PETROLOGY OF THE TRACHYTIC ROCKS OF NORTHEAST JAPAN (II)

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PETROCHEMISTRY

Bulk Composition

Bulk compositions of 16 representative samples of the trachytic rocks from the Japan Sea Borderland of Northeast Japan are given in Table 3.

The compositions of the trachytic rocks indicate a distinct limitation with regard to SiO_2 content, that is from 58 to 70% in every region, and when the range is classified into three groups of 58 to 60%, 60 to 65%, and 67 to 70%, each group is characterized by respective peculiarity both megascopically and microscopically as mentioned already.

In the Oga Peninsula where volcanic activities were continuous the SiO_2 content of the trachytic rocks increase from the lower stratigraphic horizon to the higher one accompanying with the change of the types of rock intermediate to acidic in the same sequence. In regions other than that of the Oga Peninsula, the intermediate type generally is found in the lower stratigraphic horizon.

Comparing the bulk compositions of the trachytic rocks with those of Daly's average, Type I of the trachytic rocks is intermediate between average andesite and trachyandesite, and Type II is similar to his average trachytes including alkali-trachytes and sub-alkalic trachytes, while Type III may nearly belong to rhyolite.

The writer takes the value of total alkalis as an index to distinguish the trachytic rocks among the so-called semi-alkalic rocks. That is to say, the value roughly takes the range of 6.2 to 9.0% when the range of SiO_2 is 58 to 70%, and it is a little less than that of alkalic rocks and a little greater than those of calc-alkalic rocks and tholeiitic rocks found in other regions of Japan. The situation

Table 3. Chemical compositions and norms of the trachytic rocks in the

	1	2	3	4	5	6	7	8
SiO ₂	59.77	62.49	63.10	69.64	58.81	63.64	67.27	67.61
TiO ₂	0.89	0.46	0.37	0.13	0.54	0.29	0.46	0.50
Al ₂ O ₃	16.28	15.78	16.10	15.25	19.65	17.83	15.82	15.68
Fe ₂ O ₃	2.52	3.74	2.54	1.86	5.18	3.92	2.28	1.32
FeO	3.41	1.16	1.18	1.06	1.68	0.71	0.93	2.02
MnO	0.10	0.12	0.12	0.05	0.08	0.02	0.02	0.02
MgO	2.28	1.17	0.30	0.22	1.38	1.03	1.43	1.12
CaO	3.68	3.35	3.35	0.63	2.29	1.37	2.91	2.29
Na ₂ O	4.06	4.10	4.14	5.35	4.99	4.54	5.17	4.61
K ₂ O	2.47	2.48	3.25	3.61	1.84	2.32	2.33	2.27
P ₂ O ₅	0.25	0.22	2.22	0.09	0.10	0.08	0.13	0.10
H ₂ O+	3.01	3.49	2.63	1.01	2.15	2.71	1.05	2.11
H ₂ O-	0.92	1.29	1.20	0.62	1.51	1.04	0.71	0.85
Total	99.64	99.85	100.50	99.53	100.20	99.50	100.51	100.50
Analyst	Miyagi	Miyagi	Miyagi	Miyagi	Miyagi	Miyagi	Kawano	Miyagi

1. Aphyric trachytic rock (Oga Peninsula)
- 2,3. Amphibole trachytic rock (")
4. Biotite trachytic rock (")
5. Aphyric trachytic rock (Atsumi region)
6. Amphibole trachytic rock (")
- 7,8. Aphyric trachytic rock (")

is clearly shown on the following variation diagrams of oxides.

This fact gives an important suggestion to consider the origin of the trachytic rocks as mentioned later.

Variation Diagrams of Oxides

The variation diagrams of oxides of the trachytic rocks are given in Fig. 3, comparing with those of the calc-alkalic rock series and the tholeiitic rock series in the Izu-Hakone region and of the alkalic rock series in the Circum Japan Sea rock province.

CaO-SiO₂ General speaking, CaO of Types, I, II and III of the trachytic rocks ranges from 0.3 to 3.7% for SiO₂ of the range from 58 to 70%. This value is rather low comparing with that of calc-alkalic rocks or tholeiitic rocks. The characteristics of the trachytic rocks of each region are as follows; in the Oga Peninsula, the Kita-Akita region and the Atsumi region (Type III), CaO is poorer than in the rock intermediate between calc-alkalic rocks and alkalic rocks, while that of the Taiheizan region, the Nishi-Tsugaru region and the

Green Tuff Formations of the Japan Sea Borderland of Northeast Japan

9	10	11	12	13	14	15	16
58.32	60.48	64.27	65.29	65.49	67.19	62.31	58.55
0.68	0.68	0.46	0.66	0.90	0.67	0.48	0.88
20.12	17.05	16.59	17.53	16.45	16.29	15.79	19.26
3.30	3.81	1.83	1.57	1.93	1.94	3.61	3.36
2.46	2.20	3.29	2.16	2.25	2.24	1.81	1.21
0.07	0.08	0.03	0.09	0.15	0.10	0.10	0.03
2.92	2.54	1.62	1.39	1.95	2.04	1.20	2.03
0.70	2.31	1.54	1.02	0.64	0.32	3.12	6.11
5.15	4.53	4.88	5.10	4.57	4.85	4.16	4.32
2.22	2.70	1.30	2.46	2.05	2.02	2.40	1.84
0.13	0.15	0.10	0.10	0.10	0.10	0.10	0.08
2.98	2.72	2.81	1.71	2.67	2.14	3.01	1.90
0.75	0.99	0.85	0.90	0.33	0.22	1.40	0.99
99.80	100.24	99.57	99.98	99.48	100.12	99.50	100.56
Miyagi	Miyagi	Miyagi	Miyagi	Miyagi	Miyagi	Miyagi	Kawano

9. Aphyric trachytic rock (Taiheizan region)
 10-12. Amphibole trachytic rock (")
 13. " (Nishi-Tsugaru region)
 14. Augite trachytic rock (")
 15. " (Kita-Akita region)
 16. Augite hypersthene trachytic textured rock (Atsumi region)

Atsumi region (Types I and II) and so forth are almost equal or poorer than that of alkalic rocks, even though some of them include the rocks which suffered deep alteration and the analytical values concerned are effected by the accompanied loss of lime component.

In Type IV, CaO is nearly equal to that of calc-alkalic rocks and this is worthy of attention.

Na_2O-SiO_2 Na_2O lies between 4.1 to 5.4% for SiO_2 of the range from 58 to 70%, and as SiO_2 increases, it increases conspicuously. It is generally very much higher than that of calc-alkalic rocks, and on the diagram it is plotted in the range rather near to that of alkalic rocks and away from that of the rock intermediate between tholeiitic rocks and alkalic rocks. Na_2O of Type III of the Oga Peninsula, the Atsumi and the Taiheizan regions show a value higher than that of alkalic rocks, though each of these regions indicate a different situation concerning Type I.

In short, the trachytic rocks are characterized by a little more amount of Na_2O than that of the other types of rock.

K_2O-SiO_2 K_2O of Types I, II and III of the trachytic rocks ranges from 2.0 to 3.6% for SiO_2 of the range from 58 to 70%. This value lies intermediate between those of calc-alkalic rocks or tholeiitic rocks and alkalic rocks. The only one exception is found in the Type II of the Taiheizan region, where the value is low and almost equal to that of calc-alkalic rocks. Also in Type IV of all regions, the value is low and almost the same as that of calc-alkalic rocks or tholeiitic rocks.

$Al_2O_3-SiO_2$ Al_2O_3 of the trachytic rocks has the range of about 15.2 to 20.1% for SiO_2 of the range from 58 to 70% and is apt to decrease a little as SiO_2 increases.

In all types the value of Al_2O_3 is generally much higher than that of tholeiitic rocks and the range occupies the area a little near to the curve of the alkalic rocks. Moreover, in Types II, III and IV from the Atsumi region and Types I and II of the Taiheizan region, the value of Al_2O_3 is higher than that of alkalic rocks. Thus it may be a noteworthy fact that some trachytic rocks correspond to the "high alumina rock type".

Figure 3. Variation diagrams of oxides of the trachytic rocks compared with those of the tholeiitic rock series (T) and the calc-alkali rock series (C) of the Izu-Hakone region and the alkalic rock series (A) of the Circum Japan Sea rock province.
 Solid circle : Oga Peninsula Open circle : Atsumi region
 Solid triangle : Kita-Akita region Open triangle : Taiheizan region
 Cross : Nishi-Tsugaru region Square: The fourth type

$FeO + Fe_2O_3 - SiO_2$ $FeO + Fe_2O_3$ of the trachytic rocks has the range of 2.0 to 7.0 for SiO_2 of the range from 58 to 70% and as SiO_2 increases it decreases.

Generally speaking, $FeO + Fe_2O_3$ of the trachytic rocks is much poorer than that of tholeiitic rocks, and on the diagram it is plotted from the intermediate area between those of calc-alkalic rocks and alkalic rocks towards the cruce of alkalic rocks. Regarding Types II and III of the Oga Peninsula and Types III and IV of the Atsumi region, the value of $FeO + Fe_2O_3$ is much more poorer than that of alkalic rocks.

$MgO - SiO_2$ MgO of the trachytic rocks has the range of 1.0 to 2.9% for SiO_2 of the range from 58 to 70% and as SiO_2 increases it decreases in general.

If a wide view should be taken, most of the value of MgO lie between those of tholeiitic rocks and of alkalic rocks, but in a more minute view, different characteristics are distinguished among the rocks from the various regions. That is to say, in the Oga Peninsula, going from Type I towards Type III, the value is similar to that of tholeiitic rocks at first, but it decreases remarkably as SiO_2 increases, and in Type III it shows value equal to that of alkalic rocks at last. In the Atsumi region, going from Type I towards Type III, the value changes reversely from that of alkalic rocks to that of tholeiitic rocks. While the values of all types indicate almost the same character as that of tholeiitic rocks in the Taiheizan region, and increases much more and shows equal or greater values than that of calc-alkalic rocks from the Nishi-Tsugaru region.

Norm Compositions

Norm Quartz Normative quartz in the trachytic rocks amounts from 13.9 to 15.1% in Type I, 15.4 to 27.3% in Type II, 20.5 to 25.4% in Type III and 10.8% in Type IV.

These values, compared with those of rocks in other districts of Japan, are far greater than that of alkalic rocks and a little less than that of calc-alkalic rocks or tholeiitic rocks.

Norm Feldspar Fig. 4 shows the normative feldspars plotted in the triangular diagram of the trachytic rocks, in which variation

curves of tholeiitic rocks and calc-alkalic rocks of the Izu-Hakone districts and the alkalic rocks of the Circum Japan Sea rock province are added for comparison. As is shown on this diagram, the plots of the ratio $Ab : An : Or$ in Types I, II and III of the trachytic rocks are distributed within the area limited by the values of Ab , An and Or , whose ranges are from 20 to 25%, and from 15 to 30% respectively. This area indicates the values from 0 to 25%. Or and poor Ab and An than those of calc-alkalic rocks, and when compared with alkalic rocks, it is a little poor in Or and rich in An . In this respect any value within this area shows the average character of the trachytic rocks fairly well. While in Type IV the plots of the ratio are distributed within the area very near to that of tholeiitic rocks.

Norm Mafics Enstatite is much in amount without exception in Types I, II and III of the trachytic rocks but wollastonite is com-

Figure 4. Ab-An-Or diagram of the trachytic rocks, compared with those of the tholeiitic rock series (T) and the calc-alkalic rock series (C) of the Izu-Hakone region and the alkalic rock series (A) of the Circum Japan Sea rock province.

Solid circle : Oga Peninsula Open circle : Atsumi region
 Solid triangle : Kita-Akita region Open triangle : Taiheizan region
 Cross : Nishi-Tsugaru region Square : The fourth type

puted in a very small amount in Types III and IV of the rocks of the Atsumi region. Ferrosilite is less in amount excepting in Types II and III of the Oga Peninsula and Type I and II of the Atsumi region. Fayalite is not computed in any of the types.

Classification of rock types by norm compositions Kuno¹³⁾ has proposed a classification of rock types by means of norm compositions, and from his standard norm compositions, the writer obtained the following values corresponding to the trachytic rocks;

	$\frac{\text{Or} \times 100}{\text{Or} + \text{Ab} + \text{An}}$	An : Or	Or : Ab	Colour index	Rock name
Type I	18~22	An < Or	Or < Ab	12~16	Trachytic andesite
Type II	$\frac{22 \sim 25}{\text{As exception } 14}$	An < Or	Or < Ab	9~15	Trachyte
Type III	20~32	An < Or	Or < Ab	5~8	Soda rhyolite
Type IV	15	An > Or	Or > Ab	13	Andesite

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Origin of the Trachytic Rocks

To solve the problems concerning the trachytic rocks may be one of the main keys to elucidate the peculiarities of the history of volcanic activities, through which the Green Tuff Formations distributed in Northeast Japan were produced.

Before giving his own opinion on the petrogenesis of the trachytic rocks the writer will first summarize the foregoing discussions on the petrographic characters of these kinds of rock.

(1) The volcanic activities of the trachytic rocks are intimately associated with those of the calc-alkalic rock series.

(2) The compositions of the plagioclase in the trachytic rocks range from andesine to albite, and the temperature type of andesine and some of oligoclase shows "high", while in some of oligoclase and albite, it is mostly "low" or between "high" and "low." These features may be explained as that plagioclase in the trachytic rocks crystallized as high type andesine or oligoclase primarily, but were later transformed through albitization.

(3) In some types of the trachytic rocks, alkali-feldspar occurs as independent phenocrysts or replacing those of plagioclase in part. Their optical properties belong to the low type "orthoclase cryptoperthite" of Tuttle's classification, but the crystal form of the independent phenocryst resembles sanidine. Therefore it may be reasonable to presume that alkali-feldspar in the trachytic rocks crystallized primarily as a high type sanidine, but through subsequent alteration it was transformed to the low type alkali-feldspar and was also replaced by plagioclase in part.

(4) As for mafic minerals in the trachytic rocks, amphiboles, biotite and in a few case of augite appear in the Types, I, II and III, but alkali mafics are not contained at all. On the other hand, in Type IV are found augite and hypersthene.

(5) Fairly much alkali-feldspar are contained in the groundmass of the trachytic rocks.

(6) The texture of the groundmass of the trachytic rocks shows always the so-called "trachytic texture".

(7) In the trachytic rocks, there are found more or less secondary minerals of low temperature type.

(8) As for the general properties of the chemical compositions of the trachytic rocks, Type I may correspond to the intermediate type of Daly's andesite and trachyandesite, Type II to his trachyte, Type III to his rhyolite, and Type IV to his andesite.

(9) When particular attention is paid to the alkalies, the following facts are found : Na_2O of Types I, II and III of the trachytic rocks shows the value either intermediate to between those of calc-alkalic rocks or tholeiitic rocks and alkalic rocks or near that of alkalic rocks. K_2O of them shows the value just intermediate between those of calc-alkalic rocks or tholeiitic rocks and alkalic rocks. While in Type IV, Na_2O shows the similar tendency to the above, but K_2O shows almost the same value as that of calc-alkalic rocks or tholeiitic rocks.

(10) Some of the trachytic rocks seem to belong rather to the "high alumina rock type".

(11) CaO of Types I, II and III of the trachytic rocks shows always either lower value than that of the intermediate ones between

those of calc-alkalic rocks or tholeiitic rocks and alkalic rocks or than alkalic rocks. CaO of Type IV shows the value almost similar to that of calc-alkalic rocks or tholeiitic rocks.

(12) The amount of norm quartz in the trachytic rocks of all types shows the value intermediate between those of calc-alkalic rocks or tholeiitic rocks and alkalic rocks.

(13) As for the value of norm feldspar, the reflection points of the Ab-An-Or ratio for Types I, II and III of the trachytic rocks concentrate in a certain area which indicates rich Or and poor Ab and An compared with the same kind of range concerned with calc-alkalic rocks or tholeiitic rocks but a little poor Or and rich Ab compared with that concerning alkalic rocks. On the other hand, the range almost coincides well with that of tholeiitic rocks in Type IV.

(14) According to the classification of the rock type by the norm compositions Type I of the trachytic rocks corresponds to trachy andesite, Type II to trachyte, Type III to soda rhyolite, and Type IV to andesite.

Judging synthetically from the various sources mentioned above, the petrologic characters of the trachytic rocks may be concluded as follows ;

Types I, II and III (a) From the data (8), (9), (10), (11), (12) and (13), these types of rock have characters intermediate between the calc-alkalic rock series or tholeiitic rock series and the alkalic rock series.

(b) From the data (3), (5), (6), (8), (9), (11) and (14), these types of rock have sometimes the characters similar to those of the alkalic rock series.

(c) From the data (1), (2) and (4) these types of rock have intimate connection with the calc-alkalic rock series.

(d) From the data (2), (3) and (7), these types of rock have suffered secondary alteration.

(e) From all the data, it is shown that these types of rock are not in close relation with the tholeiitic rocks series.

Type IV Most characters of this type of rock resemble those of the calc-alkalic rock series or the tholeiitic rock series, though it

has some characters of the trachytic rocks. Therefore, there may be some kinds of rock belonging the type intermediate between calc-alkalic rocks or tholeiitic rocks and the trachytic rocks.

From the foregoing conclusion on the petrologic characters of the trachytic rocks, it may fully be allowed to presume that the trachytic rocks originally has some "alkalic character"—in other words, belonged to the calc-alkalic rock series with some alkalic characters which were added as the result of contamination of either alkali olivine basalt magma or such as semi-alkalic magma as high alumina basalt magma suggested by Kuno. The alteration peculiar to it, is likewise found in the other volcanic rocks in the Green Tuff Formations, due either to the autometamorphism of such magma or to the hydrothermal solution of a later stage.

Only by these hypotheses, mentioned above, the trachytic rocks can be explained without contradiction.

PROBLEMS OF THE PETROGRAPHIC PROVINCES REPRESENTED BY THE LOWER MIOCENE AND THE MIDDLE MIOCENE SERIES

In conclusion, the writer wishes to consider the problem of the petrographic province in the Green Tuff Area of Northeast Japan. With regard to the significance of the volcanic activities of the trachytic rocks it is thought that further emphasis may be given.

As had already been mentioned, the volcanic activities of the trachytic rocks are restricted in the range between the Lower Miocene and the early Middle Miocene epochs and their geographic distributions are also restricted to the region limited by the "trachytic rock boundary", which is considered to have been land and had a certain character of "Quasi-kratogen" to the Japan Sea Borderland. The volcanic activities of the region in those geological ages were, being characterized by the intimate association with the semi-alkalic rocks—including the rock type of Kuno's high alumina basalt—, represented either by the trachytic rocks and calc-alkalic rocks or by calc-alkalic rocks alone, while by tholeiitic rocks rarely.

On the other hand, in the Oga Peninsula and the Atsumi region a small amount of such "alkalic rocks" as "trachy-dolerite" or

“sanidine bearing rhyolite” accompany the trachytic rocks.

The combination of these volcanic activities is greatly different in the character from those of the regions situated in the east of the “trachytic rock boundary”, i.e. the regions of the Green Tuff Formations in the central part of the Ou Backbone and the Pacific Ocean side of Northeast Japan. Therefore the writer presumes to limit the “petrographic province” to the Lower Miocene series and to the early Middle Miocene series in Northeast Japan and considers it better to set out another narrow petrographic province along the Japan Sea, in which the Oga Peninsula and the Sado Island lie and which is characterized by the volcanic activities mentioned above, and besides these are the two other well known rock provinces, i.e. the “Circum Japan Sea rock province” characterized by alkalic rocks and the other rock province lying near the Pacific Ocean and characterized by tholeiitic rocks and calc-alkalic rocks (both poor in alkali).

Moreover, it seems to the writer, as is shown in Fig. 1., that the trachytic rocks on the western margin of this provinces which also lie nearer to the Circum Japan Sea rock province, are alkali-feldspar bearing and more alkalic than the other types, while those on the eastern margin which lies nearer to the rock province of the Pacific Ocean side are nothing but trachytic rocks resembling calc-alkalic rocks (Type IV).

At any rate the characteristics difference of the volcanic activities of the three petrographic provinces in Northeast Japan may probably be the reflection of the difference of the geological history and structure of each province.

This fact is presumed to be one of the evidence which shows that the peculiarities of the petrographic provinces of the Japan Sea Borderland of Northeast Japan are a kind of a reflection of the geological history of the basement. As one of the data to confirm this view the writer¹⁴⁾ should like to point out the fact that the alkalic type or the semi-alkalic type of rock exists in the granitic rocks which constituent the basement of the Green Tuff Formations in the Japan Sea Borderland in Northeast Japan in a previous paper.

Another interesting theme is the relation between the petro-

graphic provinces of the Tertiary period and those of the Quaternary period in Northeast Japan.

As was pointed out by Katsui¹⁵⁾ Kawano, Yagi and Aoki,¹⁶⁾ in the volcanic activities of the Quaternary period the rocks of the "Chokai volcanic zone" is characterized by the rock series slightly rich in alkali and clearly of an intermediate character between those

Figure 5. Map showing the relations of the distributions between the trachytic rocks and Neo-volcanoes of the Japan Sea Borderland of Northeast Japan.

1. Iwaki volcano
 2. Kampu "
 3. Moriyoshi "
 4. Chokai "
 5. Gassan "
 6. Megata "
- t-t'. Trachytic rock boundary

of poor alkali rock series spreading from the Nasu volcanic zone to the Pacific Ocean side and the alkalic rock series in Circum Japan Sea rock province. In other words, as is plain on Fig. 5, volcanoes in the Chokai volcanic zone are not only situated on the Japan Sea side from the "trachytic rock boundary" but also their distributions may be said to have regional and mutual relations between those of trachytic rocks in general, though the formers are bounded from the latters by N-NE-E direction. Moreover, it is also noteworthy that the Megata volcano which is richest in alkali is situated in the subzone, in which are distributed the trachytic rocks richest in alkali.

The writer has also a great interest in the fact that the boundary

between tholeiitic rocks and alkalic rocks coincides almost completely with the "trachytic rock boundary".

Each of these facts may contribute to the presumption that the division and the characters of the petrographic provinces in the geological ages from the Lower Miocene epoch to the early Middle Miocene epoch of the Tertiary period in Northeast Japan may reflect on those of the Quaternary period.

Figure 6. Photomicrographs of the trachytic rocks.

- 1) Type I in the Oga Peninsula, crossed nicols
 - 2) Type I in the Atsumi region, ordinary light
 - 3) Type II in the Oga Peninsula, ordinary light
 - 4) The texture of groundmass of Type II in Taiheizan region, crossed nicols
 - 5) Type III in the Oga Peninsula, ordinary light
 - 6) Type IV in the Kodomari Peninsula, crossed nicols
- Xq : Xenocryst of quartz Xf : Xenocryst of alkali-feldspar
 Pl : Plagioclase Af : Alkali-feldspar Bi : Biotite
 Am : Amphibole Py : Pyroxene

REFERENCES

- 1) Nakano, N. and Kawano, Y., On the trachytic rocks from the Atsumi region, Yamagata Prefecture, Jour. Japan. Assoc. Min. Pet. Econ. Geol., **16**, 12~24, 1936.
- 2) Sugiyama, R., The relation between Tertiary volcanic activities and earth crust movement studies on Tertiary volcanic activities in Niigata Prefecture, Jour. Geogr., **65**, 118~124, 1956.
- 3) Matsumoto, T. and Ikebe, N., Volcano-stratigraphical studies on the Neogenic Hokuriku Province, North central Japan with special references to the volcanic rocks in the Toyama basin, Jour. Inst. Polytech. Osaka City Univ., Ser. G, **3**, 79~116, 1958.
- 4) Miyagi, K., Petrographic studies on the so-called semi-alkalic rocks in the Green Tuff Formations (1) Those rocks from the Monzen Group in the Oga Peninsula, Akita Prefecture, Bull. Educ. Fac. Hirosaki Univ., **5**, 22~37, 1959.
- 5) Matsumoto, T. and Ikebe, N., Some aspects of the Cenozoic geohistry in the South-western Japan, Earth Sci., **37**, 17~28, 1958.
- 6) Katsui, Y. and Fujita, Y., Sub-alkaline volcanic rocks from the Miocene of the outer northeast Japan, Earth Sci., **46**, 43~44, 1960.
- 7) Miyagi, K., Stratigraphic and petrographic studies of the Green Tuff Formations in the Oga Peninsula, Akita Prefecture (2) On the Kuguriwa lavas., Jour. Geol. Soc. Japan, **62**, 645~655, 1956.
- 8) Fujioka, K., The conception on the volcano-stratigraphy in Green Tuff region of the inner Japan, Jub. Pub. Comm. Prof. J. Suzuki's 60th birthday, 511~518, 1958.
- 9) Inoue, T., The stratigraphical studies of the igneous rocks accompanied by the oil bearing Tertiary and the basement Green Tuff in the Akita oil filed, northeastern Japan, Rep. Inst. for Min. Resour. Akita Univ., **23**, 1~79, 1960.
- 10) Ishikawa, T., Some petrological considerations on the Miocene volcanic activities in Green Tuff regions in Japan, Jour. Fac. Sci. Hokkaido Univ., Ser. 4, **10**, 471~480, 1960.
- 11) Tuttle, O.F., Optical studies on alkali-feldspars, Am. Jour. Sci. Bowen Vol., 553~568, 1952.
- 12) Kano, H. and Takayasu, T., Anorthoclase rhyolite from the Oga Peninsula, Akita Prefecture, Rep. Inst. for Min. Resour. Akita Univ., **13**, 1~14, 1955.
- 13) Kuno, H., Volcanoes and volcanic rocks, Iwanami-shoten, 1954.
- 14) Miyagi, K., Petrology of the granitic rocks which comprise to basements of the Green Tuff Formations in Japan Sea Borderland of Tohoku Districts, Jour. Japan. Assoc. Min. Pet. Econ. Geol., **45**, 174~185, 1961.
- 15) Katsui, Y., Chemical compositions of the lavas from the Chokai volcanic zone, Japan, Jour. Geol. Soc. Japan, **60**, 185~191, 1954.
- 16) Kawano, Y., Yagi, K. and Aoki, K., Petrography and petrochemistry of the volcanic rocks of Quaternary volcanoes of Northeastern Japan, Sci. Rep. Tohoku Univ., Ser. 3, **7**, 1~46, 1961.