	10	6	11	11	8	18	9	18	17	14	21	14	14	9	10	8	8	12	8	8	8	4	11	7	4	11	14	22	20	21	8	37	34	39	35	
		rounded	9	7	10	16	6	19	7	5	3	7	2	19	18	10	1	5	10	12	16	17	9	14	14	10	15	22	17	12	13	12	9	16	5	7	9	6	11	7	5	10	2	16	7	5	1	13	13	15	10	
		purple (rounded)	1	3	1	1		1	2	1		1	1	1	1	9	2		7	1	5	2	9	6	6	1	1	4	3	1	2	2	8	8	3	3	2	1	4	4	3	5	1	11	3	3		6	1	2	8	
Garnet	colourless	6	1	2	3	5	1	1	4	1	2	1	2	2	4	10	7	2	1	5	5	4	5	6	9	11	8	4	7	2	2	4	2	2	2	2	7	5	3	7	2	5	3	4	4	1	3	2				
	pale pink	27	5	19	12	7	21	12	13	7	5	8	17	31	20	11	17	58	53	46	31	58	34	34	28	29	26	32	27	23	17	22	38	13	11	11	13	18	26	30	52	19	27	23	18		23	20	26	25		
	orange	1	1	1	3			1	5	2	2	2	1	1	+	2		2	1	5	1	2	2	6	1	+	3	5	6	2	1	6	2	1	2	1	2	2	1	3	1	2		1	1		+					
Tourmaline	brown	5	2	6	4	4	2	1	3	1	3	2	2	3	1	8	+	+		4	6	1	4	3	8	4	1	2	2	1	3	1	1	4	4	2	1	1	2	2	3	2	+	1	2		4	6	4	3		
	green	2	1	2		2				2	1	2	1	1	5	1		+		1	4	+	1	1	1	1		1	1	2	1	1	1	1	2		2	1	1	2	+	+	+	1	1	1		1	+	+		
	blue					1	1			1					+					+	+		1		1	1					1				1			1	+				1				+	+	+			
Rutile													1	+		1						1					1				+		2						+													
Epidote		23	36	30	29	39	21	45	32	43	49	51	16	15	2	13	10			+							3			14	24	18	3	16	20	30	20	11	14		6	17	5	6	7	34		+	+			
Hornblende		1	1	3	1	1	+	+	+	2		1	1		+	1			3			1			1	3	1	2					+		3	+	1		+	+	+	+	1	3								
Augite		11	33	13	11	21	15	25	30	31	23	24	14	11	7	15	14			4	+	+	+	+				6	+	22	25	12	5	41	31	28	40	28	26	28	1	24	4	17	24	54	1	12	5	9		
Hypersthene			2			4		+	+	+					3	7		2			+	1	+	+				1		+						+	+				6											
Anatase											+									+		+			1							+				+	+	+	+		1											
“Chromite”		+		1		+	+							+	+		1			+	+		1		+	+			+						1	+		+	+	+	+		1	2								
Apatite		1		1		+				+		1		+		+									16				2	+								1	+		+		+									
Monazite		+					+								2						+	+	1		1	1	1					+	1				1		+									2				
Chlorite			1		3	1	+	1	2	2	2	1	1	1	7	+	10	1	3	3	6			1		4	2	3	7	25	1	+	4	1		2	1		1	1	1	5	+	8								
Biotite		+			5	1	1		+	1	2	2	1	1	7	8	23	+	4		1		1	1			1	1	2	2	1		2	1	2	2	+	+	1	1	1	5	+	4	4	1	+		2	2		
Muscovite		2	2	1	1	+	+	+		1	1		1	+						1	1	3	2	3	3	2	2	2	6	3	+	+	3	1		3		+	3	1	2	3								+		
Heavy mineral content (wt. %)		.38	.64	.38	1.00	.40	1.77	1.83	2.20	1.19	.44	.86	1.06	.47	.24	.26	.18	.23	.18	.22	.32	.19	.32	.15	.55	.48	3.36	.63	.96	1.38	1.20	.88	.25	.60	.43	3.15	1.45	1.81	.65	.70	.27	1.71	1.07	.54	.23	3.40	1.25	.05	.22	.19		

Explanation of signs: ● abundant, ○ common, × rare, + less than 1 percent.

N.B. For every Specimen Number the prefix KU is to be put.

For the locality of the examined specimen Fig. 3 and 4 should be referred to. Roman numeral with square brackets corresponds to a guide index shown in Fig. 3.

southwestern part of the anticlinal area and vertically in the lower part of the Middle Yezo Group than in other parts. This variety is considered for the most part to have been derived from older sedimentary rocks as a multi-cyclic detritus, because a sandstone pebble contains it in a considerable amount (KU 13p; Pl. 3, Fig. 1). In addition to the above, elongation of the crystal is estimated a little larger on the eastern wing than on the western and the southwestern wings (Fig. 11). Furthermore, a ratio of rounded zircon to euhedral one is higher on the western to southwestern wing than on the eastern. Outgrowth of zircon is rarely recognized.

(2) *Monazite*. It occurs as light yellow to yellowish brown, somewhat abraded euhedron. Generally, grains are outlined with dark border and are crowded with minute inclusions or dusts.

(3) *Garnet*. Colourless, pale pink and orange-coloured varieties are recognized, of which pale pink variety is prevalent and orange-coloured one is rather rare in occurrence.

According to my preliminary examination, garnet grains of various sediments seem to be identified mostly to almandite irrespective of the above recognized colours. Judging from the unit cell edge (a_0) and refractive index (n), the grains of greyish pink garnet (5R 8/2) separated from the Mikasa sandstone [Sp. No. KU 192] are also predominated by almandite (56 to 68 percent) and accompanied with pyrope (27 to 32 percent) and a small amount of spessartine or grossular or andradite, as referred to the diagrams prepared by SRIRAMADAS (1957) (see Table 6).

Table 6. Physical properties of garnet separated from the specimen KU 192 and its possible compositions.

2θ obs.	2θ corr.	$d(\text{\AA})$	hkl	a_0
74.610	74.570	1.5979	640	11.523

FeK α radiation; 30KV, 10mA; Scan. speed $1/4^\circ/\text{min.}$; Time const. 5 secs.
Slits 3-2-0.4mm.

$n=1.793\pm0.001$

Colour=5R 8/2 (greyish pink)

Possible compositions:

1) Al:68 Py:27 Gr:5

2) Al:67 Py:32 An:1

3) Al:56 Py:27 Sp:17

Garnet grains usually occur as equidimensional fragments with conchoidal fractures, though dodecahedron is sometimes met with. Abraded grains are not uncommon.

As is clearly shown in Fig. 16 and on Tables 4 and 5, garnet is a common mineral throughout the whole sequence of the Yezo Group in the Ikushumbets area, and is particularly characteristic of the lower part (Unit I of MATSUMOTO's stratigraphic division) of the Middle Yezo Group. In the corresponding stratigraphic unit of the Yubari dome, about 12 km south of the southwestern periphery of the Ikushumbets anticlinal area (Fig. 1), the same rule is kept (OKADA et al. in MATSUMOTO

and HARADA, 1964; Pl. 6, Fig. 3). Within the Mikasa Formation garnet becomes abundant southwestwards.

The abundance of garnet agrees well with the predominance of coarse-grained sediments. Furthermore, it is noted that a sandstone pebble in the Mikasa Formation bears garnet in an unexpectedly high amount (KU 13p; Pl. 3, Fig. 1), just as in the Yubari dome (Yb 427b in OKADA et al. in MATSUMOTO and HARADA, 1964).

Relations between garnet and other associated minerals are discussed in page 100.

(4) *Epidote*. Epidote occurs in general as irregular and subangular grains and sometimes as prismatic ones. It is interesting that epidote is much more abundant on the eastern wing of the anticline and on the western wing than on the southwestern wing.

Epidote is one of the index minerals of the Mikasa Formation, as FUJII (1958) has already pointed out.

(5) *Augite*. Augite occurs as pale green, prismatic grains, which present fresh character. Not a few grains exhibit a hack-saw structure.

Augite and epidote characterize the Mikasa Formation (Fig. 16 and Table 5). This is also true in the Yubari dome (OKADA et al. in MATSUMOTO and HARADA, 1964).

(6) *Hypersthene*. The occurrence of hypersthene is sporadic. Most of the grains are prismatic and much larger than the average size of other heavy minerals.

(7) *Hornblende*. Hornblende is low in frequency, but persistently occurs in all the specimens. Most of the grains are greenish-brown in colour, and a small fraction of them are green. Each grain is prismatic euhedron.

(8) *Tourmaline*. Three varieties of tourmaline are distinguished on the basis of colour; brown, green-shaded and blue. The blue variety is not common. Many of the euhedral tourmaline crystals are broken at one or both edges. Some are rounded.

(9) *Rutile*. More or less rounded prismatic or acicular grains are met with.

(10) *Apatite*. It occurs as short prismatic euhedron with bipyramidal termination or with basal pinacoid. Indeterminable acicular inclusions are common in parallel with the principal axis.

Specially noteworthy is the fact that apatite is very abundant in a tuffaceous sandstone (Sp. No. IK 1056e; see Fig. 16 and Table 4), although it is traceable in ordinary sandstones. The acicular apatite indicative of a particular genetic condition (WYLLIE et al., 1962) is not detected.

(11) "*Chromite*". The so-called chromite is sporadically met with. The grains are massive and irregular, showing conchoidal fracture. Marginal edge of a fragment presents a colour of reddish brown to deep blood-red. Judging from these features it may be either magnesiochromite or chromian spinel.

(12) *Anatase*. Anatase occurs as golden yellow, tabular grains with zoning. Since no abrasion is recognized on the grain, anatase is considered to be of authigenic origin. Its occurrence seems to be confined to coarse-grained sandstones, as has been reported by FUJII (1956).

(13) *Mica group*. Biotite and muscovite or sericite are present throughout the formation, although their amount is variable from sample to sample. Their frequency may not be evaluated in the same way as that of other associated minerals, because

they may be to a considerable extent lost during the course of separation. Muscovite or sericite, making up a part of clay matrix, is composed of aggregates of fibers. Biotite consists of brown, reddish brown and greenish varieties. Usually it shows fibrous, prismatic, or irregular platy characters, and sometimes it occurs as a hexagonal plate. Its partial alteration to chlorite is also observed.

(14) *Iron minerals.* Pyrite, marcasite, magnetite, ilmenite, hematite and leucoxene are distinguished. Their qualitative amount is shown on Tables 4 and 5.

Table 7. X-ray diffraction data of pyrite and ilmenite.

Pyrite (Sp. No. KU 227)			Ilmenite (Sp. No. IK 1056e)			
I	$d(\text{\AA})$	hkl	I	$d(\text{\AA})$	$hkil$	hkl
3	3.13	111	2	3.72	01 $\bar{1}$ 2	110
10	2.71	002	10	2.75	10 $\bar{1}$ 4	211
7	2.42	021	3	2.54	11 $\bar{2}$ 0	10 $\bar{1}$
6	2.21	112	2	2.23	11 $\bar{2}$ 3	210
5	1.917	022	2	1.865	02 $\bar{2}$ 4	220
1	1.803	122	4	1.723	11 $\bar{2}$ 6	321
8	1.634	113	1	1.629	01 $\bar{1}$ 8 02 $\bar{3}$ 2	332 22 $\bar{1}$
1 $\frac{1}{2}$	1.565	222	1 $\frac{1}{2}$	1.505	21 $\bar{3}$ 4	310
2	1.504	023	1 $\frac{1}{2}$	1.468	30 $\bar{3}$ 0	2 $\bar{1}$ 1
3	1.446	123				

Notes: 1) FeK α ; Scan. speed 2°/min.; Time const. 2.5 secs.; Slits 3-2-0.6 mm.

2) hkl and $hkil$ are cited from BERRY and THOMPSON (1962).

Of these iron minerals, pyrite is most abundant, which is identified with an X-ray analysis (Table 7). It occurs as spherule or spheroid, striated pyritohedra, isometrics and clusters of globules. Moreover, spherular pyrite almost always replacing radiolarian or probably other spheric microfossil remains is confined in occurrence to the lower part of the Middle Yezo Group and is particularly common in the Yunosawa Sandstone, whereas in the Mikasa Formation spherular one is very rare, but pyritohedral or isometric pyrite is common. Similar occurrence of pyrite is also observed in the Cretaceous succession in the Yubari dome, where spherular pyrite replacing microfossils occurs in Member L₁ [of K3_p age] of the Middle Yezo Group (MATSUMOTO and HARADA, 1964) (Pl. 6, Fig. 3), but does not occur in the overlying Mikasa Formation (MATSUMOTO and HARADA, 1964). In addition, authigenic marcasite presenting radial texture as reported by OKADA (1960a) is detected only in a specimen KU 32 of the lower part of the Middle Yezo Group (Table 3).

Such an interesting occurrence of a certain type of iron sulphides may suggest a special sedimentary environment which will be a subject of further study.

As a special case ilmenite exclusively makes up the bulk of heavy minerals of a tuffaceous sandstone [Sp. No. IK 1056e] (Tables 4 and 7; Pl. 4, Fig. 2).

E. A few comments on heavy minerals

1. Index minerals of the Mikasa Formation and heavy mineral suites

Heavy mineral analysis reveals that a combination of garnet and zircon and that of epidote and augite which are altogether more than 80 percent of the whole non-opaque heavy minerals are very significant as indices of the Mikasa Formation. Especially, the garnet-zircon suite is characteristic of the southwestern wing of the anticlinal area, and the combined suite of the garnet-zircon and the epidote-augite characterizes both the eastern and the western wings.

From the standpoint of source rocks, the heavy mineral assemblages are grouped into the following five suites:

- 1) Euhedral zircon-garnet-green hornblende-green and blue tourmaline-rutile-biotite-iron minerals.....acid igneous origin
- 2) Epidote-augite-hypersthene-brown hornblende-(apatite)-iron minerals.....intermediate to basic igneous origin
- 3) "Chromite"-iron minerals.....ultrabasic origin
- 4) Rounded zircon-rounded garnet-rounded rutile tourmaline.....sedimentary origin
- 5) Anatase-spherular pyrite-marcasite-leucoxene.....authigenic origin

Of the above suites, the first, second and fourth ones, *i.e.* those of acid to basic igneous origin and of sedimentary one are predominant.

2. Behaviour of heavy mineral grains

It is very difficult to extract quantitatively from coagulated sediments factors controlling the behaviour of mineral grains in the process of transportation and sedimentation. In this respect, researches of recent sediments give us useful information for better understanding of sediments of old ages. BURRI (1929), PETTIJOHN and RIDGE (1933), RITTENHOUSE (1943), Van ANDEL (1954), etc. studied heavy mineral behaviours in recent sediments and clarified many interesting facts. Summarizing the results of these previous works, important factors controlling a mineral assemblage are the texture and mineral composition of source rocks, nature of transportation media, velocity of the media, distance of transportation, bottom condition of a basin of deposition and specific gravity, size and shape of mineral grains.

In this study, a few interesting facts have been observed on behaviours of zircon, garnet, epidote and augite. The amount of zircon and garnet increases with decreasing content of epidote and/or augite (Figs. 13 and 14; Pls. 3-6). There is a linear relation between zircon and garnet and also between epidote and augite (Figs. 12 and 15). In general, concentration of mineral in sediments is intensely influenced with its grain size (RITTENHOUSE, 1943; Van ANDEL, 1955). In the studied area, zircon and garnet are, on one hand, obviously concentrated in the coarse-grained facies on the western and the southwestern wings of the anticline, and on the other, epidote and augite are characteristic of the fine-grained facies on the eastern wing and in the northern part of the western wing (Pl. 4, Figs. 1-4, 5; Pl. 5, Figs. 2-6; Pl. 6, Figs. 1, 2). In this connection, garnet tends to gather in far the coarser fraction and therefore in the coastal areas (HAWKES et al., 1931; TAKAHASHI et al., 1950; McMASTER, 1962). On

the other hand, augite assembles in finer fraction, according to KONDO's study of recent coastal sediments (KONDO, 1960).

In addition to the grain size, the specific gravity of a mineral seems to be significant for controlling the distribution of a mineral under the influence of the winnowing by current. Zircon and garnet have similarly high specific gravity to behave in common with each other, as do epidote and augite.

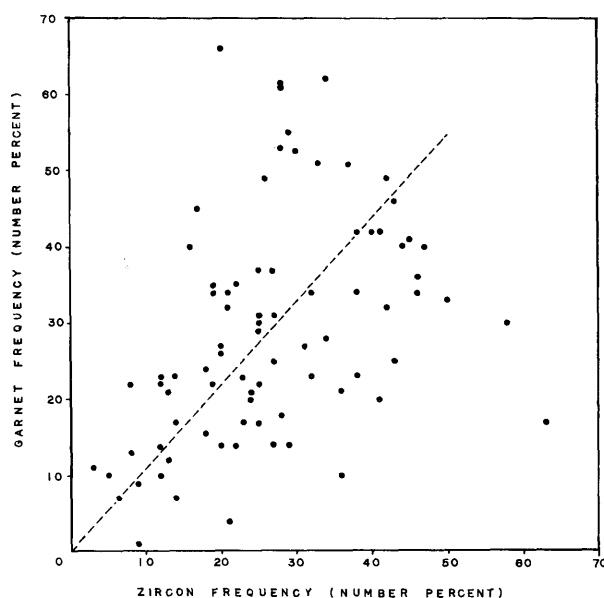


Fig. 12. Relation between the frequencies of zircon and garnet.

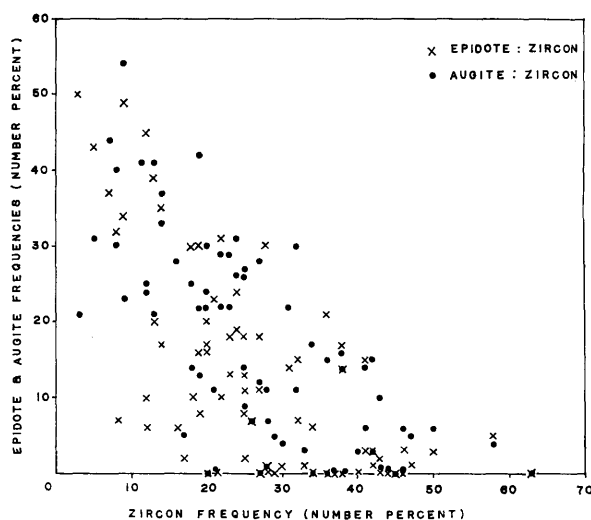


Fig. 13. Relations between the frequencies of zircon and epidote and between those of zircon and augite.

In this respect, PETTIJOHN and RIDGE (1933) have reported in their study of beach sand at Cedar Point, Lake Erie, Ontario, that in the direction of transport garnet declines notably ; hornblende increases complementarily ; and diopside and hypersthene are almost constant in frequency.

Likewise a sort of progressive sorting-action is considered to have caused the above mentioned characteristic distribution of particular minerals in the Mikasa Formation.

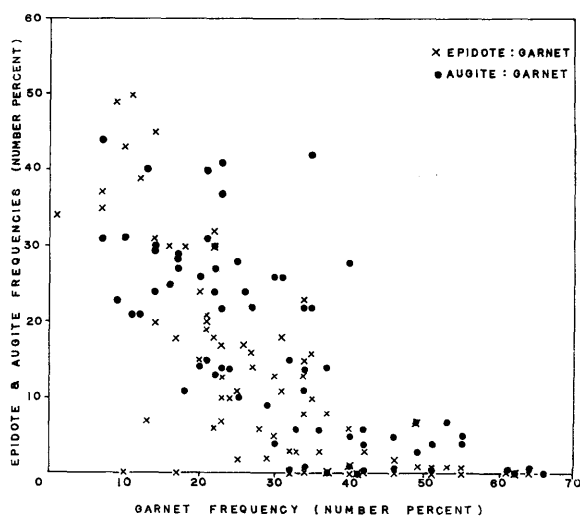


Fig. 14. Relations between the frequencies of garnet and epidote and between those of garnet and augite.

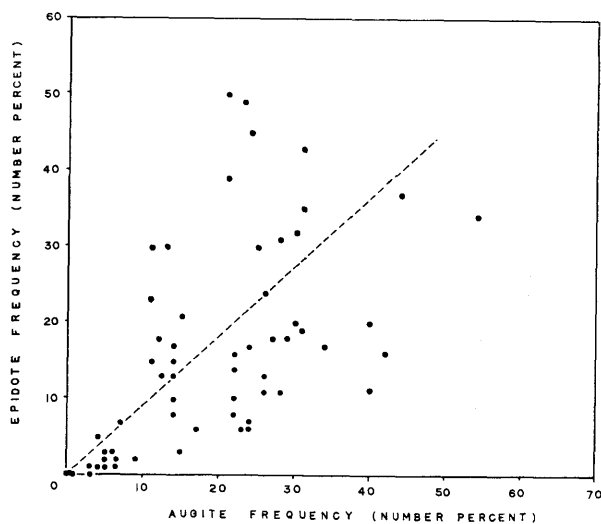


Fig. 15. Relation between the frequencies of epidote and augite.

F. A note on the sandstones of the Cretaceous section along the Ikushumbets Valley

The Cretaceous section along the Ikushumbets Valley is very important in that a standard stratigraphy of the Middle and Upper Yezo Groups has been established there (MATSUMOTO, 1959; see Fig. 5). Therefore, it is desirable to give some petrologic comments on the sandstones of each stratigraphic unit. Stratigraphic division used in this paper follows that of MATSUMOTO (1959) and MATSUMOTO et al. (1960).

1. Lower part of the Middle Yezo Group [I]

a. The Yunosawa Sandstone

Thirteen specimens of the Yunosawa Sandstone (FUKADA et al., 1953) have been examined (Tables 2 and 4). All are more or less calcareous and fall in the sub-graywacke clan. However, the roundness of detrital grains is not so good. Of major constituents quartz is for the most part of igneous origin. Rock fragments consist mainly of andesitic rocks and sandy to silty sedimentaries. Heavy mineral assemblages are overwhelmed by zircon and garnet of almost equal amount, being accompanied with a small amount of tourmaline (Fig. 16; Pl. 3, Figs. 2-5). As an interesting fact, the spherular authigenic pyrite described in page 99 is characteristic of the whole Yunosawa Sandstone, especially of the alternating part, the lower horizon of the Yunosawa. It is likewise noteworthy that a specimen KU 32 is characterized by an authigenic marcasite (Table 4; Fig. 16).

b. The Sequence above the Yunosawa Sandstone

The sandstone of this sequence is different from the preceding one in that it bears a considerable amount of clay matrix (Table 2). Consequently it is for the most part graywacke. Heavy mineral assemblages of the sandstone, however, do not basically deviate from those of the underlying sequence, except for the forerunning appearance of augite and epidote (Fig. 16; Pl. 3, Fig. 6). Spherular authigenic pyrite is sporadically met with.

2. Mikasa Formation [II]

a. Basal and Lower Members [IIa and IIb]

In this sequence the sandstone is clearly distinguishable from that of the underlying sequence I. The sandstone is graywacke and is always considerably muddy (Fig. 17; Table 2). Further remarkable feature is that augite and epidote get suddenly significant besides zircon and garnet (Fig. 16; Pl. 4, Figs. 1, 3, 4).

A bed represented by a specimen IK 1056e at the base of Member IIa is tuffaceous sandstone rich in volcanic rock fragments (andesitic). This sandstone abounds in ilmenite, which occupies about 90 percent of heavy minerals, and is also characterized by apatite as a transparent heavy mineral (Pl. 4, Fig. 2).

b. Middle Member [IIc]

As this unit is wholly made up of siltstone, there is no sandstone to be described here.

c. Upper Member [IId]

Characters of the sandstone are exactly the same as those of Members IIa and

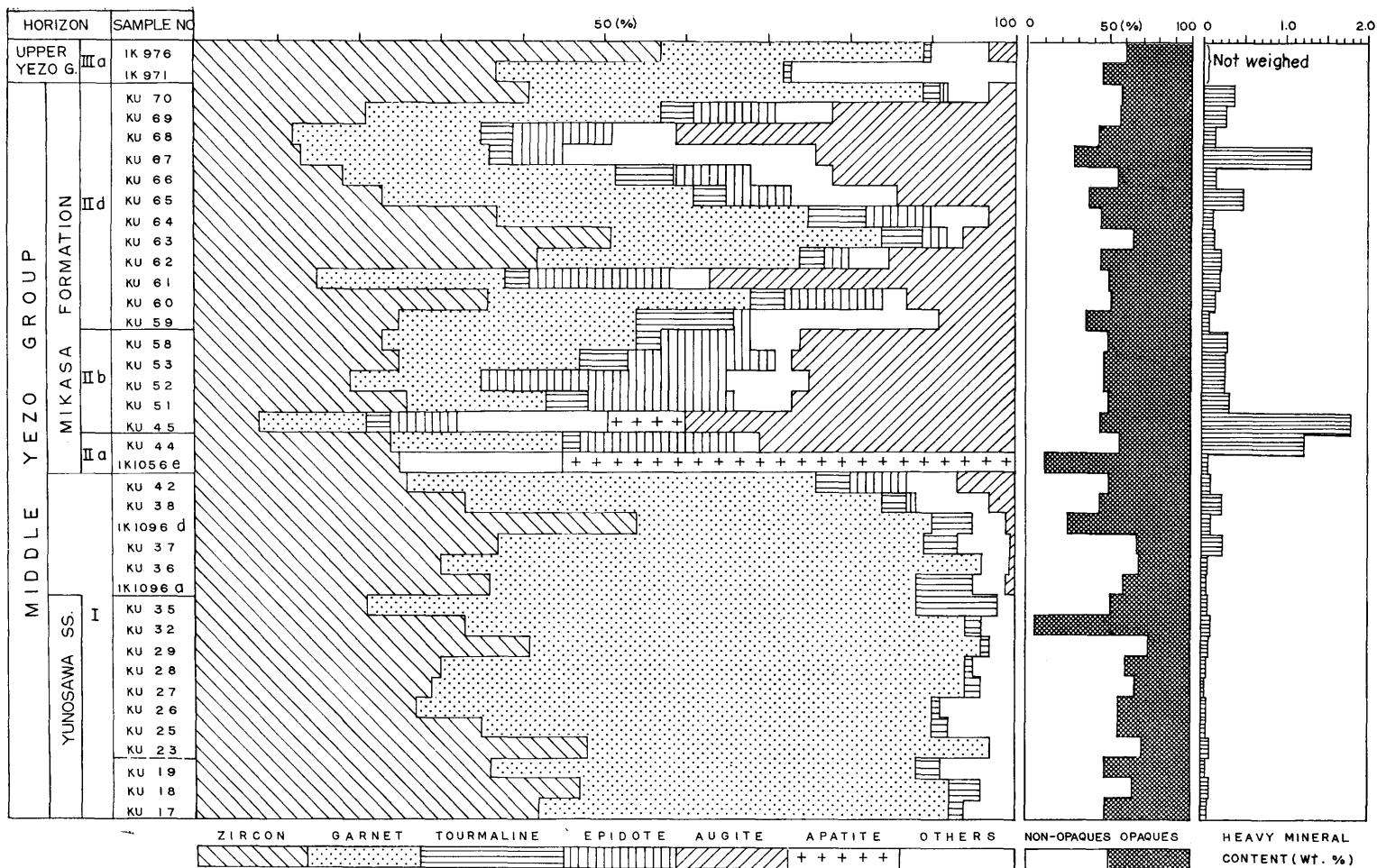


Fig. 16. Vertical change of non-opaque heavy mineral compositions of the sandstones in the standard stratigraphic section along the Ikushumbets Valley [XII] (on the eastern wing) (see also Fig. 5).

IIb (Table 2; Pl. 1, Fig. 2). Some of the sandstones are considerably calcareous. Some specimens contain a dominant amount of zircon and garnet, but these minerals are always accompanied to a certain extent by augite and epidote.

3. Upper Yezo Group [III]

The Upper Yezo Group is mainly composed of siltstone, with some intercalated beds of sandstone and tuff. So far as the examined specimens are concerned, a specimen IK 971 belongs to the graywacke, and the other two, IK 1121 and IK 1263 are tuffaceous sandstones which are remarkably predominated by andesine plagioclase (Pl. 1, Fig. 3).

According to the available specimens and the results of FUJII's study (1958), heavy mineral composition of the Upper Yezo Group is rather similar to that of the sequence above the Yunosawa Sandstone (Pl. 4, Fig. 5).

The above mentioned features of the sandstone are precisely exhibited in Fig. 16 and 17.

These characters of the sandstone of each stratigraphic unit are very similar to

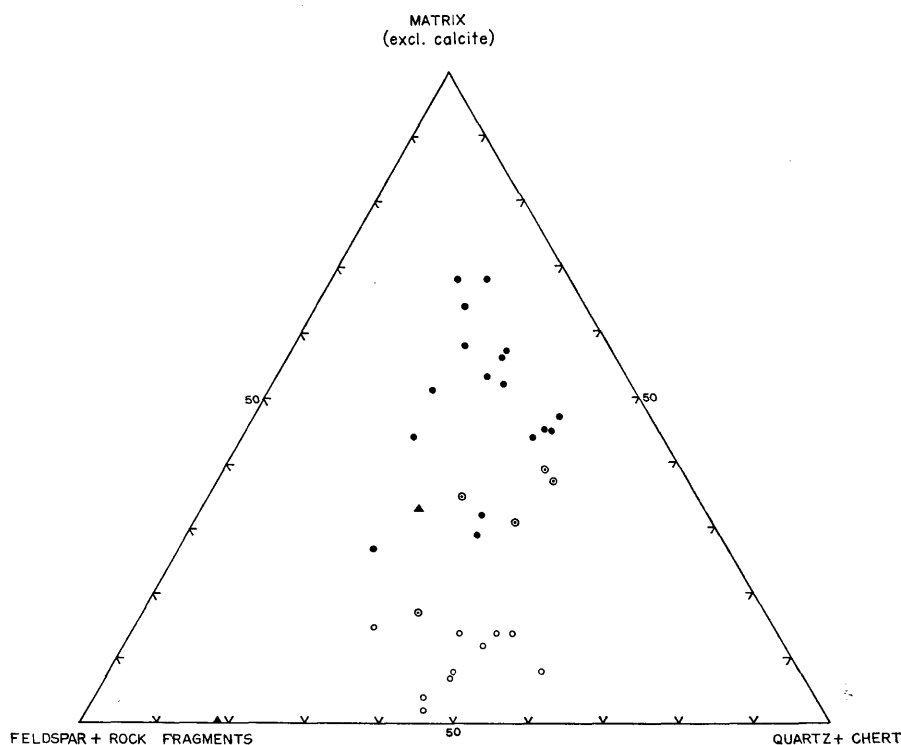


Fig. 17. Diagram showing compositional difference of the sandstones of the Mikasa Formation and its overlying and underlying sequences in the Ikushumbets Valley [XII] (eastern wing).

- Yunosawa Sandstone.
- ⊙—Sequence above the Yunosawa Sandstone.
- Mikasa Formation.
- ▲—Upper Yezo Group.

those of the sandstone of the corresponding stratigraphic sequence in the Yubari dome (OKADA et al. in MATSUMOTO and HARADA, 1964) (Pl. 6, Figs. 3-6).

G. A note on the Lower Tertiary sandstones

In the Ishikari coal field it has been already pointed out by IMAI (1924) and many other authors that the Cretaceous System is overlain by the Palaeogene Ishikari Group with parallel unconformity. Certain parts of the Cretaceous sediments, for instance, the Hakobuchi Group of a regressive facies, are said in some places to be hardly discriminated from the Lower Tertiary because of their lithologic similarity (TAKAO, 1952).

In the Ikushumbets anticlinal area the Cretaceous is also overlain by the Palaeogene with a parallel unconformity (IMAI, 1924; YABE, 1927; TASHIRO, 1951; TAKAO, 1952; MATSUMOTO [Editor], 1954, etc.). In particular, the Mikasa Formation on the western wing is in contact with the Palaeogene Ikushumbets coal-bearing Formation, both of which are apparently similar in aspects to each other.

Several petrological studies have been undertaken for the Lower Tertiary. Recently IJIMA has analysed heavy minerals of them (IJIMA, 1957, 1959). I myself also attempted a petrologic study (OKADA, 1960a). From these and other petrographic and mineralogic studies (OTATUME et al., 1939; TAKAO, 1952; Ikegami, 1958, 1959, 1960, etc.), the petrologic distinction of the Ikushumbets Formation from the Mikasa Formation may be described in the following.

1. Sandstones of the Ikushumbets Formation

The Ikushumbets sandstone, which is fine- to medium-grained and sometimes conglomeratic, is yellowish gray (5Y 8/1) to light gray (N7) in colour, being usually scattered with small brownish spots and sometimes stained with brownish laminae. The sandstones consist mainly of quartz, chert, andesitic rock fragments and feldspars as detritus and are more or less calcareous. They are divided into two rock types, subgraywacke and graywacke, of which the former is predominant. The feldspar content throughout the whole sandstone is at most 16 percent.

A characteristic feature of the Ikushumbets sandstone is the carbonate cement of a considerable amount, which comprises calcite and siderite (OKADA, 1960a). Siderite occurs generally either as brownish spots of irregular shape (aggregates of microcrystallines) or as laminae. The siderite in the Lower Tertiary sediments of the Ishikari coal field was first noticed by OTATUME and FUKUSHIMA (1939), and its study was extended by Ikegami (1958, 1959, 1963) and OKADA (1960a). According to Ikegami (1959), it sometimes occurs as nodules of various sizes in the sandstone and also in the shale of the Ikushumbets Formation.

In addition to the above, other minerals typical of the Ikushumbets sandstone are some sulphides such as pyrite and marcasite, both of which occur in very high frequency. Marcasite presents a peculiar outline of stellate form (OKADA, 1960a, Pl. 11, Fig. 7). Of the transparent heavy minerals, zircon, garnet and tourmaline are important, being accompanied with anatase. Rarely glaucophane is met with.

For more details of the heavy mineral assemblages of the Ikushumbets sandstone,

readers may refer to IJIMA (1957, 1959) and OKADA (1960a).

2. Comparison between the Ikushumbets and the Mikasa sandstones

Sandstones of the Ikushumbets and the Mikasa Formations on the western and the southwestern wings, where they are in contact, are both characterized by sub-graywackes. Therefore, sandstone composition in terms of major constituents is very similar to each other (Fig. 18). The Ikushumbets sandstone, however, is distinguished from the Mikasa in the presence of siderite, which is also known throughout the non-marine Lower Tertiary in the Yubari area, such as the Noborikawa (TAKAO, 1952 and preliminary observation of myself), the Horokabets (IKEGAMI, 1963) and the Yubari Formations (IKEGAMI, 1963 and preliminary observation of myself).

Furthermore, the Ikushumbets and the Mikasa sandstones are respectively characterized by the dissimilar heavy mineral suites as follows:

- 1) The Ikushumbets sandstone: zircon-garnet-tourmaline-marcasite-pyrite-anatase
- 2) The Mikasa sandstone: garnet-zircon-epidote-augite

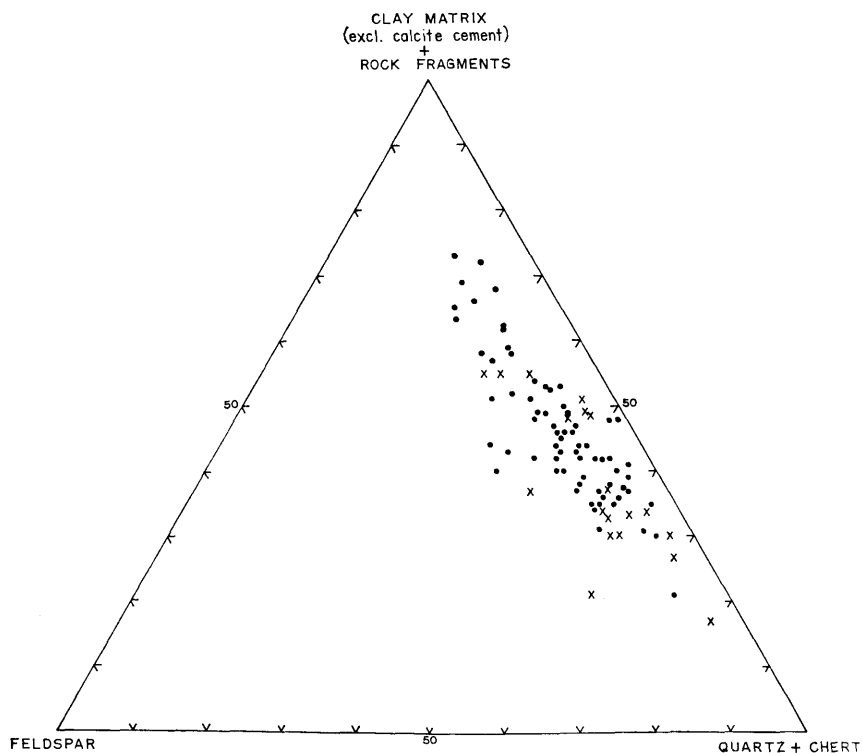


Fig. 18. Comparison in major mineral composition between the sandstones of the Middle Yezo Group and those of the Palaeogene Ikushumbets Formation.

●—Middle Yezo Group.

x—Ikushumbets Formation (OKADA, 1960a).

V. Concluding Remarks

On the grounds of the described facts I discuss in this chapter about the source rocks and sedimentary environments of the Mikasa Formation.

1. Source rocks

Possible framework of source rocks of the Mikasa sandstone is summarized as follows from the major components and heavy mineral associations, as well as kinds of pebbles and cobbles:

Older sedimentary rocks: cherts with and without radiolarians, graywacke, slate and acid to intermediate tuff

Acid igneous rocks: granitic rocks (bearing microcline) and aplite

Intermediate to basic igneous rocks: andesite, porphyrite and diabase

Ultrabasic rocks

Besides, FUJII (1958), in this petrographic study of the Cretaceous sandstones, postulated low-grade metamorphic rocks as one of the Mikasa Formation.

Of these, the most predominant is older sedimentaries and others are subordinate. Especially, in relation to the basic to ultrabasic source rocks, the presence of chromian spinel or magnesiochromite is significant, since it has not been reported from the Yezo Group except for my preliminary study (OKADA, 1962). The mineral is, however, so little in amount that its transportational direction is hardly determined.

General palaeogeographic accounts of the provenance of the detritus of the Mikasa Formation are discussed in the following.

2. Sedimentary environments

To begin with, it seems to be relevant for the discussion to summarize sedimentologically analysed features of the Mikasa Formation.

(A) Megafacies

	Western wing	Southwestern wing	Eastern wing
(a) Thickness	180-270 m	110-240 m	240-405 m
(b) Change of lithofacies	moderate	great	little
(c) Conglomeratic parts	common	predominant	poor
(d) Sandstone pattern	graywacke subgraywacke	subgraywacke	graywacke
(e) Coarse clastics/silt ratio	8-19	62-120	1.5-6
(f) Coaly layers	3-4 (each less than 20 cm thick) at the upper horizons	not yet found	absent
(g) Redbeds	present	not yet recognized	absent
(h) Sedimentary structure	ripple marks and cross-lamination	ditto	not common
(i) <i>Ostrea</i>	common	common	absent or only fragmental if present
(j) <i>Trigonia</i>	common in limited beds	common in limited beds	not common
(k) Ammonites	generally rare, occurring in limited beds	very rare	common, except in IId

(l) Other marine shells	moderate in particular beds	not common	common
(B) Microfacies (especially of sandstones)			
(m) Sorting	moderate	good	poor
(n) Grain-size distribution	sometimes unimodal C-D (fairly well-rounded); rarely B	unimodal C-D	polymodal B (subangular); rarely C
(o) Roundness			
(p) Maturity	moderate	high	low
(q) Heavy mineral suites	garnet-zircon-epidote-augite	garnet-zircon	epidote-augite-garnet-zircon

As is easily understood from the above facts, the Mikasa Formation on the eastern wing in general represents comparatively offshore sediments, that on the western wing sediments of shallower facies than those on the eastern, and that on the southwestern wing the beach-like deposits under strong current-agitation, the last of which may mean a margin of the depositional basin.

As an outline of the palaeogeographic framework, therefore, a mountainous land must have been generally on the west side of the basin. The main provenance of the detritus of the Mikasa Formation was certainly in this land. This conclusion generally conforms to what MATSUMOTO (1943, p. 184-5) had outlined from his stratigraphical study. The shoreline was not necessarily parallel to the trend of the folding. It may have been rather oblique to the latter, running roughly north to south or NNW-SSW, and may have had some irregularity. The site of the southwestern wing of the Ikushumbets anticline may have been incidentally very close to the seashore. Throughout the period of sedimentation of the whole Yezo Group, the emergence of the western uplift proceeded more intensely during the Gylakian stage than in any other stages of the Group and most strongly so in the middle part of Upper Gylakian (middle Turonian).

In connection with the above conclusion it is noted that sediments of the Middle Yezo Group narrowly exposed on the north side of the Pombets fault (Figs. 2-4) is similar in both lithology and composition to the Mikasa Formation on the western wing of the Ikushumbets anticline (see Table 5 and Fig. 1 on Plate 5 as regards the heavy mineral assemblages). Hence, there seems to have been at that time on uplift along the Pombets fault on a scale significant enough to control the nature of sediments, although TANAKA (1959) assumed the existence of such an up-warping belt.

3. Volcanism

Volcanic activity during the period of sedimentation slightly influenced the sediment in this area, as is suggested from the intercalation of acid to intermediate tuff, tuffite and tuffaceous sandstone in a few limited places.

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Hakuyu OKADA

Sedimentology of the Cretaceous Mikasa Formation

Plates 19—24

Plate 19

Explanation of Plate 19

- Figs. 1, 4, 5, 6 and 7. Examples of the Mikasa sandstone from the western to southwestern wing of the anticline. Note an abundance of chert grains. All are of crossed nicols; $\times 25$.
1. Subgraywacke from the Ikushumbets Valley [II]; KU11.
 4. Calcite-cemented subgraywacke from the Pombets Valley [I]; KU85.
 5. Ditto; KU94.
 6. Graywacke from the Yamamoto-no-sawa [V]; KU193.
 7. Calcite-cemented subgraywacke from the Washi-no-sawa [VII]; KU227.
- Fig. 2. Example of the Mikasa sandstone from the eastern wing along the Ikushumbets Valley [XII], Graywacke; KU69. Crossed nicols; $\times 25$.
- Fig. 3. Tuffaceous feldspar sandstone of the Upper Yezo Group from the eastern wing along the Ikushumbets Valley; IK1121. Crossed nicols; $\times 25$.

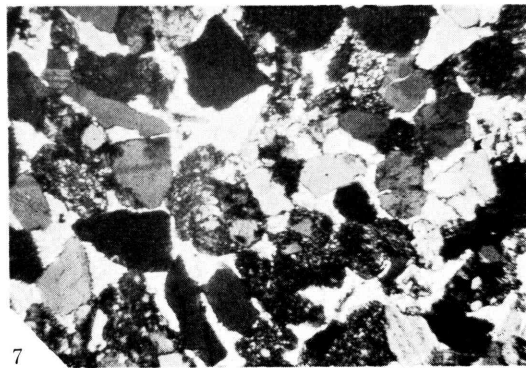
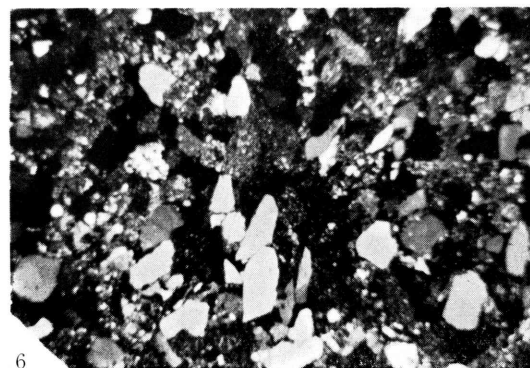
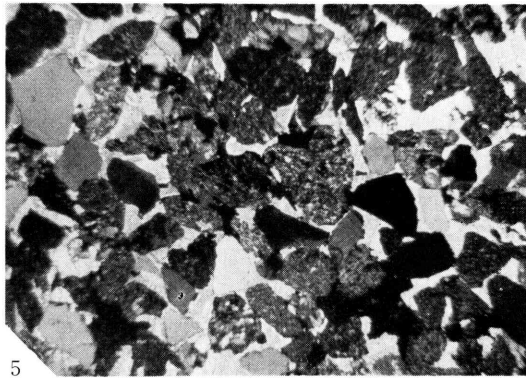
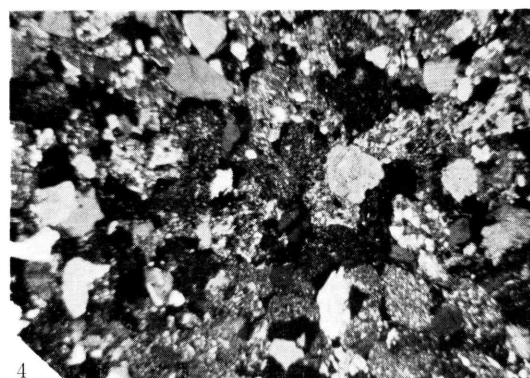
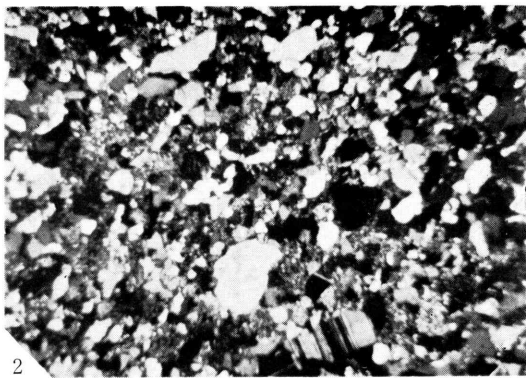
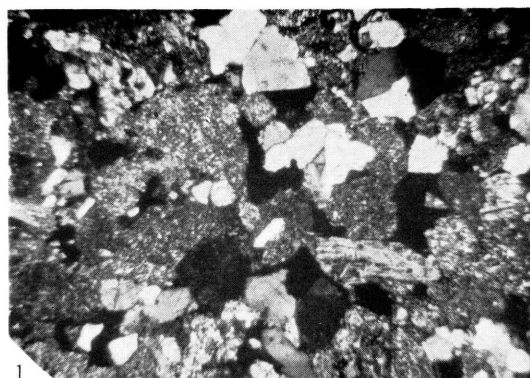


Plate 20

Explanation of Plate 20

Fig. 1. Example of the Mikasa sandstone from the south-western wing of the anticline. Also note an abundance of chert grains. Crossed nicols.

1a. Sparry calcite-cemented subgraywacke from the Nabe-no-sawa [VI]; KU166. $\times 25$.

1b and 1c. Details of the same specimen, KU166, showing the abraded chert grains in

Figure 1b and presence of radiolarian remains in Figure 1c. $\times 50$.

Figs. 2-6. Examples of the Mikasa sandstone from the eastern wing. Crossed nicols; $\times 25$.

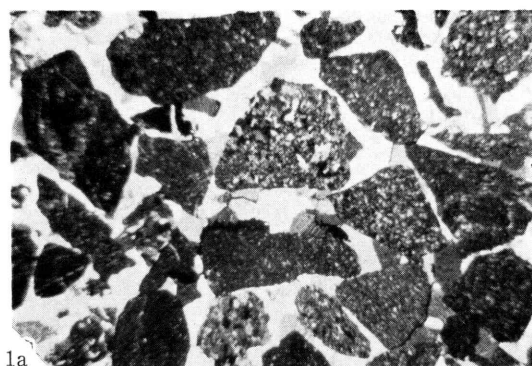
2. Calcite-cemented subgraywacke from the Temmaku-no-sawa [IX]; KU177.

3. Graywacke from the Temmaku-no-sawa [IX]; KU178.

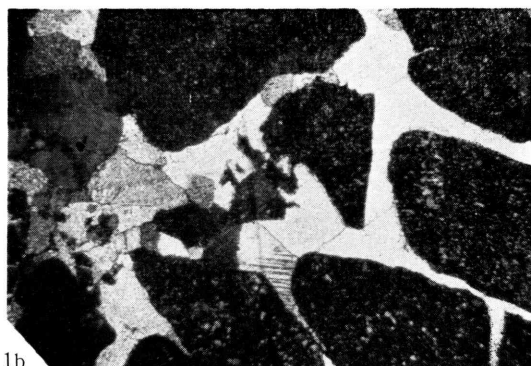
4. Calcite-cemented subgraywacke from the Temmaku-no-sawa [IX]; KU185.

5. Graywacke from the Taki-no-sawa [X]; KU242.

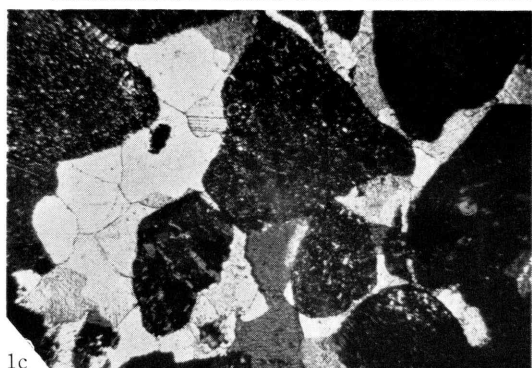
6. Calcite-cemented subgraywacke from the Taki-no-sawa [X]; KU249.



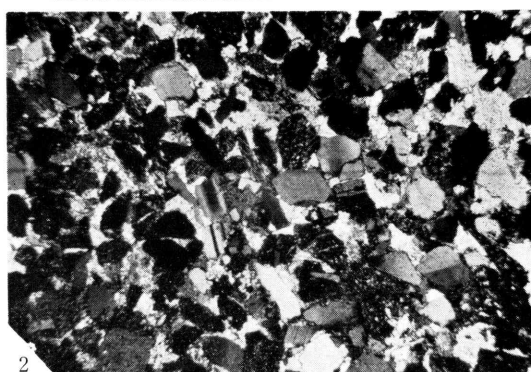
1a



1b



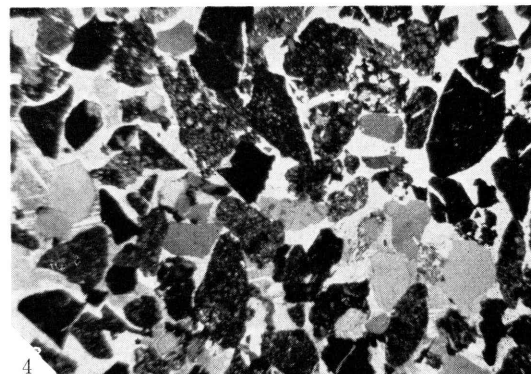
1c



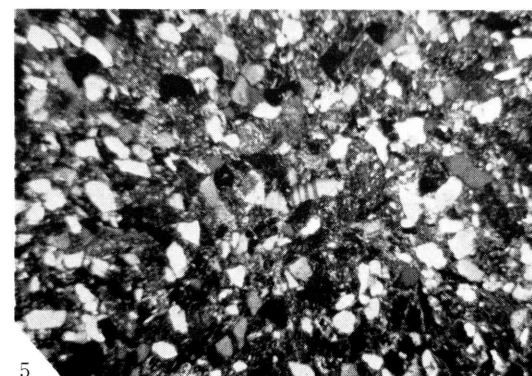
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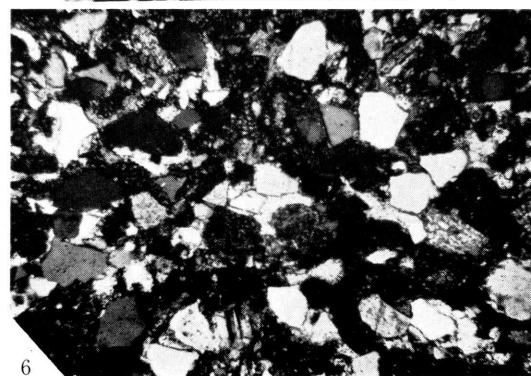
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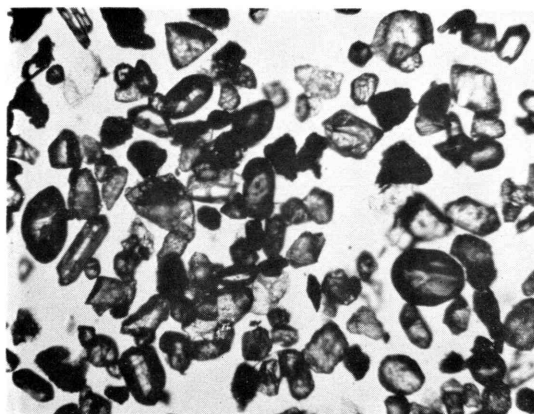


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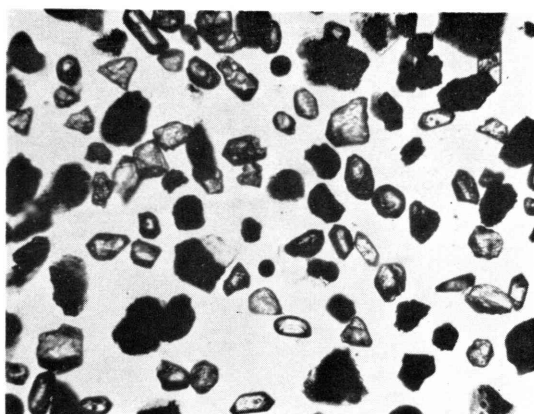
Plate 21

Explanation of Plate 21

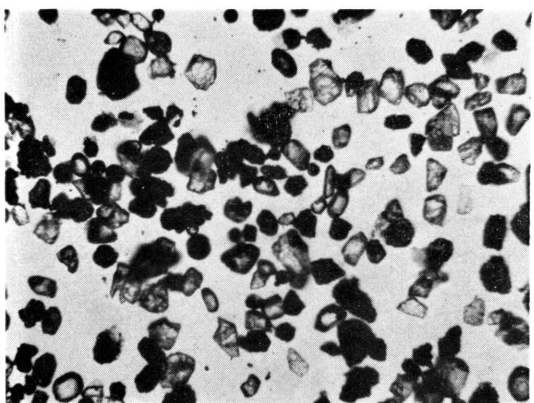
- Fig. 1. Heavy residue concentrated from a sandstone pebble [KU13p] in the Mikasa sandstone on the western wing of the anticline along the Ikushumbets Valley, showing a preponderance of garnet and zircon. Purple rounded zircon is common. $\times 50$.
- Figs. 2-6. Heavy residues of the sandstone of the Lower part of the Middle Yezo Group on the eastern wing of the anticline along the Ikushumbets Valley. Note that all are characterized by garnet and zircon. All figures $\times 50$.
- 2 and 3. Alternating part (lower part) of the Yunosawa Sandstone. 2: KU17 and 3: KU19.
- 4 and 5. Massive part (main part) of the Yunosawa Sandstone. 4: KU26 and 5: KU29.
6. Sequence above the Yunosawa Sandstone. KU36.



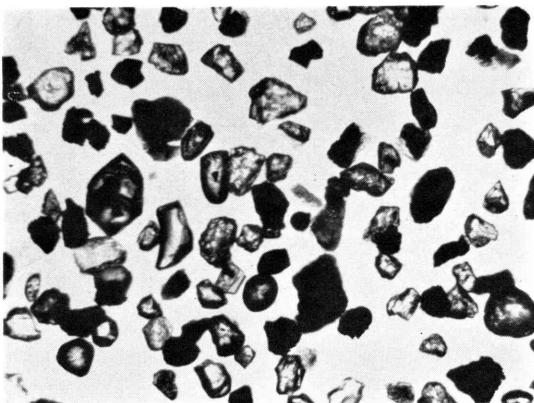
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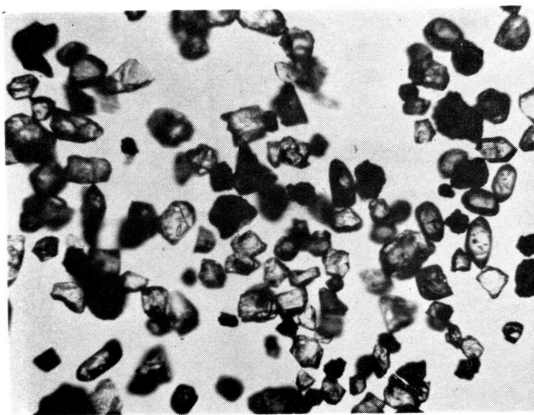
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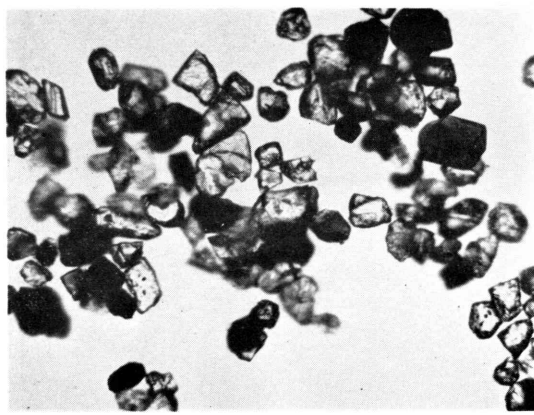
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Plate 22

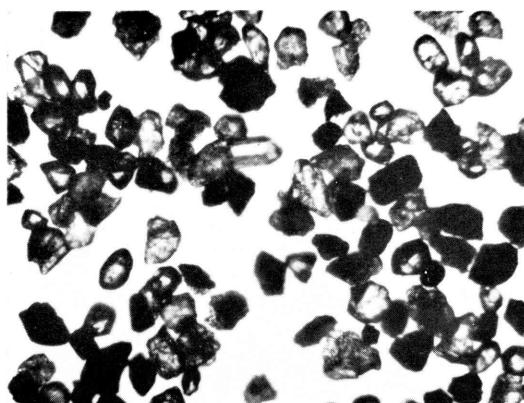
Explanation of Plate 22

Figs. 1-4. Heavy residues of the Mikasa sandstone on the eastern wing along the Ikushumbets Valley. Note an abrupt change in mineral association of the Mikasa Formation from that of the underlying strata, lower part of the Middle Yezo Group. All figures $\times 50$.

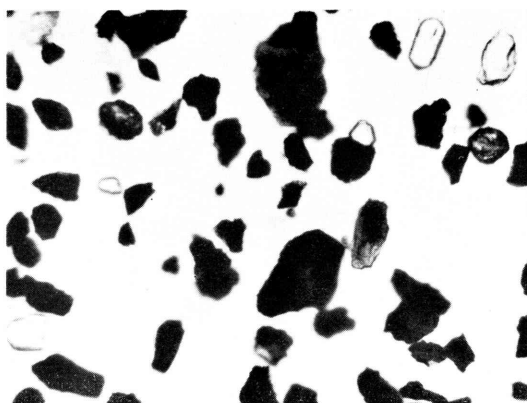
1. Member IIa of the Mikasa Formation. Epidote and augite are predominated, each of which looks similar on the photo. KU44.
2. Member IIa of the Mikasa Formation. Tuffaceous sandstone characterized by ilmenite (black) and apatite (white). IK1056e.
- 3 and 4. Member IIb of the Mikasa Formation. Epidote and augite are also abundant. 3: KU52 and 4: KU53.

Fig. 5. Example of the heavy residue of the Upper Yezo Group on the eastern wing along the Ikushumbets Valley. A marked difference of the Group from the Mikasa Formation is in the preponderance of zircon and garnet. IK976. $\times 50$.

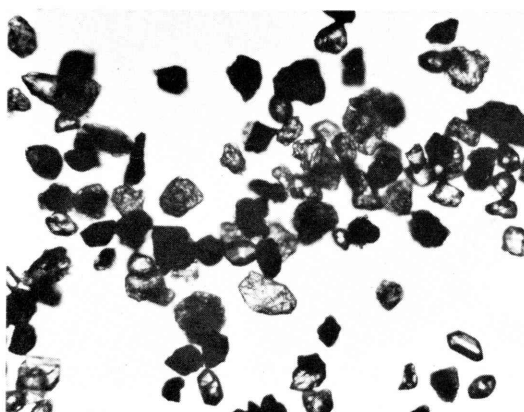
Fig. 6. Mikasa sandstone on the western wing along the Pombets Valley. Epidote is predominant. KU94. $\times 50$.



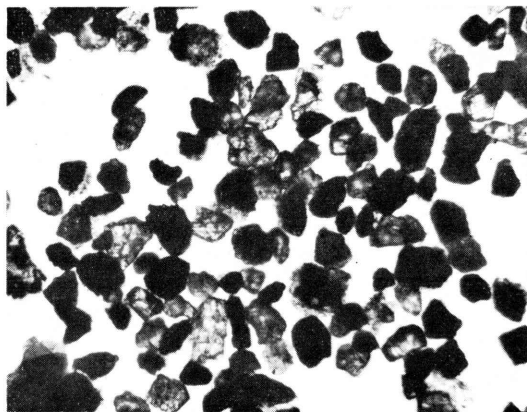
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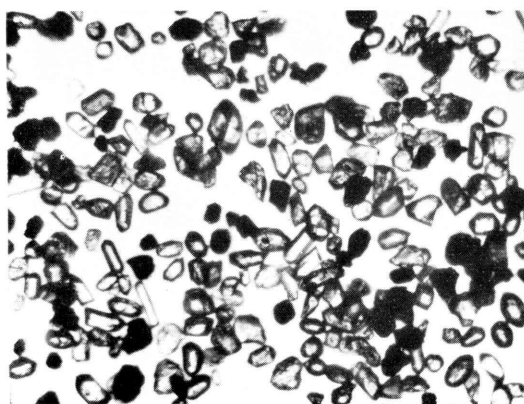
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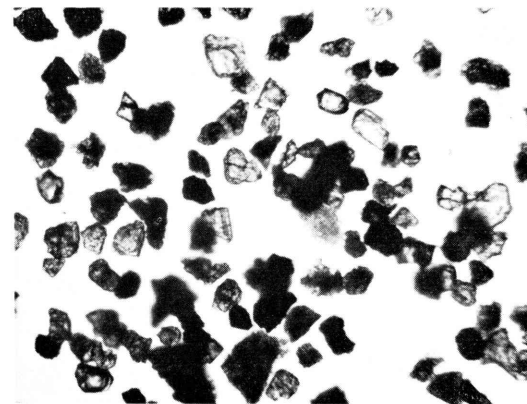
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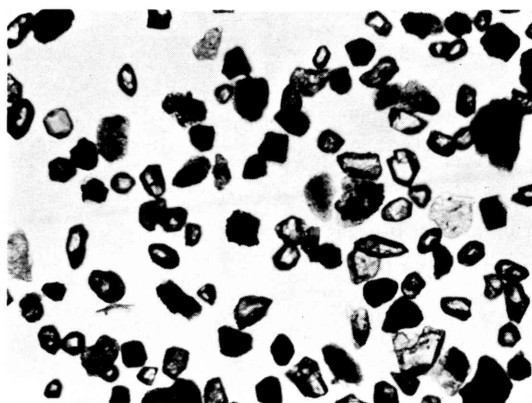


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Plate 23

Explanation of Plate 23

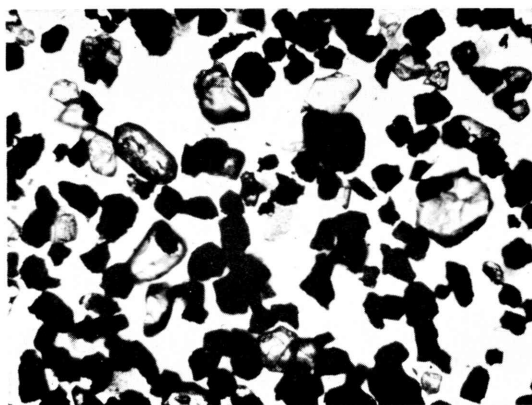
- Fig. 1. Example of the heavy residue of the sandstones of the Middle Yezo Group exposed on the north side of the Pombets fault. Characterized by zircon, garnet, augite and epidote. KU 142. $\times 50$.
- Figs. 2-6. Heavy residues of the Mikasa sandstone on the southwestern to eastern wing of the anticline, indicating the concentration of zircon and garnet. All figures $\times 50$.
2. KU 192, from the Yamamoto-no-sawa [V] (western wing).
 3. KU 193, from the ditto.
 4. KU 225, from the Washi-no-sawa [VII] (western wing).
 5. KU 226, from the ditto.
 6. KU 172, from the No. 4 Map-no-sawa [VIII] (eastern wing).



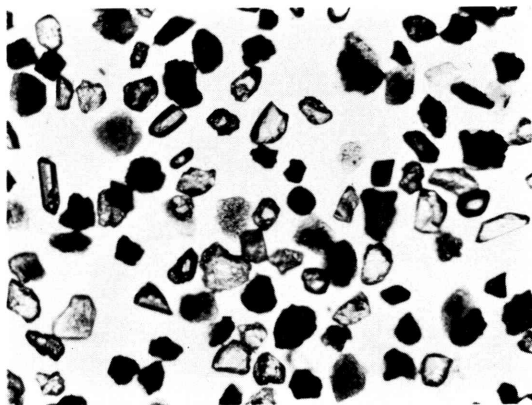
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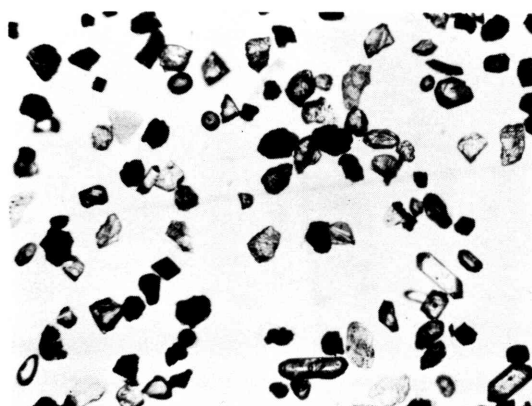
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Plate 24

Explanation of Plate 24

- Figs. 1-2. Heavy residues of the Mikasa Formation in the southern part of the eastern wing, showing the suite of zircon, garnet, epidote and augite. $\times 50$.
1. KU 173 from the No. 4 Map-no-sawa [VIII].
 2. KU 183 from the Temmaku-no-sawa [IX].
- Figs. 3-6. Heavy residues of the Middle Yezo Group cropped out in the Yubari dome, showing a vertical change in mineral association just as in the type section along the Ikushumbets Valley. All figures $\times 50$.
3. Yb 411 from the Member L1 [K3 β] (MATSUMOTO and HARADA, 1964). Note the preponderance of garnet and zircon.
 4. Yb 18 from the Member MK 1 [K4 α] of the Mikasa Formation (MATSUMOTO and HARADA, 1964). Augite is predominant.
 5. Yb 253 from the Member MK 3 [K4 β] of the Mikasa Formation (MATSUMOTO and HARADA, 1964).
 6. Yb 21 from the ditto. Note the augite concentrate.



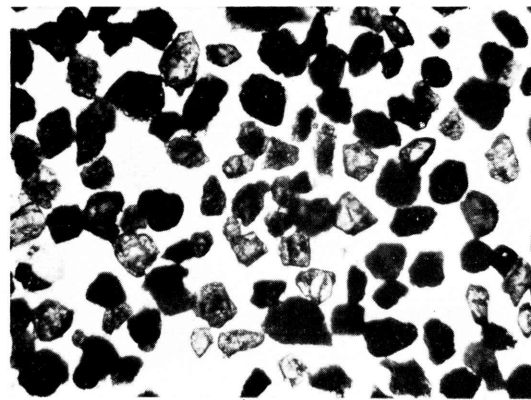
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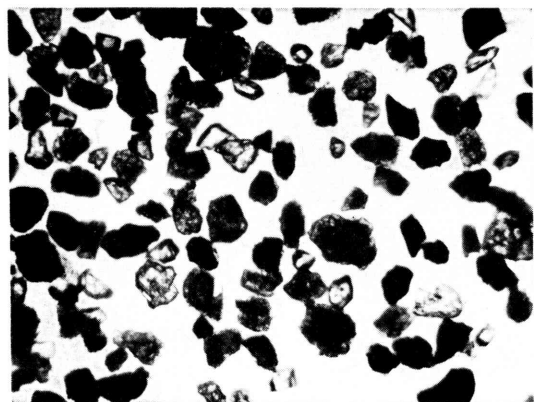
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