

26. Some Heavy Accessory Minerals in Granitic Rocks from the Tsukuba District, Ibaraki Prefecture.*

By Takeshi ICHIMURA,

Yamagata University.

(Received June 28, 1955.)

Introduction

The Tsukuba district includes the southern end of the Abukuma Range and is geologically a well-known area which has already been investigated by H. Yamada¹⁾, B. Suzuki²⁾, R. Ōhashi³⁾, S. Shimizu⁴⁾, Y. Ōdaira⁵⁾, H. Satō⁶⁾, K. Sugi⁷⁾, H. Fujimoto⁸⁾, H. Tsuya⁹⁾, G. Kojima¹⁰⁾, H. Shibata¹¹⁾, K. Kawada¹²⁾, S. Okada¹³⁾ and others. It is mainly built up of granitic rocks and various kinds of metamorphosed sediments assigned to the Upper Paleozoic in association with such basic or ultra-basic rocks as gabbro, norite and gabbro pegmatite as well as anorthosite. The most important rock exposed here is represented by biotite granite traversed by many dykes of pegmatite and aplite. It affected greatly the Paleozoic sediments distributed extensively on the hilly land near Mt. Tsukuba, resulting in the contamination of sediments due to the intrusion, formation of ball granite, *lit par lit* injection of

* Communicated by N. Nasu.

- 1) H. YAMADA, *Geol. Map, Mito, 1:200,000 and Its Explanatory Text*, (1888).
- 2) B. SUZUKI, *Bull. Geol. Surv. Japan*, **18** (1905).
- 3) R. ŌHASHI, *Jour. Geol. Soc. Tokyo*, **18** (1911).
- 4) S. SHIMIZU, *Jour. Geogr.*, **25** (1913).
- 5) Y. ŌDAIRA, *Ms. Geol. Inst. Tokyo Univ.*, (1925).
- 6) H. SATŌ, *Geol. Map, Tsukuba, 1:70,000 and Its Explanatory Text*, (1927).
- 7) K. SUGI, *Jour. Geol. Soc. Tokyo*, **34** (1927), 358-375: *Jour. Geol. Soc. Tokyo*, **35** (1928): *Jap. Jour. Geol. & Geogr.*, **8** (1930), 29-112.
- 8) H. FUJIMOTO, *Jour. Geol. Soc. Japan*, **45** (1938), 377.
- 9) H. TSUYA, *Bull. Earthq. Tokyo Univ.*, **17** (1937), 517-534.
- 10) G. KOJIMA, *Kagaku*, **13** (1943), 167-168.
- 11) H. SHIBATA, *Stud. Geol. & Min. Inst.*, T. K. D., 1944: *Jour. Geol. Soc. Japan*, **57** (1951): *Sc. Rept. T. K. D.*, [C], **3** (1954), 159-161.
- 12) K. KAWADA, *Jour. Geol. Soc. Japan*, **53** (1947), 622-627: *Jour. Geol. Soc. Japan*, **54** (1948), 639: *Sc. Rept. T. B. D.*, [C], **2** (1953), 217-307.
- 13) S. OKADA, N. SHIMODA & H. SHIBATA, *Stud. Geol. & Min. Inst. T. K. D.*, (1954), 197-203.

igneous materials, etc. Such geological features attracted the writer's attention to the granitic rocks of this district. In addition, the writer was born in this district and was, therefore, in a favourable position to examine these granitic rocks from place to place. During his repeated field works, various specimens were collected from many localities of this granitic area. They were mineralogically investigated, and some of them were chemically analysed. In the former case, the writer had a special interest in heavy accessory minerals which had almost been neglected formerly in the microscopical investigation of such granitic rocks, because they have quite a similar character in the same granitic body except for its contaminated part.

The writer crushed various specimens obtained from different parts of granitic bodies including the contact aureole, and the heavy accessory minerals extracted in this way were crystallographically and optically investigated to confirm whether there are dissimilarities or not in different kinds of granitic rocks. The results are summarized in this paper.

General Features of Mother Rocks

The granitic rocks under consideration begin to be exposed at the southern periphery of the hilly land adjoining Mt. Tsukuba, Mt. Ashio, Mt. Kaba, Mt. Amabiki and the surrounding area. They are mostly biotite or two-mica granites with varying petrographical and chemical characters. These granites are traversed by pegmatite or aplite and intruded through with the Upper Paleozoic sediments, giving striking contact effects and capturing their fragments as well as the big gabbroic xenoliths which are composed of uralite gabbro, hornblende gabbro, olivine gabbro, norite, gabbro pegmatite in association with amphibolite and anorthosite. Most of such granites are being quarried at many places of the area extending over Hōjō, Oda, Shichiku-mura, Makabe, Yubukuro, Minedera-san, Yamanoo, Amabiki, Nishiyama, Mito, Inada, etc. Of these, the so-called "Inada granite" is very famous as a building stone of high quality.

In Okada's recent paper¹⁴⁾, the granites exposed in this district are divided into such three types as the Tsukuba-type granite, Inada-type granite and Kamishiro-type granite. In these cases, The Tsukuba-type granite consists of biotite or two-mica granite and is well exposed at the

14) S. OKADA, *op. cit.*, (1954), 217-307.

southern part of this granitic area, passing northwards into the Inada-type granite which surrounds the Kamishiro-type granite near Nishiyama, Mito and Kitanakayama.

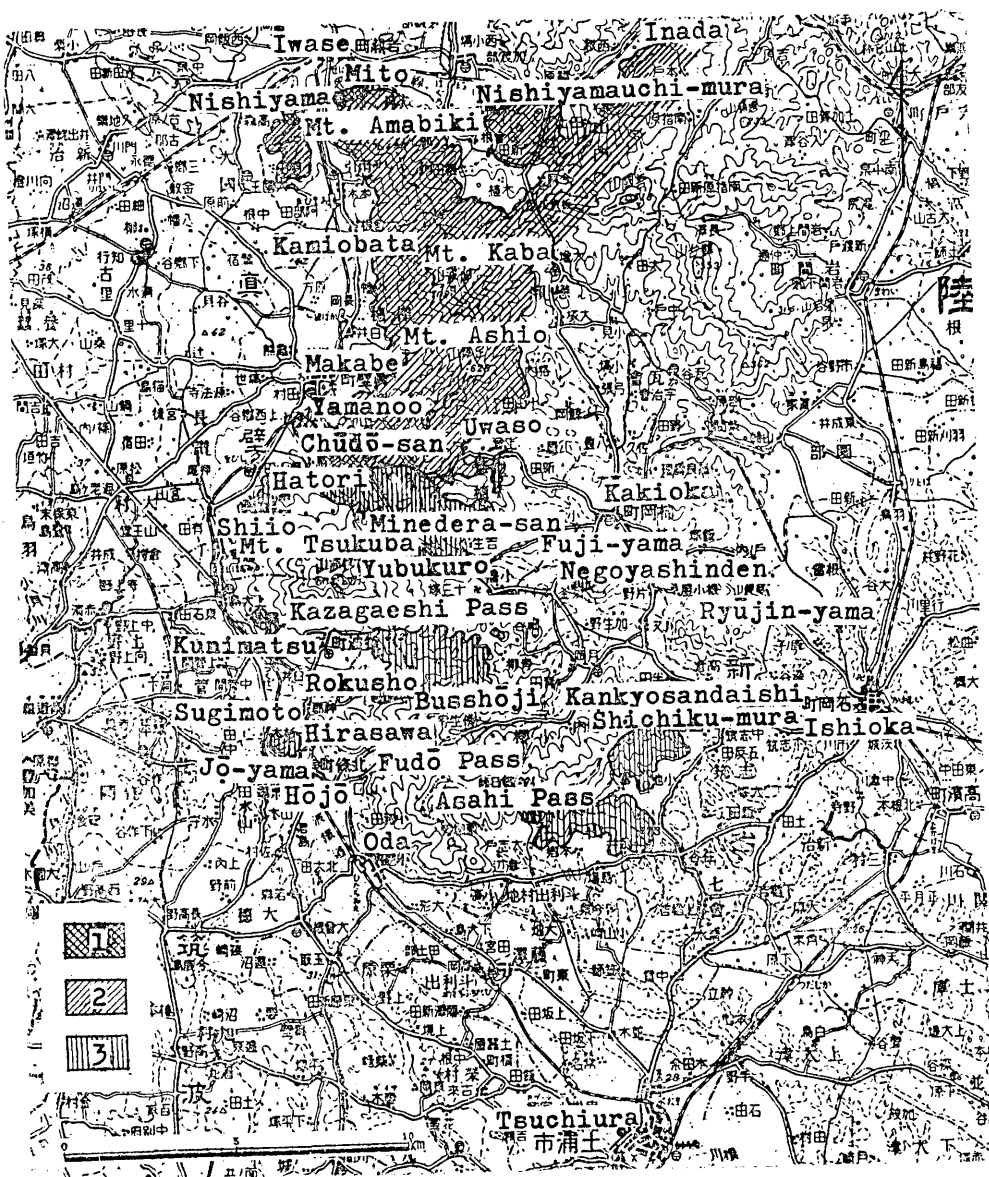


Fig. 1. Map showing the distribution of granitic rocks in the Tsukuba district.
1=Kamishiro-type granite, 2=Inada-type granite, 3=Tsukuba-type granite.

The Tsukuba-type granite is partly represented by a porphyritic biotite granite which are in contact with metamorphosed sediments characterized by the occurrence of various kinds of contact minerals such as andalusite, cordierite, diopside, hornblende, garnet and sillimanite.

The porphyritic biotite granite of this district consists of quartz, orthoclase, oligoclase, andesine, biotite and various kinds of heavy accessory minerals. The most characteristic feature is the abundance of the large phenocrystic orthoclase, frequently more than 2 cm. long. Some of orthoclase crystals, large or small, indicate a perthitic intergrowth by containing irregular albite patches. This type of porphyritic biotite granite is widely distributed in the area which includes Hōjō, Oda, Rokusho, Kazagaeshi Pass, Fudō Pass, Fuji-yama, Asahi Pass, Kunitatsu, Tsukuba-machi, Shiio, Minedera-san and others. In the contact aureole, it contains abundant xenoliths of intruded sediments and partly resulted in the formation of a ball granite as is shown by that of Minedera-san. The frequency of these xenoliths increases on approaching the contact where irregular aplitic veins commonly occur without any sharp boundary between the mother rock.

The porphyritic biotite granite, on the other hand, grades into the non-porphyritic variety with a minor amount of muscovite at Shichikamura and Oda as well as on Jō-yama or elsewhere. It is also very noteworthy that the foundation of Mt. Tsukuba is built up of the porphyritic biotite granite on which a large mass of gabbroic rock is found as an erosion remnant.

The Inada-type granite is largely exposed at the mountainous area situated at the north of the line connecting Uwaso to Hatori. It is non-porphyritic granite with some features different from the Tsukuba-type granite, being composed of quartz, orthoclase, oligoclase, andesine, biotite, muscovite and its accessory minerals. The specimens collected on Chūdō-san, Mt. Ashio and Mt. Kaba as well as at the Kamiobata quarry of Amabiki-mura indicate different textures from coarse to fine. Some of these have dark colors due to the abundance of minute biotite flakes and are rich in xenoliths. They can be obtained at the Chūdō-san quarry and its vicinity. The boundary between the Inada-type granite and Tsukuba-type granite could not be confirmed exactly by the writer. As to the Kamishiro-type granite, the writer is unfortunately not acquainted with its mode of occurrence. It is, therefore, eliminated from the writer's present paper.

Chemically speaking, the silica percentage of the porphyritic biotite granite shows a tendency to become lower than the non-porphyritic variety. For instance, the biotite granite obtained from Jō-yama shows a high percentage of silica as compared with the porphyritic variety of Jō-yama and Hirasawa. The same may be said in comparing the porphyritic variety with the Inada-type granite which is non-porphyritic. The results of chemical analyses carried out on several mother rocks are summarized in the following table (Table I).

Table I. Chemical composition of some granites from the Tsukuba district.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
SiO ₂	74.48	65.88	64.23	66.63	70.91	74.38	71.80
Al ₂ O ₃	14.00	17.48	18.09	16.28	14.38	14.33	15.11
Fe ₂ O ₃	0.15	0.49	0.58	0.15	0.40	0.26	0.28
FeO	1.52	4.02	4.11	4.47	2.54	1.40	2.03
MgO	0.35	0.75	1.38	1.24	0.28	0.17	0.20
CaO	2.57	4.01	4.99	3.33	2.60	1.80	2.27
Na ₂ O	3.44	3.55	3.04	3.53	3.30	3.10	3.24
K ₂ O	2.99	2.59	2.83	2.59	2.59	3.48	2.93
H ₂ O+	0.25	0.73	0.39	0.66	0.89	0.65	0.77
H ₂ O-	0.06	0.06	0.09	0.12	0.25	0.26	0.32
TiO ₂	0.13	0.47	0.35	0.58	0.36	0.18	0.34
P ₂ O ₅	0.09	0.16	0.12	0.21	0.32	0.15	0.24
MnO	0.28	0.20	0.27	0.09	0.30	0.11	0.18
S					0.11	0.03	0.05
ZrO ₂						0.05	
Total	100.34	100.19	100.47	99.88	99.23	100.35	99.78
Norm							
Q	36.12	23.94	20.22	24.18	34.68	38.34	35.94
or	17.79	15.57	16.68	15.57	15.57	20.57	17.24
ab	28.82	28.30	25.68	29.87	27.72	26.20	27.25
an	11.95	19.18	23.91	15.57	11.12	8.06	9.73
C	0.71	2.04	1.22	1.94	2.04	2.45	2.45
Fs	2.90	6.60	7.00	7.26	4.09	2.24	3.30
En	0.90	1.90	3.50	3.10	0.70	0.40	0.50
mt	0.23	0.70	0.93	0.23	0.70	0.46	0.46
il	0.30	0.91	0.61	1.06	0.76	0.30	0.60
ap	0.34	0.34	0.34	0.34	0.67	0.34	0.67

(to be continued.)

Table I.

(continued.)

Niggli's value

si	405.54	238.46	238.52	277.75	369.35	433.56	383.63
al	44.77	41.81	39.42	40.00	44.06	48.95	47.44
fm	11.77	20.54	23.16	24.00	16.25	9.44	12.82
c	15.03	17.60	19.82	14.75	14.38	11.19	13.14
alk	28.43	20.05	17.60	21.25	25.31	30.42	26.60
mg	0.25	0.23	0.34	0.32	0.13	0.07	0.13
k	0.37	0.34	0.37	0.67	0.35	0.43	0.37
c/fm	1.28	0.86	0.86	0.61	0.88	1.19	1.03

or : ab : an in norm

or	30.38	24.69	25.17	25.52	28.61	37.51	31.80
ab	49.21	44.89	38.75	48.96	50.95	47.79	50.26
an	20.41	30.42	36.06	25.52	20.44	14.70	17.94

- (1) Two-mica granite from the Jō-yama quarry, Analysed by K. Azuma.
- (2) Porphyritic biotite granite from the Jō-yama quarry, Analysed by K. Azuma.
- (3) Porphyritic biotite granite from the Hirasawa quarry, Analysed by K. Azuma.
- (4) Porphyritic biotite granite from the Hirasawa quarry, Analysed by S. Tanaka.
- (5) Biotite granite from the Kitaishi quarry, Kabaho-mura, Analysed at Geol. Surv.
- (6) Biotite granite from the Hikage-yama quarry, Nishiyamauchi-mura, Analysed at Geol. Surv.
- (7) Hornblende biotite granite from the Fujita-yama quarry, Kabaho-mura, Analysed at Geol. Surv.

Mineralogical and Optical Characters of Heavy Accessory Minerals

The writer crushed many specimens collected from the Tsukuba district to extract heavy accessory minerals from granitic rocks. For this purpose, he used Thoulet solution and could concentrate such heavy accessory minerals as zircon, monazite, apatite, garnet, titanite, allanite and magnetite. Of these, zircon is the commonest accessory mineral in all kinds of granitic rocks. It occurs as colorless or pink crystal with a long or short prismatic habit. Mostly, the crystals have a well-defined form which is composed of prism and pyramid, although there are sometimes rounded crystals. They are simple or complicated combination of $a(100)$, $m(110)$, $p(111)$, $x(311)$ and $u(331)$. So far as has been examined by the writer, the commonest form is represented by such combinations as p and a , p and m or p , a and m , but various types of crystal form associated with x or u can be seen in biotite or two-mica granites from the Oda quarry and the Kamiobata quarry, although u is rather rare as compared with the frequent occurrence of x .

Sometimes, both the colorless and pink zircon are found together, as is shown by several cases of the Hirasawa quarry (Fig. 2) and also in the specimen from the hill near Sugimoto. In such cases, the colorless zircon is more abundant than that with a pink color, and it seems that there is a transition stage of color between them. The colorless variety is always very clear and transparent, taking usually a long and sharp prismatic form in contrast with the short prismatic habit of the pink crystal. Frequently, it contains microlites with unknown characters, and the amount of such colorless zircon is increased in the specimens from Hirasawa, Kankyosandaishi (Fig. 3) and Rokusho where the Tsukuba-type granite is exposed at or near the contact with Paleozoic sediments. The same may be said of the specimens rich in xenoliths. This is one of the chief points different from the Inada-type granite obtained on Mt. Amabiki, Mt. Kaba and Mt. Ashio, in which beautiful zircon crystals are scarcely present and those with a short prismatic habit are rather abundant. The combination of a , p , m and x is frequently seen in the specimens obtained from the Kamiobata quarry (Fig. 4) and the Oda quarry.

The length of these crystals shows a wide range. The largest crystal is 0.35 mm. long in the colorless variety, whereas it is 0.25 mm. long in the pink one. The beautiful crystal with a sharp outline was found in the specimens from the Hirasawa quarry and the Kankyosan quarry (Fig. 4). The zircon crystals mentioned above are generally enclosed in biotite flakes to which they afford a pleochroic halo along the contact between them.

The occurrence of monazite is also known occasionally in granitic rocks of the Tsukuba district. It has a stout prismatic or somewhat rounded form, being composed of $a(100)$, $m(110)$, $b(010)$, $u(021)$, $w(101)$, $v(\bar{1}11)$ and $x(\bar{1}01)$. As is indicated by many crystals, a , b , m and w are easily recognized when compared with u , v and x . The mineral is weakly pleochroic, viz., x =light greenish yellow and z =light yellow. The extinction angle, $Z \wedge c$, is 2° . Some of the crystals enclose minute particles undetermined.

It is very noteworthy that monazite is found in almost all specimens including the Tsukuba-type granite and Inada-type granite, although its amount is variable from place to place. The high frequency of this mineral is shown by various specimens from the Hirasawa quarry (Figs. 5-6). Jō-yama quarry, Kamiobata quarry, Oda quarry and Mt. Ashio as well as from the pass between Uwaso and Makabe.

In these cases, granitic rocks of the Hirasawa quarry reveal the highest frequency of monazite crystals. The writer also examined biotite-rich granite near the contact and transition part between such a granite and aplitic rock. Occasionally, they contain good crystals suitable for determining such faces as a , m , b , u , v , x and w . The largest crystal is 0.27 mm. long and 0.19 mm. across. The aplitic rock exposed here is similarly rich in minute crystals of monazite as compared with the ordinary porphyritic biotite granite.

A characteristic feature is also shown by the abundance of apatite crystal (Fig. 7). It is a common mineral in the porphyritic biotite granite of the Tsukuba-type, particularly in the specimens from near the contact, where biotite is remarkably increased. Most of the apatite crystals are contained in such biotite flakes, but isolated crystals may also be seen in these specimens. The apatite crystals examined by the writer generally assume a short prismatic or rounded form. The largest crystal with an elongated form is 0.37 mm. long. They are colorless and mostly very clear in appearance. Rarely, such prismatic crystals have a dark grey core which seems to be a decomposed part. They may be a combination of several forms, viz., pyramid, prism and base, but there is no distinct face exactly determined except prism. Sometimes, enclosures of unknown character are to be seen.

The specimens collected from the direct contact have a tendency to be rich in this mineral. It is, however, quite or almost absent in the Inada-type granite and in the specimens from the quarry situated at the south of Kankyosandaishi.

Besides these, garnet is also a well-known mineral in granitic rocks of this district. The most important locality is represented by Yamano where beautiful crystals with icositetrahedral habit were found from pegmatites. They are, however, nearly exhausted at present. In other localities, garnet is only an accessory mineral which is about 2 mm. across in the large crystals. The mineral is pink or rarely colorless and commonly assumes a rounded form without showing any well-defined crystal faces. Such garnet crystals can be seen in the specimens from Jō-yama, Hirasawa, Negoyashinden and others. Of these, the pink variety shows some similarities to almandite.

In the specimens from near Rokusho, the writer noticed the frequent occurrence of titanite, which is found together with zircon, apatite and monazite, although its crystal can not be recognized with the naked eye. It has a light brown color and occurs in an anhedral

form, being not infrequently associated with biotite flakes. Titanite is, however, a scanty ingredient of the granitic rocks under consideration, and it is nearly or entirely absent in the writer's specimens from other localities except when secondarily derived from biotite in its chloritization.

Similarly, allanite may be seen to a very small extent. It is a black or dark brown mineral with a subhedral or anhedral form. In thin sections, this mineral is distinctly pleochroic from brownish yellow (X) to reddish brown (Y) or light yellow (Z), and its absorption is $Y > X > Z$. When the crystal is in contact with biotite flake, the former gives a striking pleochroic halo to the latter. Such optical characters can be determined in the specimens from near Rokusho where the porphyritic biotite granite frequently contains allanite crystals. Sometimes, they enclose minute apatite crystals and are occasionally characterized by a zonal structure. The writer similarly found allanite in the porphyritic biotite granites from Hirasawa and Jō-yama.

Geological Significance Suggested by Some Heavy Accessory Minerals

As has already been stated, granitic rocks of this district contain various kinds of heavy accessory minerals which have some features differing from place to place. One of these is indicated by zircon. This mineral is characterized by the occurrence of two different crystal habits, long prismatic or stout prismatic. Such types of crystals are to be commonly found in the Tsukuba-type granite including biotite or two-mica granite. In this case, long and sharp prismatic crystals are abundantly present as compared with those of another type. The Inada-type granite, on the other hand, is nearly free of elongated forms, although colorless and pink zircon crystals are co-existing as in the case of the Tsukuba-type granite.

As to the dissimilarities in crystal habits and colors indicated by zircon, the writer has already noticed them in several granites and associated gold placers in Hainan Island¹⁵⁾. A similar idea has been proposed recently by Karakida¹⁶⁾ who discussed on the zircon zone at the contact of the Cretaceous granodiorite and granite. The same may be said of the zircon crystals contained in the Tsukuba-type and Inada-type granites which were supposed by Shibata to have successively

15) T. ICHIMURA, *Mem. Fac. Sc. Taihoku Imp. Univ.* [iii], 1 (1944), 126-128.

16) Y. KARAKIDA, *Jour. Geol. Soc. Jap.*, 60 (1954), 517-532.

been intruded. Such difference of crystal habit as mentioned above is, however, unavailable in confirming the order of intrusion between these two types of granite.

As to the geological age of granitic intrusion in this district, there are some different opinions. Tomita applied his zircon method to the Inada-type granite exposed in the Toriashi district farther north, and he fixed its geological age as the Miocene. This had, however, already been discussed by Kawada¹⁷⁾ who supposed that its intrusion had taken place after the deposition of the Toriashi Group (Permian) and before that of the Torinoko Group (Jurassic).

Monazite is not a mineral so significant as in the case of zircon, because it shows the same crystallographical and optical characters in all the specimens of granitic rocks obtained from various localities of the Tsukuba district. It is, however, noteworthy that this accessory ingredient is more abundantly present in the contact aureole, particularly in the granitic rocks of the Hirasawa quarry, where they had remarkable contact effects on the Paleozoic sediments.

A quite similar tendency is shown by the distribution of apatite crystals whose amount is proportional to that of biotite. It is clearly indicated in the porphyritic biotite granite. The high frequency of monazite and apatite, therefore, suggests that these granites were once found close to the contact, if metamorphosed sediments were already eroded away from the contact aureole.

Garnet, titanite and allanite are, however, unimportant heavy accessory minerals having little bearing on the writer's present idea, because they are contained in quite negligible amount.

Summary

(i) Biotite granite or two-mica granite is extensively exposed in the Tsukuba district, where the Upper Paleozoic sediments were intensely metamorphosed by their large intrusive bodies. They are represented by the Tsukuba-type, Inada-type and Kamishiro-type granites which were successively intruded.

(ii) Of these, the Tsukuba-type and Inada-type granites were selected to investigate their heavy accessory minerals. These granites were crushed, and heavy accessory minerals were separated by using Thoulet solution.

17) K. KAWADA, *op. cit.* (1953), 256, 304.

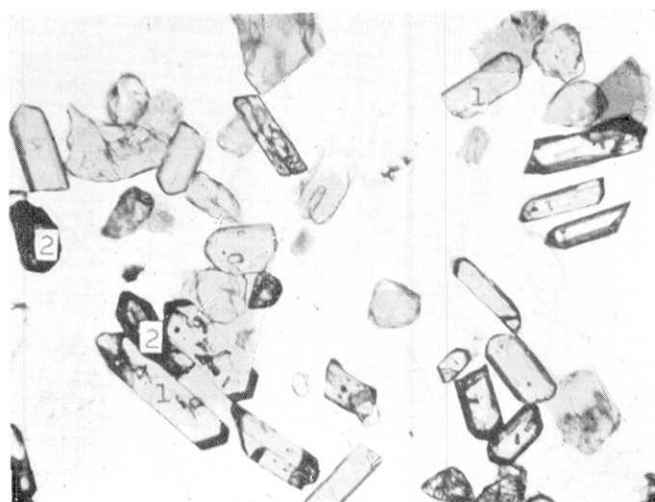


Fig. 2. Colorless or pink zircons of porphyritic biotite granite. (Hirasawa). $\times 100$. 1=Colorless zircon, 2=pink zircon.
Tsukuba-type granite.

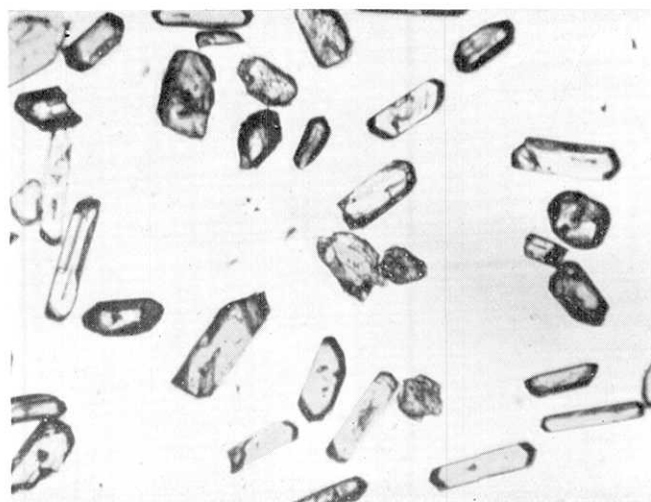


Fig. 3. Zircon crystals of two-mica granite. (Kankyosandaishi). $\times 100$.
Tsukuba-type granite.

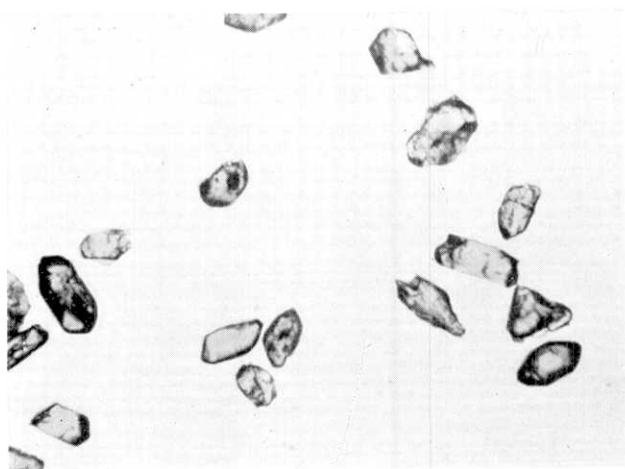


Fig. 4. Zircon crystals of biotite granite. (Kamiobata quarry).
× 100. Inada-type granite.

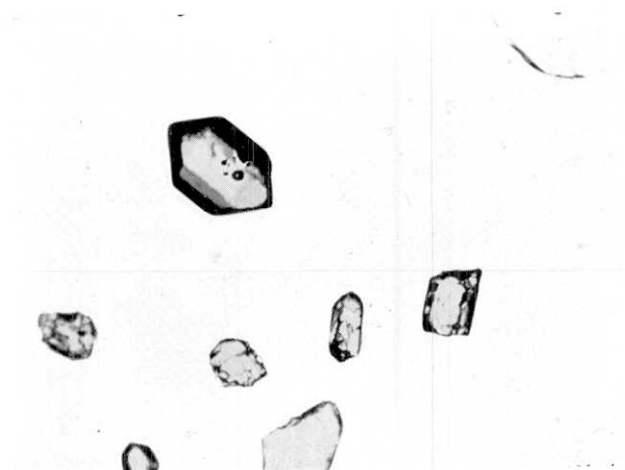


Fig. 5. Monazite crystal of porphyritic biotite granite. (Hira-
sawa). × 100. Tsukuba-type granite.

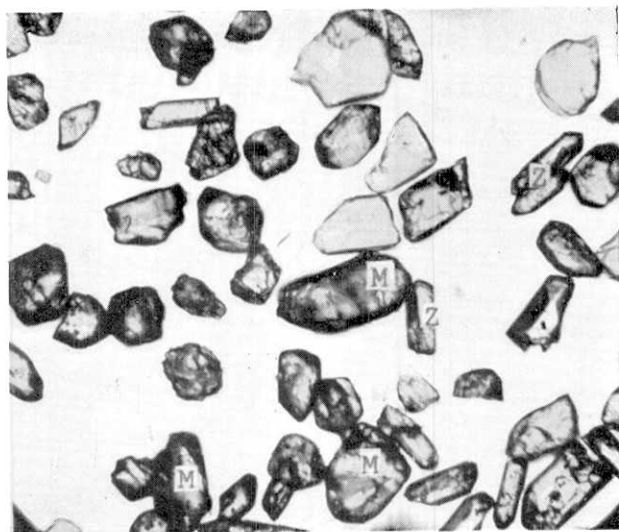


Fig. 6. Zircon and monazite crystals of porphyritic biotite granite. (Hirasawa). $\times 100$. M=Monazite, Z=Zircon.
Tsukuba-type granite.

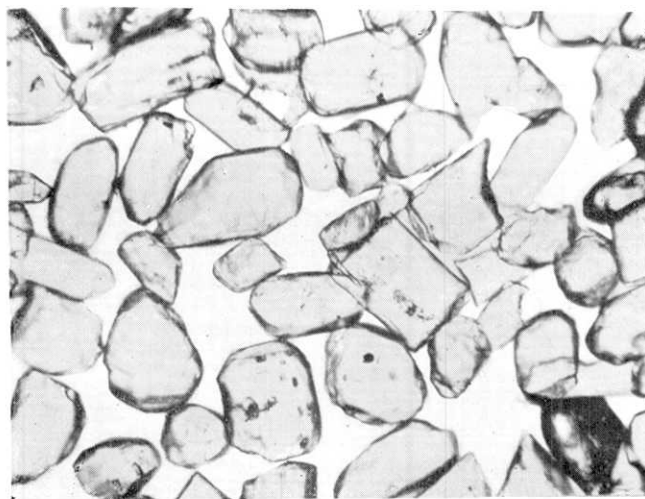


Fig. 7. Apatite crystals of porphyritic biotite granite. (Hirasawa). $\times 100$.
Tsukuba-type granite.

(iii) The heavy accessory minerals thus obtained and examined are zircon, monazite, apatite, garnet, titanite and allanite. The amount of these minerals varies from place to place.

(iv) The commonest one is shown by zircon which has different crystal habits and colors even in the same specimen. The zircon taken out from the Tsukuba-type granite is characterized by the abundance of sharp and long prismatic forms. It is colorless and has a very clear appearance. On the contrary, that of the Inada-type granite is mostly represented by stout prismatic crystals which are occasionally rounded. Such difference in crystal form may be of use in clarifying the distinction between these two types of granite.

(v) Moreover, it is noteworthy that the same specimens contain colorless and pink zircon crystals together in various proportions. This is a common feature to be seen in the biotite or two-mica granite of the Tsukuba district. In such a case, it is, however, uncertain whether there are zircon crystals derived from Paleozoic sediments subjected to contamination.

(vi) Monazite and apatite are also important accessory minerals of granitic rocks exposed in the contact aureole. They are especially concentrated near the contact, where Paleozoic sediments are highly metamorphosed. In such a case, the frequency of apatite seems to increase in proportion to the amount of biotite.

26. 筑波地方産花崗岩の副成分重鉱物

山形大学 市 村 毅

筑波地方に産する2種の花崗岩（稲田型花崗岩と筑波型花崗岩）に含まれる副成分重鉱物の中、ジルコン、モナヅ石、磷灰石、クサビ石、柘榴石、褐簾石などについて、顕微鏡下の研究を行った。この結果、ジルコンは、貫入期を異にするこれ等兩種の花崗岩を区別するに役立ち、又モナヅ石や磷灰石には、両花崗岩共、秩父系との接触部やそれに近い場所、或はその捕獲岩に富む場合に殊更集中する傾向があることを確めた。然し柘榴石とかクサビ石とか褐簾石には、斯る特徴が認められない。
