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Author(s)	MUKAE, Michitoshi
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Volcanostratigraphical Study on the Miocene Volcanism in the Shimane Prefecture, Japan

By

Michitoshi MUKAE

With 3 Tables, 5 Text-figures and 7 Text-plates

ABSTRACT: There may be no doubt in that the volcanostratigraphical method, as well as any other means so far ordinarily applied, is also to play an important role in the research of sedimentary formations intercalated with more or less amounts of pyroclastic rocks. From this point of view, the author here intends to report an outline of the study in relation to the regions composed of so-called "Green Tuff" in the San-in province.

Basing on the activities and petrographical features of respective volcanics, inspection for several volcanisms appeared in the related basin has been carried out, illustrating that the volcanics concerned are,in general, represented either by the calcic series that might have been active through the periods from the middle to the upper Miocene or by the alkaline suite that might have begun to extrude in the lower Pliocene after a very long and silent interval nearly at the close of the former eruption.

Both mineralogical and petrochemical characteristics of the calcic series have been specifically pursued for scrutiny in comparison to other kinds of volcanics found scattered in the same province. In consequence, it has become clear that the activities of the series in question should be classified into three cycles, each of which might be represented distinctively by a formation composed of the pyroclastics showing certain petrographical characteristics and reasonably correlative to the stratigraphical division determined from the biostratigraphical or other data.

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Tables, Text-figures and Text-plates

I. INTRODUCTION

The San-in Neogene province is situated in the most southwestern marginal region composed of the "Green Tuff", an important geologic unit in Japan. For the purpose of finding out certain connection of the volcanic activities with the sedimentaries formed in the related regions and scrutinizing the geologic relationship between the Cenozoic volcanisms in the so-called San-in mixed province, the present work has since the end of the World War II been put into operation under the leadership of Prof. S. IMAMURA, the head of the research group of the San-in Neogene as well as with assistance of other members in the very group of Geological and Mineralogical Institute of Hiroshima University. The part taken by the author in the very research has been connected merely with volcanological and petrological study relating to the San-in "Green Tuff" occurred especially in Shimane prefecture. On the basis of the results compiled recently from the researches, the author wants (1) to describe an outline of the geology distributed in the related provinces, (2) to inspect the petrographical and petrochemical data obtained for certain volcanic rocks and thus (3) to demonstrate the volcanostratigraphical view with respect to their stratigraphic relations.

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III. BRIEF NOTES OF PREVIOUS WORKS

1. *Previous studies before 1945*

As for the earliest investigations of geology distributed in the San-in Neogene sedimentary basin, we have to allude to numerous works, such as the geological map (scale 1: 200,000) and explanatory text of Hamada given by S. SUZUKI (1896), those of Daisen given by S. ÔTSUKA (1896) and those of Oki given by M. YAMAKAMI (1895). Since 1900 to 1945, a lot of noteworthy reports on the geology, the palaeontology, the geological age, the petrography and so on concerning the San-in Neogene Formation have been published. Because of their most intimate relation to the volcanostratigraphical research made by the author, some of the literatures hitherto collected must here be introduced. The study executed by S. YAMANE (1910, 1911) on Iwami province have been referred to general geology distributed around Hamada. Of all the investigations of the alkaline rocks from Oki Islands made by some geologists, the petrological studies made public by T. TOMITA on the titles of "Geology of Dôgo, Oki Islands in the Japan Sea" (1936) and of "On the Chemical Compositions of the Cenozoic Alkaline Suite of the Circum-Japan Sea Region" (1935) are most worthy and closely connected with the author's work. The volcanostratigraphical study made by T. TOMITA and E. SAKAI on the title of "Cenozoic Geology of the Huzina-Kimati, Izumo Province, Japan" (1939) is especially to be remarked.

2. *Researches of Cenozoic geology since 1945*

Since the end of the World War II, the latest researches on the San-in Neogene basin in Shimane prefecture started in 1949 by S. IMAMURA and his collaborators have already covered nearly all over the basin with extending annually from an area to the other. Many noticeable results have often been read by the members of the group at every annual meeting of the Japan Geological Society and discussed especially at the symposia of the "Green Tuff". There are some important data already published, among which those given by S. IMAMURA on the New Miocene *Sassafras* (1957), given by Y. TAI either on the stratigraphy of the Shimane peninsular region (1952–1955) or remarkably on the microbiostratigraphy (1956–1957), given by H. YOSHIDA on the geotectonic problems (1952), and given by M. MUKAE on the Miocene volcanic activity (1954) and others are most noteworthy. The latest stratigraphical correlation-table concerning every main area has already been given by S. IMAMURA and M. MUKAE at the symposium of "Green Tuff" in 1955. Besides the above-mentioned works, we have also some other valuable reports given by A. HARUMOTO on the petrogeny of melilite-nepheline-basalts from Nagahama (1952), given by S. TANEDA (1952), by K. YAMAGUCHI (1955) on Volcano Sambe and read by S. NISHIYAMA (1956) on the stratigraphy in the west-central area of the Shimane peninsula and so forth.

IV. OUTLINE OF San-in NEOGENE GEOLOGY

The problems discussed in this paper are related mainly to the San-in Neogene developed widely both in the main-land district along the Sea of Japan and in the Shimane peninsular district. A geological map of the San-in Neogene, compiled roughly from the original maps drawn by our collaborators and fairly revised by the author according to his interpretation, is introduced for explanation. As to the Cenozoic geology of these districts we have to cite the most worthy research made by T. TOMITA and E. SAKAI (1939), on the basis of which our studies on the correlation of stratigraphy in each area are still being continued. As a result of the latest data made by our group, however, a part of the study may be revised from various standpoints to more or less extent. The San-in Neogene consists of some sedimentary formations intercalated with volcanic rocks produced in the period from the middle Miocene(F_2) to the lower Pliocene (H_1), where the letters with suffix in the respective parentheses indicate the biochronological scale suggested by N. IKEBE (1948). Because of certain geologic differences appeared obviously between the Shimane peninsular district situated in the central part of the sedimentary basin and the main-land district situated on the periphery, the stratigraphies concerned are, for convenience, explained separately as to each district.

According to the stratigraphical columns given by S. IMAMURA and his group (1957), the Neogene in the main-land district, resting directly on the pre-Miocene granitic rocks or schists, is divided into two groups of the Iwami[1] and the Izumo[2] in ascending order, among which the former is futhermore subdivided into the Hata[3] subgroup (F_2), the Kawai[4] (F_3), the Kuri[5] (F_3-G) and the Ômori[6] (G) formations and the latter, into the Fujina[7] (G) and the Matsue (H_1) formations. For correlating these formations throughout all areas, the volcanostratigraphical research made chiefly by the author is surely considered to be accountably useful, as is so in the case of bio- and litho-stratigrahical studies accomplished by other specialists. The Hata subgroup, called and identified by the author as the lowest volcanic formation correlative to the 1st volcanic cycle of the San-in Neogene volcanism, is distributed in the four main areas of Hamada City, Ômori, the southern Izumo City and the southern area of Matsue City, which are certainly corresponding to the great embayments suggested geotectonically

1) Iwami 石見 2) Izumo 出雲 3) Hata 波多 4) Kawai 川合 5) Kuri 久利 6) Ômori 大森
7) Fujina 布志名

by H. YOSHIDA (1952) on one hand and to the inland-basins in the San-in Neogene sedimentary subprovince proposed by Y. TAI (1957) on the other. Some valuable plant fossils, for example, *Sassafras Yamanei IMAMURA*(S. IMAMURA, 1957) are contained in the lower parts of the subgroup in the Hamada City area and the *Myrica (Comptoniphyllum)-Liquidambar* flora of Daizima type, in the upper parts in the former area, the southern Izumo City and the southern area of Matsue City. The Kawai formation, lying unconformably on the former and representing the first sedimentaries in shallow-sea, consists of basal conglomerates and coarse-grained sandstones intercalating pyroclastic rocks and is scattered on the northern sides of the former subgroup or directly on the pre-Miocene granitic rocks nearly throughout the main-land district. Some worthy fossils of marine molluscs and foraminifera such as *Siratoria siratoriensis* ÔTUKA etc. (Y. ÔTUKA, 1937 and S. IMAMURA, 1952) are found in the very formation. The Kuri formation, lying conformably upon the former, consists of thick beds of black shale accompanying plagioliparites and their tuffs in the lowest parts, and includes marine fossils such as *Propeamussium tateiwai* KANEHARA etc. (S. IMAMURA, 1952, K. OKAMOTO and Y. TAI, 1957). The volcanic rocks intercalated in these two formations, ranging from intermediate to acidic in property, are identified as the 2nd volcanic cycle by the author. The Ômori formation, consisting of the volcanics called the 3rd cycle by the author and accompanied with some thin sedimentary beds containing rarely marine molluscs, is widely distributed along the northwestern periphery of the main-land district from the Ômori to the Yasuki area. These two formations seem, in part, to be disconformably related to each other. The Fujina formation, including both the Kimati and the lower Huzina beds defined formerly by T. TOMITA and E. SAKAI, consists of basal conglomerates, coarse- to fine-grained sandstones and sandy shales, and is distributed from northeast to southwest continuously and linearly along the coastal zone, containing marine molluscs and foraminifera. Some thin beds of pyroclastic rocks are intercalated in this formation. Its relation to the former is un- or dis-conformable in the main-land district. The Matsue formation will hereafter be alluded to in the description of the peninsular district. Besides the formations mentioned above, the Tsunozu[1] formation (I_1) containing *Metasequoia japonica* (ENDÔ), *Stegodon* sp. etc. (S. IMAMURA, 1957) and the Kokubunji[2] bed(J) are also distributed in the Hamada City area. The same tuffs as those included in the Daisen volcanic zone are observed similarly in the uppermost part of the Tsunozu formation, and some lava-domes rest conformably upon the former around Mts. Ôe-takayama in the Ômori area (S. IMAMURA and H. YOSHIDA, 1955).

On the other hand, some remarkable works as to the geology of the peninsular district are to be contributed to Y. TAI (1952–1955). According to his studies, the Neogene in this district situated in the central part of the basin is believed to represent a cycle of sedimentation named the Shinji group, and classified into the Koura, the Furue and the

1) Tsunozu 都野津 2) Kokubunji 国分寺

Matsue formations, which are correlated to the stratigraphy in the former district situated on the periphery of the basin by his skillful interpretation basing on smaller foraminifera (1955). The Koura formation is subdivided into two members of the Koura shales and the Koura sandstones, recently being considered as the middle Miocene (F_2–F_3). The former member consists only of shales containing some fossils of fresh-water molluscs and plant-leaves, and the latter, of sandstones, shaly tuffs and pyroclastic rocks including also some fossils. The Furue formation is subdivided into three members of the Jôsôji shales, the Ushikiri alternation and the Furue mudstones. The Jôsôji member, consisting of black shales accompanying a small amount of green pyroclastic rocks and tuffaceous sandstones, is correlated to the upper bed of Tamatukuri formation defined by T. TOMITA and E. SAKAI.

The Ushikiri alternation member consists of alternated beds of pyroclastic rocks, lavas, tuffaceous sandstones and black shales, being correlated to the Ômori formation. The member of the Furue mudstones consists only of thick beds of mudstones recently identified with the upper Miocene (G) in age from the microbiostratigraphical point of view. The Matsue formation is subdivided into three members of the Terazu sandstones, the Kawatsu tuffs and the Kuroda sandstones. The first member consists of medium-grained sandstones accompanying some thin beds of lignite and some beds of pebbly sandstones, the second, of olivine-trachybasalts, hornblende-trachybasalts and tuffaceous beds, and the third, of sandstones, tuffaceous sandstones and conglomerates. This formation is identifiable with the lower Pliocene (H_1) on the basis of some geochronologically worthy fossils such as *Turritella saishuensis* YOKOYAMA etc. (Y. TAI, 1956 d).

V. PETROGRAPHICAL NOTES CONCERNING EACH VOLCANIC CYCLE BELONGING TO MIOCENE VOLCANISM

1. *Volcanic cycles*

As for the Miocene volcanic activity appeared in the San-in Neogene, the author has in the former paper (1954) proposed a concept concering four volcanic cycles, among which three are belonging to the calcic series and one, to the alkaline suite studied in most details by T. TOMITA (1935–1951). In this paper, however, the latter must be excluded from the Miocene volcanism, because it is geochronologically regarded as a part of the Matsue formation and is recently revised as the lower Pliocene (H_1). Thus, the author hereunder purposes to allude merely to the former three cycles appeared in the period of Miocene.

According to the latest study made by the author, each activity in the Miocene volcanism is petrographically characterized with such features as will later be mentioned. It is most probable that the 1st cycle might have been in activity in the stage of the Hata subgroup (F_2) occurred only within the inland-basins of the related province. The rocks, which are connected with this cycle and show the variation from basic to acidic in property, are clearly included in the pigeonitic series (H. KUNO, 1950). The 2nd cycle is considered to have been appeared in the stage of the Kawai and the Kuri formations (only in F_3) overall both districts of the main-land and distinctively of the peninsula, including rocks ranging from intermediate to acidic in property. The 3rd cycle seems to have been active in the stage of the Ômori formation (G) throughout both districts, and the rocks concerned, varying from basic to acidic, is certainly included in a member of the hypersthenic series. Considering the results so far obtained for volcanostratigraphical correlation regarding the petrographical characters shown in every cycle, the Neogene stratigraphies thus systematized in every area throughout the San-in sedimentary basin are proved to be in good identities with the biostratigraphical data.

2. *Mineralogical Notes*

The author here intends to present the mineralogical inspection concerning not only the Miocene volcanic rocks separated into three cycles on the basis of the author's idea but also some other Cenozoic rocks within the San-in Neogene sedimentary province, as are listed in Table 1. According to the investigations on the characteristics regarding various specimens that were collected from every area surveyed by the author and some collaborators, it is conspicuous that the similarlities in mineralogical constituents are found in many specimens belonging to each cycle. As are shown in Table 1, the rocks collected mainly from Izumo City area are selected as the representative type-specimens variable from basic to acidic in property, and are chemically analysed. Basaltic and andesitic rocks appeared in the Miocene volcanism are characterized with their contents of pyroxenes and calcic plagioclases, generally, accompanying no olivines and no primary amphiboles, while, on the contrary, both alkaline olivine-basalts and trachybasalts are characterized with a large amount of olivine and alkaline minerals. Acidic rocks such as plagioliparites and rhyodacites are also characterized with their contents of plagioclases accompanying a small amount of quartz-phenocryst aside some exceptions of dacites rich in quartz and of quartzose rhyolites appeared in Izumo City area.

Basalts and andesites occurring in the 1st cycle clearly fall in the category of the pigeonitic series defined by H. KUNO, because rhombic pyroxenes are not included in the groundmass, as are shown in Table 1-a. As for basaltic andesites, two-pyroxene-andesites and augite-andesites, the specimens collected from Hamada City, Ômori and the southern area of Matsue City are mineralogically almost similar to those attainable from Izumo City, and clearly belonging to the pigeonitic series. Dacitic rocks are also characterized with their contents of pyroxenes and plagioclases throughout four areas. Quartzose rhyolite is characterized with a large amount of phenocrysts of quartz and feldspars. Rock-specimens same as those obtained from Izumo City area are collected also from the Hata subgroup in Hamada City and Ômri.

The representative rocks belonging to the 2nd cycle are plagioliparites, distributed widely throughout almost all areas, which are characterized only with a relatively small amount of plagioclase in phenocryst and usually with their occurrence as pyroclastic rocks and as wall-rocks of the so-called "Kuroko" and gypsum deposits commonly appeared in the San-in province. The specimens collected from each area demonstrate the resemblance in their mineralogical and petrochemical characteristics, as are shown in Tables 1–b and 2. The type-specimens of the 2nd cycle are selected from Ômori and the peninsular districts. Although mineralogical characters of andesitic rocks are, on account of their severe alteration in each area, difficult to be clarlified, some specimens in the collections from Ômori area and the peninsular district seem to be included in a part of the pigeonitic series. In the 3rd cycle are included various kinds of rocks indicating a series varying from basic to acidic in property. As are illustrated in Table 1–c, the specimens collected from Izumo City area are taken as the type-specimens. According to certain data, basalts and andesites are clearly belonging to the hypersthenic series. Dacites from the same area are characterized with certain amounts of phenocrysts of plagioclase and quartz accompanying a minor quantity of hornblende and biotite. Leucocratic andesites associated with a small amount of phenocrysts of plagioclase and/or no pyroxenes is also one of the representatives among the related rocks occurred in both districts. In the western area of the peninsular district are developed a considerable amount of rhyolites and rhyodacites, belonging volcanostratigraphically to the volcanism in the 3rd cycle, in which the ore deposits concerning the Kuroko far later produced are found included.

Besides the Miocene calcic rocks mentioned above, the data for the specimens collected from the Matsue formation developed in Matsue City are presented in Table 1–d, according to which the very specimens are clearly included in the alkaline suite. The data for the volcanostratigraphically problematical specimens from Mts. Wakura and Dake in Matsue City and one from Mts. Ôe-takayama are shown in Table 1–e. The formers are evidently included in the calc-alkaline series, because they are characterized with plagioclase and cristobalite accompanying a few opacitized hornblende and show the speciality in their petrochemical properties. The latter is clearly correlated to the rocks from the Daisen zone.

From the data for mineralogical characters, the Miocene volcanic rocks appeared in the districts concerned are summarized as follow:

1) The related volcanics are surely considered to be a part of the calcic series, whereas the basic and intermediate rocks indicate certain characteristics in their contents of plagioclases and pyroxenes associated with no olivines and no primary amphiboles, and plagioliparite is thought to be a representative in acidic rocks.

2) The rocks appeared in the 1st cycle are clearly assumed as a part of the pigeonitic series, and those found in the 3rd cycle, as a part of the hypersthenic one.

Table 1. Petrographical notes as to some volcanic rocks

1-a The Hata volcanic rocks :- the 1st cycle

No. of Anal.	Sign of rock	No. of specimen, Locality, Occurrence	Rock-name, Texture	Kuno's Class.	Phenocryst	Groundmass	No. Micro-photo.
1	B_1	0-540801 Atodani, Mitoya-chô, Iishi-gun. Flow~dike.	Olivine-bearing augite-basalt. Doleritic.	IIIb.	About 55% in volume. Labradorite: Euhedral, tabular, 3.2×1~1.5×0.6mm., usually 1.8×1mm. rarely zoned. $N_2'=1.570$~1.569, $A_n=65$. Antigorite (pseudomorph of olivine): rare.	About 45% in volume. Augite: 22%, subhedral~granular, 0.4~0.3mm. $\alpha'=1.705$, $\gamma'=1.722$, $2V \doteqdot +45°$. Plagioclase: 13%. Pigeonite: 5%, subhedral, 0.4~0.3mm. long, $2V \doteqdot +0°$, $Z \Lambda c=27°$~$20°$. Olivine (pseudomorph): 3%, subhedral-rounded, 0.6~0.4mm. long, almost altered to antigorite or rarely to iddingsite. No reaction to pyroxene. Magnetite: 2%, eu-~subhedral, 0.2~0.1mm. No rhombic pyroxenes. Sometimes tridymite in amygdale.	18-1
2	B_1	51-58 Yoshino, Kubota-mura, Hikawa-gun. Flow.	Augite-basalt. Intergranular.	Xc	0%	100%, intergranular. Labradorite: 67%, An=56, lath-shaped, 0.35~0.1mm. long, twinned on albite law. $N_1'=1.557$. Augite: 28%, fine granular, 0.05~0.02mm., $\gamma'=1.711$. Magnetite: 5%, fine granular. Sometimes quartz in interstices.	18-2
3	PA_1	51-53 Onya, Hata-mura, Iishi-gun. Flow.	Augite-basaltic andesite. Glomeroporphyritic.	Xc	8% Labradorite: 7%, subhedral~tabular, 1.6~0.8mm. long, zoned, An=75~70. Augite: 1%, subhedral, 0.7~0.3 mm. long, rarely twinned on (101).	92%, interganular. Labradorite: 67%, lath-shaped, 0.1mm. long, twinned on albite law. An=64~55. Augite: 24%, fine grained, 0.05~0.02mm. $\gamma'=1.713$. Magnetite: 1%, fine-grained, 0.03~0.02mm. Quartz: rare in interstices.	

1-a The Hata volcanic rocks :- the 1st cycle (continued)

No. of Anal.	sign of rock	No. of specimen, Locality, Occurrence	Rock-name, Texture	Kuno's Class.	Phenocryst	Groundmass	No. Micro-photo.
4	$2PA_1$	53-42 Kakeya-chô, Iishi-gun. Flow.	Two-pyroxene-andesite. Porphyritic.	Xc?	20% Bytownite: 16%, An=90~80. Augite: 3%. Hypersthene: 1%, 2V=−57°.	80% Plagioclase, altered colored minerals and iron ores.	18-3
5	$2PA_1$	56-819 Higashiiwasaka, Yagumo-mura, Yatsuka-gun. Flow.	Two-pyroxene-andesite. Porphyritic.		About 32% Plagioclase: 19%, euhedral, tabular, 3~0.5mm. long, zoned, andesine~labradorite?. Augite: 12%, euhedral, 1.6~0.5mm. long, accompanying pigeonitic augite. Magnetite: 1%, euhedral, 0.4~0.2mm.	Abut 68% Cryptocrystalline~glassy, light colored.	18-4
6	PA_1	53-19 Yaeyama, Hata-mura, Iishi-gun. Flow.	Augite-andesite. Porphyritic.	Xc?	28% Andesine: 24%, An=54~45. Augite: 4%, 2V=+51°, γ'=1.681.	72% Oligoclase: 71%, An=29~25. Iron ores: 1%.	18-5
	$2PA_1$	53-18 Yaedaki, Hata-mura, Iishi-gun. Flow.	Two-pyroxene-andesite. Porphyritic.	Vc	32.4% Labradorite: 24.9%, An=58~54, rarely relict-like bytownite (An=85) in core. Augite: 3.4%. Bastite: 2.7%. Magnetite: 1.4%.	67.6%, pilotaxitic. Labradorite: An=56~48. Augite: 2V=+50°, 51.5°, 52.5°, γ'=1.722, ZΛc=43°.	
	$2PA_1$	53-22 Anami, Hata-mura, Iishi-gun. Flow.	Two-pyroxene-andesite. Glomeroporphyritic.	Vd-c.	27.6% Labradorite: 16.1%, large~medium, euhedral~corroded. twinned on albite & Carlsbad. zoned gradually, An=74~66. Augite: 5.4%, medium~fine, 2V=+50°, γ'=1.722, ZΛc=46°. Hypersthene: 4.4%, large, almost altered to bastite, sometimes enclosed in augite. 2V=−62°, γ'=1.721. Magnetite: 1.7%, granular.	72.4%, almost plagioclase. Labradorite: An=63~62. Augite: rare. Magnetite: a few.	

	$2PA_1$	51–45 Miyauchi, Hata-mura, Iishi-gun. Flow.	Two-pyroxene-andesite. Porphyritic.	Vc	48.9% Labradorite: 35.1%, euhedral, tabular, 1.2~0.4mm. long, twinned on albite & Carlsbad, distinctly zoned. some is xenocrystic bytownite (An=82~75). Augite: 4.7%, euhedral, 1.2~0.2 mm. long, 2V=+50°~45°, γ'=1.722, Z⁄lc=43°. Bastite: 6.3%, euhedral, 0.5~0.2mm. long. Pigeonite: rare. Magnetite: 2.8%, granular, 0.4~0.1mm.	51.1% Cryptocrystalline~glassy, dark colored.	
	PA_1	53-31 Ryuzugataki, Matsukasa, Kakeya-chô, Iishi-gun. Flow.	Augite-andesite. Porphyritic.	Xc	7.5% Andesine: 4.0%, euhedral, tabular, 2.0~0.2mm. long, zoned fairly. An=53~48, sometimes includes pyroxenes. Augite: euhedral, 1.3~0.2mm. long. rarely twinned on (101). 2V=+53°, Z⁄lc=42°, γ'=1.722. 2V=+50.5°, Z⁄lc=44°. Magnetite: 0.8%, granular, 0.09~0.03mm. Quartz: rare.	92.5%, trachytic. Andesine~labradorite: lath-~needle-shaped. An=53. Augite: very fine. Magnetite: very fine. Glass. No rhombic pyroxenes.	
7	Da_1	52–67 Maeneba, Hiebara-mura, Hikawa-gun. Flow.	Biotite-augite-bearing dacite. Porphyritic.		10% Andesine: 9%, euhedral, tabular, 1.2~0.6mm. long, zoned fairly, twinned on albite, An=47~38. Augite: eu-~ subhedral, rare. Biotite: rare, anhedral, opacitized. 1.5~0.3mm. long.	90%, trachytic Feldspathic, accom. by microcrystals of colored minerals and iron ores.	18–6
8	Da_1	53–17 Yaedaki, Hata-mura, Iishi-gun. Flow.	Rhyodacite. flow.		5%, chiefly plagioclase. Andesine: An=48~45, rarely zoned, twinned on albite & Carlsbad. Augite: rare. Magnetite: rare, granular.	95%, flow texture. Feldspathic, colorless.	18–7

1–a The Hata volcanic rocks :– the 1st cycle (continued)

9	Rhy_1	53–63 Nishiyamanaka, Nishisusa-mura, Hikawa-gun. Flow.	Quartzose rhyolite. Nevaditic.		31% Feldspar: 20%, potash-oligoclase, euhedral, tabular, 1.2mm. long. sometimes brecciated. An=24~22, 2V=−62.9°~59°, includes perthitic orthoclase. Quartz: 11%, corroded~flaky, 1.5~0.2mm. Biotite: rare, chloritized.	69%, flow texture. Felsic, sericitized.	18–8

1–b The Kawai and Kuri volcanic rocks :– the 2nd cycle

No. of Anal.	Sign of rock	No. of specimen, Locality, Occurrence	Rock-name, Texture	Kuno's Class.	Phenocryst	Groundmass	No. Micro-photo.
	PA_2	0–5052401 Kannonzaki, Chikumi-mura, Yatsuka-gun. Flow.	Propylite. Porphyritic.		About 10% Plagioclase: euhedral, 2~0.6mm. long. tabular, altered hard (kaoline, albite, zeolite etc.). Augite: euhedral, 0.15~0.1mm.	About 90% Plagioclase: lath-shaped. Augite, Iron ores, and Secon. mins.	19–1
10	$2PA_2$	56–15 Isotake, Ôda city. Flow.	Two-pyroxene-dacitic andesite. Glomeroporphyritic.		About 22% Plagioclase: 18%, euhedral, tabular, 1.2~0.4mm., zoned. Augite: 3%, eu-~subhedral, 1.6~0.3mm. Rhombic pyroxene: 0.5%, euhedral, under 1.2mm. long, altered to bastite. Magnetite: 0.5%, euhedral, 0.6~0.2mm.	Abut 78% Cryptocrystalline, scattered with plagioclase-needles, light colored.	19–2
	Rhy_2	T–10263 Jôsôji, Furue-mura, Yatsuka-gun. Flow.	Plagioliparite. Porphyritic.		12% Plagioclase: euhedral, tabular, 1.2~0.5mm. zoned. An=36~26, oligo-andesine.	88% Felsic, microcrystalline.	19–3 19–4
11	Rhy_2	56–16 Yamakuraji, Shizuma, Ôda city. Intrusive flow.	Plagioliparite. Flow.		About 5% Plagioclase: euhedral, tabular, 1.2~0.4%, zoned. Magnetite: rare, rounded~irregular, 0.2mm.	About 95%, flow texture. Glassy, light colored.	19–6 19–7

12	Rhy_2	56–20 Nima-chô, Nima-gun. Intrusive-flow.	Plagioliparite.				
13	Rhy_2	56–17 Jitôsho, Isotake, Ôda city. Flow.	Plagioliparite.				
14	Rhy_2	56–19 Sarugahana, Shimo-ubeo, Mihonoseki-chô. Intrusive-flow.	Plagioliparite. Microcrystalline.		About 1%, Plagioclase.	About 99% Microcrystalline, with needles of feldspars, rare iron ores, light colored.	19–8
15	Phy_2	56–24, ditto.	Plagioliparite.				
16	Rhy_2	56–21, Nima-chô, Nima-gun.	Plagioliparite.				
17	Rhy_2	56–22, ditto.	Plagioliparite.				
18	Rhy_2	56–23, ditto.	Plagioliparite.				

1–c The Ômori volcanic rocks :– the 3rd cycle

No. of Anal.	Sign of rock	No. of Specimen, Locality, Occurrence	Rock-name, Texture	Kuno's Class.	Phenocryst	Groundmass	No. Micro-photo.
19	B_3	52–4 Kanetsuki, Hiebara-mura, Hikawa-gun. Flow, partially dike.	Two-pyroxene-basalt. Intergranular.	Vd	0%	100% Labradorite: 53.6%, lath-shaped, 2.5~1.0mm. long. twinned on albite. An=70~67. Augite: eu-~subhedral, 0.08~0.05mm. Hypersthene: eu-~subhedral, 0.08~0.05mm. Glass and chloritic minerals: in interstices. pyroxenes and glass: 43.4%. Magnetite: 3%, fine granular, 0.08~0.02mm.	20–1

1-c The Ômori volcanic rocks :- the 3rd cycle (continued)

No. of Anal.	Sign of rock	No. of Specimen, Locality, Occurrence	Rock-name, Texture	Kuno's Class.	Phenocryst	Groundmass	No. Micro-photo.
	B_3	51-59 Yahatabara, Kubota-mura, Hikawa-gun. Flow.	Two-pyroxene-basalt. Intergranular.	Vd	About 18% Plagioclase (labradorite): 15%, tabular, 2~0.4mm. long. rarely zoned. twinned on albite and Carlsbad. Hypersthene: eu-~subhedral, 1mm. long, somewhat altered to bastite, sometimes surrounded with monoclinic pyroxene. Augite: sub-~anhedral.	About 82%, intergranular. Plagioclase (labradorite~andesine): 45%, lathy, 0.1~0.06 mm. long, twinned on albite. Augite: euhedral~granular, under 0.05mm. Hypersthene: euhedral, fine, tabular, 0.1~0.05mm. long. pyroxenes: 33%. Magnetite: fine granular, 0.02mm±.	20-2
20	$2PA_3$	51-60 Yahatabara, Kubota-mura, Hikawa-gun. Flow.	Two-pyroxene-andesite. Porphyritic.	Vd	3% Labradorite: euhedral, tabular, 0.5mm. long, twinned on Carlsbad law. remarkably zoned. An=72~56.	97%, intergranular. Plagioclase: 57%, lath-shaped, 0.08mm. long. Augite: 35%, 2V=+38°, γ'=1.710. Hypersthene: 4%. Magnetite: 1%, fine granular.	20-3
21	$2PA_3$	51-31 Kentabara, Asayama-mura, Hikawa-gun. Flow.	Two-pyroxene-andesite. Porphyritic.	Vd	21.2% Labradorite: euhedral, tabular, 1.2~0.5mm. long, twinned on albite and Carlsbad. distinctively zoned, An=70~60. Augite: 3.2%, euhedral, 1.2~0.35 mm. long. rarely twinned. 2V=+48°, γ'=1.710, $Z\Lambda c \fallingdotseq 26°$. Hypersthene: 1.8%, euhedral, 0.5~0.2mm. long, weak pleochroism, 2V=−65.3°~62.2°.	78.8%, pilotaxitic. Plagioclase and pyroxene.	20-4
22	Da_3	52-6 Mimigu, Asayama-mura, Hikawa-gun. Flow.	Dacite. Porphyritic.		27.5% Andesine: 22.4%, euhedral, tabular, 4~0.4mm. long, remarkably zoned. twinned on albite and Carlsbad. An=55~41. Opacitized hornblende: 3.6%, eu~subhedral, 0.7~0.3mm. long. Corroded quartz: 0.4%, 2mm. dia. aboundant inclusions, often anomalous +2V. Magnetite: 1.1%, granular, 0.2mm.	72.5% Plagioclase: subhedral, under 0.2mm. Augite: sub-~euhedral, under 0.2mm. Chloritic minerals: Quartz: granular, 0.2mm.	20-5

23	2PA'$_3$	51–1 Sugezawa, Oda, Kiku-mura, Hikawa-gun. Flow.	Augite-leucoandesite. Porphyritic.	Vd	2.4% Plagioclase (andesine): 1.8%, euhedral, tabular, 2.5~0.8mm. long, distinctively zoned and twinned on albite and Carlsbad. Augite: 0.3%, subhedral, 0.5mm. long, often chloritized. Magnetite: 0.3%, granular, 0.25mm.. Apatite: rare. short prismatic, 0.25mm.	97.6%, felty. Feldspathic with quartz and needles of hypersthene.	20–6
24	Da$_3$	52–36 Maki, Asayama-mura, Hikawa-gun. Flow.	Dacite. Porphyritic.		33.5% Andesine: 20.3%, euhedral, tabular, large crystal, 1.6~1.0mm. long, fine ones, 0.6~0.5mm. long, twinned on albite and Carlsbad. An=44~41 Quartz: 9.8%, corroded or flaky, 5~1.2mm. diameter. Hornblende: 0.8%, euhedral, somewhat opacitized. 0.8mm. long. Magnetite: 2.6%, granular, 0.3~0.2mm.	66.5% Felsic, colorless, rarely with chlorite and magnetite.	20–7
	Da$_3$	F2772801 The summit of Mt. Ôin. Flow.	Dacite. Porphyritic.		Abot 47% Plagioclase (andesine): 25%, euhedral, tabular, 3.6~1.2mm. long, zoned distinctively. Corroded quartz: 16%, sometimes anomalous, large crystals =4.5~3.6mm. fine ones=0.8~0.25mm. diameter. Augite: 3%, eu~subhedral, short prismatic, 0.85~0.35mm. long. Magnetite: 3%, granular, 0.26~0.6mm.	About 53% Microcrystalline, felsic.	
25	Rhy$_3$	56–12 Ôtoshi-Inome, Wanibuchi, Kawashimo-chô, Hirata city, Hikawa-gun. Flow.	Rhyolite. Microcrystalline.		About 5%. Feldspar: 5%, euhedral, tabular, 2.8~1mm., altered, twinned on Carlsbad. Quartz: rare	About 95% Microcrystalline, felsic, nearly colorless.	20–8

I-d The alkaline rocks in the main-land district

No. of Anal.	Sign of rock	No. of Specimen, Locality, Occurrence	Rock-name, Texture	Kuno's Class.	Phenocryst	Groundmass	No. Micro-photo.
26	OTB_1	T830-2 Koshibara, Matsue city. Flow.	Olivine-trachybasalt. Intergranular~ophitic.	IIIb	3.5% Olivine: 2.8%, 2V=+87.5°, γ′=1.709. Labradorite: 0.7%, xenocrystic, zoned reversely, An=42→60→65.	96.5% Labradorite: 65.7%, An=68~65. Augite: 12.5%, 2V=+48°, α′=1.677. Olivine: 3.9%, 2V=−88.5°. Magnetite: 4.8%. Glass: 9.6%.	21-1
	OTB_1	T271016-1 N-Ichinari, Matsue city. Flow.	Olivine-trachybasalt. Doleritic.	IIIb	1% Olivine: Plagioclase: 1.6~1.2mm., long, xenocrystic, zoned reversely.	99% Bytownite: 61.6%, euhedral, tabular~lath-shaped, 0.6~0.3 mm. long, An=79~72. Titaniferous augite: 20.5%, subhedral~granular, 0.2~0.1mm. Olivine: 9.0%, subhedral~granular, 0.5~0.1mm. 2V=+89°. Magnetite: 3.6%. Glass: 4.3%, dark colored. Biotie: rare, brown, strong pleochroism.	21-2
	OTB_1	T26923-1 The northern part of Shimane University, Kawatsu, Matsue city. Flow.	Olivine-trachybasalt. Intergranular~doleritic.	IIIb	5.6% Olivine: 4.6%, euhedral, 1.0~0.5 mm. 2V=+87.5°, 90°, somewhat altered to antigorite along crack, includ. magnetite.	94.4% Plagioclase: 63.1%, euhedral, tabular~lathy. 0.5~0.2mm. long. Augite: 17%, short prismatic~granular, 0.15~0.035mm., Z∠c=40°. Olivine: 7.5%, euhedral~granular, 0.25~0.1mm. dia., somewhat altered to antigorite and iddingsite. Magnetite: 2.2%, rod or grain, 0.15~0.015mm. Chloritic minerals in interstices: 4.6%.	

I-d The alkaline rocks in the main-land district

No. of Anal.	Sign of rock	No. of Specimen, Locality, Occurrence	Rock-name, Texture	Kuno's Class.	Phenocryst	Groundmass	No. Micro-phto.
	OTB_1	53-6 S-Kuroda, Matsue city. Flow.	Olivine-trachybasalt Intergranular~doleritic.	IIIb	About 10% Labradorite: 8%, euhedral, tabular, 2.5~1mm. long, xenocrystic. Olivine: 2%, euhedral~rounded, 0.7mm.	About 90% Andesine: 58%, lathy, 0.15mm. long, anorthoclase? in interstices. Olivine: 14%, rounded, 0.15~0.08mm. Augite: 13%, sub-~anhedral, 0.08mm. titaniferous. Magnetite and chloritic mineral: 5%.	
27	aPA_1	T 26924-2 Ichinari, Matsue city. Dike~neck.	Olivine-augite-basaltic andesite. Porphyritic.	Xc	9% Andesine: 6.7%, euhedral~flaky, 2.5~0.8mm. long, distinctively zoned and twinned, An=56~43, sometimes relic in core. Augite: 0.3%, $2V=+49°$, $Z\Delta c=45°$, $2V=+51°$, $Z\Delta c=44°$. Olivine: 2%, pseudomorph or opacitized, sometimes surrounded by augite.	91% Andesine: sub-~anhedral, under 0.15mm. long, An=42. Augite: eu-~subhedral, 0.25~0.08mm. long, $2V=+51.5°$, $\gamma'=1.711$, $Z\Delta c=44°$, Magnetite: fine grain. 0.03~0.02mm. Anorthoclase in interstices.	21-3
	aPA_1	53-1 Gakuzan, Matsue city. Dike~neck.	Olivine-augite-basaltic andesite. Porphyritic.	IIIb	12.4% Plagioclase: 8.3%, euhedral, tabular, 2~0.8mm. long, xenocrystic in core, An=45~42. Olivine: 3.1%, pseudomorph, opacitized or antigorite, 0.8~0.15mm.	88.6% Labradorite: lath-shaped, 0.8~0.15mm. long, An=56~53. Augite: eu-subhedral, 0.55~0.023 mm. includ. pigeonitic augite. Magnetite: granular~dust-like. especially in pseudomorph of olivine. Accessory: Apatite and zircon common.	21-4

1-e The rocks belonging to the Daisen volcanic zone

No. of Anal.	Sign of rock	No. of specimen, Locality, Occurrence	Rock-name, Texture	Kuno's Class.	Phenocryst	Groundmass	No. Micro-photo.
28		53-13 Ômisakibana, Matsue city. Flow. (from Mts. Wakura and Dake)	Hornblende-bearing cristobalite-andesite. Trachytic.		0%	100% Labradorite: 33%, euhedral, lath-shaped, twinned on albite & Carlsbad. An=56~54. Opacitized hornblende: 2%, anhedral, 0.1~0.08mm. long, brown, strong pleoch. Cristobalite and glass: 65%, rich in interstices, $\omega=1.488$. Magnetite: fine granular, rare.	21-5
		T-269233 The west-food of Mt. Wakura, Nange, Matsue city. Flow. (from Mts. Wakura and Dake)	Cristobalite-andesite. Trachytic.		0%	100% Plagioclase: about 50%, euhedral, lath-shaped, under 0.15mm. long. Cristobalite: about 45%, in interstices. Microlites of colored mins.: about 5%, needle-shaped. Opacite: sporadically. Magnetite: rare.	21-6
		I-5105244 Yadaki-Nishida, Yuzato-mura, Nima-gun. Flow. (from Mts. Ôe-takayama)	Biotite-hornblende-dacite. Porphyritic.		About 32% Plagioclase: 21%, euhedral, tabular-flaky, 2.5-0.5mm. long, remarkablyzoned, labradorite~andesine. Hornblende: 5.5%, eu~subhedral, long tabular, 1.6~0.25mm. long, strong pleoch.=dark green to light greenish yellow. $Z \Delta c=$ 23°~14°, partly opacitized. Quartz: 3.5%, euhedral~corroded, 0.85~0.15mm. dia. uniaxial. Biotite: 1.5%, euhedral, 1.0~0.15 mm. long tabular, partly opacitized, dark brown to light brownish yellow. Magnetite: 0.5%, fine granular, under 0.05mm.	About 68% Felsic, very rare colored min. apatite.	21-7 21-8

3. *Petrochemical Notes*

The author here wants to account for the chemical composition of some rocks separated into three cycles alluded to already and of some other Cenozoic volcanic rocks in the Shimane prefecture. Number of specimens analysed chemically both by the author and by Y. NAGAOKA, a member of collaborators, are 28, in which the data are given for 25 specimens belonging to the Miocene rocks and for the remainders obtained from other Cenozoic rocks (Table 2). Some variation diagrams concerning the chemical compositions are illustrated on Figs. 1∼5. Since the alkali-lime index, suggested by Peacock, given for the Miocene rocks indicates 63.5% in SiO_2 and 4.5% in CaO (Fig. 1), the rocks concerned are clearly to be included in a member of the calcic series. The specimens separated into each cycle are numerically too small to scrutinize their petrochemical characters and the triangular diagrams concerning their major components have accordingly been limited to be drawn.

Table 2. Petrochemical notes as to some volcanic rocks

2-a The rocks belonging to the lst cycle (The Hata)

No. sign Analyst	1 B_1 Mukae	2 B_1 Mukae	3 PA_1 Mukae	4 $2PA_1$ Nagaoka	5 $2PA_1$ Nagaoka	6 PA_1 Nagaoka	7 Da_1 Mukae	8 Da_1 Mukae	9 Rhy_1 Mukae
SiO_2	50.32	52.85	55.09	55.35	59.48	59.83	66.13	70.74	85.42
Al_2O_3	17.22	15.60	18.14	17.81	15.99	17.37	14.88	13.99	7.52
Fe_2O_3	4.32	4.43	6.59	5.58	3.15	2.98	3.83	1.44	0.92
FeO	5.44	4.02	2.38	3.57	2.40	3.71	2.84	1.86	0.95
MnO	0.37	1.03	1.21	0.53	1.91	0.63	1.40	0.23	tr.
MgO	4.55	3.22	2.89	2.33	1.47	1.62	0.48	0.41	0.30
CaO	9.40	11.08	7.33	7.81	2.56	7.33	3.39	1.97	0.24
Na_2O	4.52	2.24	2.66	3.48	6.35	4.20	3.30	4.25	0.96
K_2O	0.94	1.84	1.14	0.85	2.44	1.72	1.99	2.44	1.44
TiO_2	0.58	1.05	0.65	0.43	2.19	0.21	0.55	0.35	0.09
P_2O_5	0.49	—	—	0.18	0.46	0.35	—	—	—
H_2O+	2.42	0.97	1.92	0.69	1.70	0.53	0.80	1.05	1.13
H_2O-		1.50	0.58	1.45		0.47	0.44	0.46	0.27
Total	100.57	99.83	100.58	100.06	100.10	100.95	100.03	99.19	99.24
Norm									
Q	—	9.06	15.54	12.24	6.42	11.88	29.82	30.72	72.84
C	—	—	—	—	—	—	1.12	0.61	3.98
F { or	5.56	10.56	6.67	5.56	14.46	10.01	11.68	14.46	8.34
F { ab	38.25	18.34	23.06	29.34	53.97	35.63	27.77	36.15	8.38
F { an	23.91	27.52	33.64	30.30	7.78	23.63	16.96	10.01	1.11
Salic tot.	67.72	65.48	78.91	77.44	82.63	81.15	87.35	91.95	94.65
P { wo	8.00	11.48	1.04	3.48	0.58	4.06	—	—	—
P { en	3.40	8.10	7.20	5.80	3.70	4.10	1.20	1.00	0.80
P { fs	0.79	3.70	—	2.24	1.58	4.88	3.56	1.98	1.06
O { fo	5.60	—	—	—	—	—	—	—	—
O { fa	4.08	—	—	—	—	—	—	—	—
M { mt	6.26	6.50	9.51	8.12	4.64	4.41	5.57	2.09	1.39
M { hm	—	—	—	—	—	—	—	—	—
M { il	1.22	2.13	1.37	0.76	4.26	0.41	1.22	0.76	—
A ap	1.34	—	—	—	1.34	1.01	—	—	—
Femic tot.	30.69	31.91	19.12	20.40	16.10	18.92	11.55	5.83	3.25
Total	98.41	97.39	98.03	97.84	98.73	100.07	98.90	97.78	97.90

2-b The rocks belonging to the 2nd cycle (The Kawai and Kuri)

No.	10	11	12	13	14	15	16	17	18
Sign	$2PA_2$	Rhy_2	Rhy_2	Rhy_2	Rhy_2	Rhy_2	Rhy_2	Rhy_2	Rhy_2
Analyst	Nagaoka	Mukae	Mukae	Nagaoka	Mukae	Mukae	Mukae	Mukae	Mukae
SiO_2	64.98	70.14	74.69	74.94	74.98	75.30	75.43	75.60	76.63
Al_2O_3	14.88	16.36	13.11	11.02	14.42	14.46	13.09	13.35	12.65
Fe_2O_3	1.88	1.67	0.85	1.10	1.06	0.89	1.57	0.59	0.66
FeO	2.15	0.22	0.49	0.83	0.16	0.15	0.29	0.15	0.19
MnO	1.68	—	—	0.63	—	—	—	—	—
MgO	0.93	0.09	0.12	0.32	0.16	0.11	0.11	0.20	0.17
CaO	5.42	1.36	0.06	2.20	0.16	0.32	0.12	0.18	0.12
Na_2O	4.21	6.14	4.01	5.76	5.65	5.40	4.73	4.31	3.93
K_2O	0.94	1.05	4.12	1.11	2.30	1.80	4.02	4.07	4.04
TiO_2	1.83	—	—	0.84	—	—	—	—	—
P_2O_5	0.45	—	—	0.19	—	—	—	—	—
H_2O+ / H_2O-	0.58	2.79	1.95	0.83	1.34	1.85	0.98	0.90	1.75
Total	99.93	99.82	99.40	99.77	100.23	100.28	100.34	99.35	100.14
Norm									
Q	25.26	27.42	34.98	33.72	33.24	36.36	32.16	34.14	37.98
C	—	2.65	1.73	—	2.35	3.16	0.71	1.43	1.73
F or	5.56	6.67	24.46	6.67	13.34	10.56	23.91	24.46	23.91
F ab	35.63	51.35	34.06	49.25	47.16	45.59	39.82	36.15	33.01
F an	18.90	6.95	0.56	0.56	1.11	1.39	0.56	1.11	0.56
Salic tot.	85.35	95.04	95.79	90.20	97.20	97.06	97.16	97.29	97.19
P wo	1.74	—	—	4.29	—	—	—	—	—
P en	2.30	0.20	0.30	0.80	0.40	0.30	0.30	0.50	0.40
P fs	2.64	—	0.13	0.26	—	—	—	—	—
M mt	2.78	0.70	1.39	1.62	0.70	0.70	0.93	0.70	0.70
M hm	—	1.28	—	—	0.64	0.48	0.96	0.16	0.16
M il	3.50	—	—	1.52	—	—	—	—	—
A ap	1.34	—	—	—	—	—	—	—	—
Femic tot.	14.30	2.18	1.82	8.49	1.74	1.48	2.19	1.36	1.26
Total	99.65	97.22	97.61	98.69	98.94	98.54	99.35	98.65	98.45

2-c The rocks belonging to the 3rd cycle (The Ômori)

No.	19	20	21	22	23	24	25
Sign	B_3	$2PA_3$	$2PA_3$	Da_3	$2PA_3'$	Da_3	Rhy_3
Analyst	Mukae	Mukae	Mukae	Mukae	Mukae	Mukae	Mukae
SiO_2	50.00	58.51	59.41	65.25	65.65	68.26	71.32
Al_2O_3	14.73	16.11	15.69	12.88	11.75	12.40	14.66
Fe_2O_3	5.20	1.85	2.99	5.87	5.68	2.97	2.37
FeO	7.49	5.01	4.72	2.88	2.75	3.02	0.12
MnO	—	0.24	—	—	0.21	0.35	—
MgO	4.31	2.98	3.17	4.64	1.33	3.40	0.12
CaO	10.06	8.51	7.50	1.56	4.71	1.03	0.73
Na_2O	1.71	1.94	2.06	2.46	3.10	2.93	6.04
K_2O	2.02	1.75	0.93	1.91	1.60	2.27	1.08
TiO_2	0.41	0.77	0.94	0.59	1.05	1.30	—
P_2O_5	—	—	—	—	—	—	—
H_2O+	0.70	0.29	0.81	0.56	0.71	0.88	3.28
H_2O-	2.53	1.49	1.03	0.82	1.19	0.57	
Total	99.16	99.45	99.25	99.42	99.73	99.38	99.72

2-c The rocks belonging to the 3rd cycle (The Ōmori): -continued

No.	19	20	21	22	23	24	25
Norm							
Q	5.70	17.40	22.08	33.24	31.56	34.68	30.36
C	—	—	—	3.77	—	3.37	2.24
F or	11.68	10.56	5.56	11.12	9.45	13.34	6.67
F ab	14.15	16.24	17.82	20.96	26.20	24.63	50.83
F an	26.69	30.02	30.58	8.06	13.62	5.00	3.61
Salic tot.	58.22	74.22	76.04	77.15	80.83	81.02	93.71
P wo	9.74	5.10	2.78	—	4.06	—	—
P en	10.80	7.50	7.90	11.60	3.30	8.50	0.30
P fs	8.71	6.60	4.62	—	—	1.72	—
O fo	—	—	—	—	—	—	—
O fa	—	—	—	—	—	—	—
M mt	7.66	2.78	4.41	7.42	6.50	4.41	0.23
M hm	—	—	—	0.80	1.28	—	2.24
M il	0.76	1.52	1.67	1.22	2.13	2.43	—
A ap	—	—	—	—	—	—	—
Femic tot.	37.67	23.50	21.38	21.04	17.27	17.06	2.77
Total	95.89	97.72	97.42	98.19	98.10	98.08	96.48

2-d The rocks belonging to the Alkaline Suite

No.	26	27
Sign	OTB_1	aPA_1
Analyst	Mukae	Mukae
SiO_2	48.04	51.82
Al_2O_3	16.97	17.33
Fe_2O_3	4.47	7.70
FeO	4.51	1.91
MnO	0.30	0.27
MgO	7.59	3.51
CaO	7.40	6.67
Na_2O	5.36	5.50
K_2O	1.63	2.76
TiO_2	0.51	0.41
P_2O_5	0.49	0.71
H_2O+	1.01	0.31
H_2O-	1.47	1.74
Total	99.75	100.64
Norm		
Q	—	—
C	—	—
F or	9.45	16.68
F ab	30.39	40.35
F an	17.51	14.18
L lc	—	—
L ne	8.24	3.41
Salic tot.	65.59	74.62
P wo	6.50	6.03
P en	—	—
P fs	—	—
O fo	13.30	6.16
O fa	3.47	—
M mt	6.50	5.80
M hm	—	3.68
M il	0.91	0.76
A ap	1.34	1.68
Femic tot.	32.02	24.11
Total	97.61	98.73

2-e The hornblende-bearing cristobalite-andesite from Mts. Wakura and Dake.

No.	28
Analyst	Mukae
SiO_2	62.36
Al_2O_3	20.16
Fe_2O_3	2.46
FeO	2.20
MnO	0.16
MgO	1.58
CaO	5.14
Na_2O	3.34
K_2O	1.31
TiO_2	0.33
P_2O_5	0.16
H_2O+	0.46
H_2O-	0.51
Total	100.17
Norm	
Q	24.06
C	4.08
F or	7.78
F ab	27.77
F an	25.30
Salic tot.	88.99
P wo	—
P en	4.00
P fs	1.85
M mt	3.71
M hm	—
M il	0.61
A ap	—
Femic tot.	10.17
Total	99.16

Table 3. Ratios of Chemical Compositions

Cycle	No.	SiO_2	Al_2O_3/CaO	Tot.FeO/MgO	Al_2O_3/(Na_2O+K_2O)	Na_2O/K_2O	mol. % Or:Ab:An	mol. % Fo:Fa:Q	wt. % Alkali:Fe_2O_3:MgO	wt. % Q:F:M	Sign
1st Cycle	1	50.32	1.8	2.2	3.2	4.8	6:43:51	57:23:20	27:51:22	0:76:24	B_1
	2	52.85	1.4	2.8	3.8	1.2	12:23:65	15:5:80	25:55:20	10:64:26	B_1
	3	55.09	2.5	3.3	4.8	2.3	7:25:68	11:0:89	24:58:18	18:73:9	PA_1
	4	55.35	2.3	3.9	4.1	4.1	6:32:62	10:3:87	27:59:14	14:73:13	$2PA_1$
	5	59.48	6.3	4.9	1.8	2.6	16:66:18	12:4:84	55:36:9	7:86:7	$2PA_1$
	6	59.83	2.4	4.3	2.9	2.4	10:40:50	7:7:86	40:49:11	13:73:14	PA_1
	7	66.13	4.4	16.0	2.8	1.7	16:39:45	1:3:96	41:55:4	33:62:5	Da_1
	8	70.74	7.1	8.3	2.1	1.7	20:53:27	1:1:98	63:33:4	33:64:3	Da_1
	9	85.42	31.4	6.0	3.1	0.7	43:46:11	0:0:100	51:43:6	79:19:2	Rhy_1
2nd Cycle	10	64.98	2.8	6.0	2.9	4.5	6:47:47	3:2:95	50:41:9	28:65:7	$2PA_2$
	11	70.14	12.0	19.0	2.3	5.9	9:73:18	0:0:100	78:21:1	30:70:0	Rhy_2
	12	74.69	219.0	10.5	1.6	1.0	40:59:1	0:0:100	85:14:1	37:63:0	Rhy_2
	13	74.94	5.0	7.7	1.6	5.2	11:87:2	1:0:99	74:22:4	35:59:6	Rhy_2
	14	74.98	90.0	9.6	1.8	2.4	20:76:4	0:0:100	85:13:2	35:65:0	Rhv_2
	15	75.30	45.2	8.6	2.0	3.0	17:78:5	0:0:100	86:13:1	39:61:0	Rhy_2
	16	74.43	109.0	15.5	1.5	1.2	36:63:1	0:0:100	81:18:1	33:67:0	Rhy_2
	17	75.60	74.0	3.4	1.6	1.1	38:59:3	0:0:100	90:8:2	35:64:1	Rhy_2
	18	76.63	105.0	4.6	1.6	1.0	40:58:2	0:0:100	88:10:2	40:60:0	Rhy_2
3rd Cycle	19	50.00	14.0	2.8	4.0	0.9	14:19:67	20:12:68	17:63:20	7:60:33	B_3
	20	58.51	1.9	2.3	4.4	1.1	12:20:68	9:6:85	26:53:21	19:61:20	$2PA_3$
	21	59.41	2.1	2.3	5.2	2.2	6:22:72	8:4:88	21:57:22	24:59:17	$2PA_3$
	22	65.25	8.3	1.8	2.9	1.3	22:45:33	9:0:91	24:50:26	39:47:14	Da_3
	23	65.65	2.5	6.1	2.5	1.9	15:43:42	3:0:97	32:59:9	36:56:8	$2PA_3'$
	24	68.26	12.0	1.8	2.4	1.3	27:53:20	6:1:93	35:43:23	39:49:12	Da_3
	25	71.32	20.1	18.8	2.1	5.6	10:79:11	0:0:100	73:26:1	33:67:0	Rhy_3
	26	48.04	2.3	1.2	2.4	3.3	12:42:46	85:15:0	29:39:32	0:74:26	OTB_1
	27	51.82	2.6	2.6	2.1	2.0	19:49:32	100:0:0	38:46:16	0:86:14	aPA_1
	28	62.36	3.9	2.9	4.3	2.5	9:33:58	4:2:94	42:44:14	27:67:6	
Alkaline Suite	29	36.00	0.8	1.7	2.3	2.0	—	72:28:0	18:54:28	0:47:53	
	30	41.97	1.3	1.4	3.3	2.0	14:15:71	—	17:50:33	0:59:41	
	31	47.77	1.8	1.7	3.0	1.6	14:30:56	—	24:50:26	0:71:29	
	32	52.35	2.3	2.4	2.6	1.7	15:40:45	—	35:49:16	0:81:19	
	33	57.51	4.7	4.0	1.9	1.1	27:44:29	—	56:36:8	1:92:7	
	34	62.63	7.8	10.6	1.6	1.0	32:51:17	—	67:30:3	7:89:4	
	35	66.97	11.7	14.4	1.4	1.0	40:58:2	—	70:28:2	13:81:6	
	36	72.71	19.6	26.0	1.4	1.0	40:58:2	—	65:34:1	30:66:4	
	37	47.76	1.4	1.0	4.9	2.0	12:33:55	63:26:11	16:44:40	0:64:36	
	38	44.22	1.7	2.1	3.8	2.0	14:41:45	75:0:25	19:57:24	0:75:25	
	39	45.46	1.4	0.8	2.9	2.8	17:41:42	72:15:13	21:43:36	0:66:34	
	40	48.40	2.0	1.3	3.0	1.0	27:34:39	56:39:5	25:44:31	0:71:29	
	41	50.69	1.4	1.5	2.6	1.3	25:43:32	67:5:28	33:42:25	0:73:27	
	42	61.41	9.9	∞	2.5	0.4	56:31:13	0:0:100	63:37:0	43:57:0	
	43	65.51	10.5	11.0	1.6	0.5	56:37:7	4:9:87	73:25:2	19:80:1	
	44	67.51	21.4	24.1	1.4	0.9	60:33:7	3:10:87	67:32:1	19:77:4	
	45	45.75	23.5	3.2	2.3	4.1	16:57:27	57:33:10	35:51:14	0:83:17	
	46	61.15	17.8	∞	1.6	1.5	32:62:6	0:100:0	73:27:0	0:97:3	
	47	73.39	26.5	∞	1.5	1.2	35:63:2	0:0:100	94:6:0	23:76:1	
	48	66.55	26.6	∞	1.4	1.2	37:62:1	0:0:100	90:10:0	7:93:0	
Daisen	49	69.16	3.6	1.8	2.5	2.8	11:48:41	3:1:96	60:26:14	27:66:7	
	50	66.54	3.7	2.5	3.2	2.2	12:39:49	4:0:96	53:34:13	36:59:5	
	51	66.29	3.5	2.5	3.1	2.5	10:40:50	4:0:96	52:35:13	26:70:4	
	52	65.59	4.8	3.1	2.6	2.7	13:51:36	4:0:96	55:34:11	25:71:4	
	53	65.80	3.4	1.7	2.6	1.8	15:41:44	4:3:93	54:35:11	21:72:7	
Shimonoseki	54	51.63	3.4	1.6	4.4	0.7	17:19:64	17:4:79	20:51:29	16:62:22	
	55	52.23	3.7	1.1	7.6	1.4	9:19:72	20:7:73	11:49:40	17:46:37	
	56	51.24	3.1	1.3	7.4	2.1	6:19:75	19:1:80	13:51:36	19:59:22	
	57	58.11	3.4	1.7	3.4	3.0	8:36:56	10:0:90	34:43:23	21:66:13	

The petrochemical characters of the Miocene volcanic rocks, in comparison with one of other Cenozoic volcanic rocks relating to the alkaline suite and the Daisen volcanic zone, and as an exception, with one of the Shimonoseki volcanic rocks presumably concerning the middle Cretaceous, will hereunder be discussed. First of all, the data obtained for the Cenozoic volcanic rocks from other localities are referred to as follows:

1) As the data representing the Circum-Japan Sea Alkaline Suite:

Chemical types of Nos. I–VII obtained from the paper given by T. TOMITA in 1935, and those of Nos. 1–13 obtained from his paper in 1950 are valid, but No. 6 is neglected because of its absence in the author's hand.

2) As the data corresponding to the Daisen volcanic zone:

Fours for the specimens obtained from Volcano Sambe (given by S. KÔZU and B. YOSHIKI in 1929) and one for quartz-andesite obtained from the same volcano (read by K. YAMAGUCHI in 1955) are cited.

3) As the data concerning the Shimonoseki volcanic rocks:

Fours for the specimens sampled from the Hikoshima islet in the Kanmon district (given by Y. OHJI in 1952) are selected out.

A. Inspection for the bulk composition:—Fig. 3

On Fig. 3, the bulk compositions of the Miocene rocks are compared with those of other Cenozoic volcanic rocks, and certain constituents of the Cenozoic volcanic rocks of Japan given by S. TANEDA (1950) are referred to.

a. Al_2O_3:—Fig. 3-1

The values for Al_2O_3 from the Miocene volcanic rocks are normally plotted within the scope for the Cenozoic volcanic rocks of Japan on TANEDA's variation diagram, but those in the basic parts show a relatively downward inclination. The point for the rock from Mts. Wakura and Dake is situated on the line for the Daisen zone.

b. Na_2O+K_2O:—Fig. 3-2

The values in the acidic part indicate a remarkably upward tendency. The point for the specimen attained from Mts. Wakura and Dake falls on the line of the Daisen zone.

c. K_2O:—Fig. 3-3

The values in the acidic part have an apparent tendency toward the higher side.

d. Na_2O:—Fig. 3-4

The values in the acidic part show the same relation as those for the former.

e. CaO:—Fig. 3-5

The values are normal.

f. MgO:—Fig. 3-6

The values are normal.

g. Total FeO:—Fig. 3-7

The values in the basic and intermediate parts are surely observed in the higher side, while, on the contrary, those in the acidic parts are plotted in the lower side.

Fig. 1 The alkali-lime index

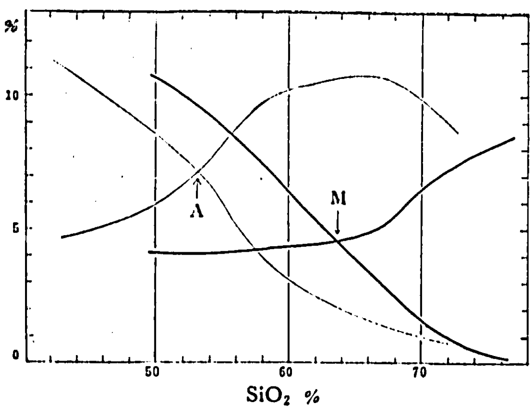
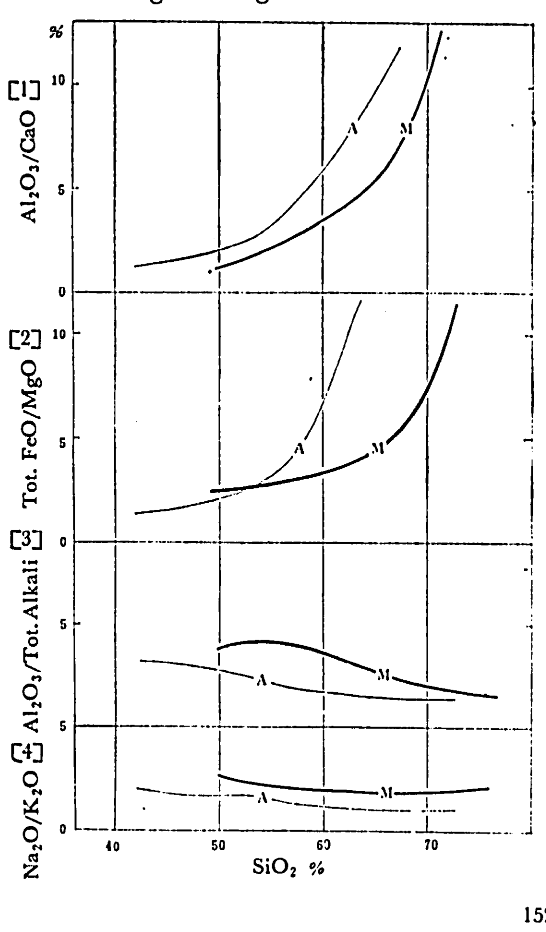


Fig. 2 Diagrams for ratios



B. Ratios for certain compositions:–Fig. 2

a. Ratios of Al_2O_3 to CaO for SiO_2 on the abscissa. :—Fig. 2–1

The values in the acidic parts are conspicuously recognized in the higher side.

b. Ratios of total iron oxides to MgO for SiO_2 on the abscissa :—Fig. 2–2

The values in the acidic part are in the same relation as those for the former.

c. Ratios of Al_2O_3 to total alkalies for SiO_2 on the abscissa :—Fig. 2–3

The values in the basic part point to a downward inclination.

d. Ratio of Na_2O to K_2O for SiO_2 on the abscissa :—Fig. 2–4

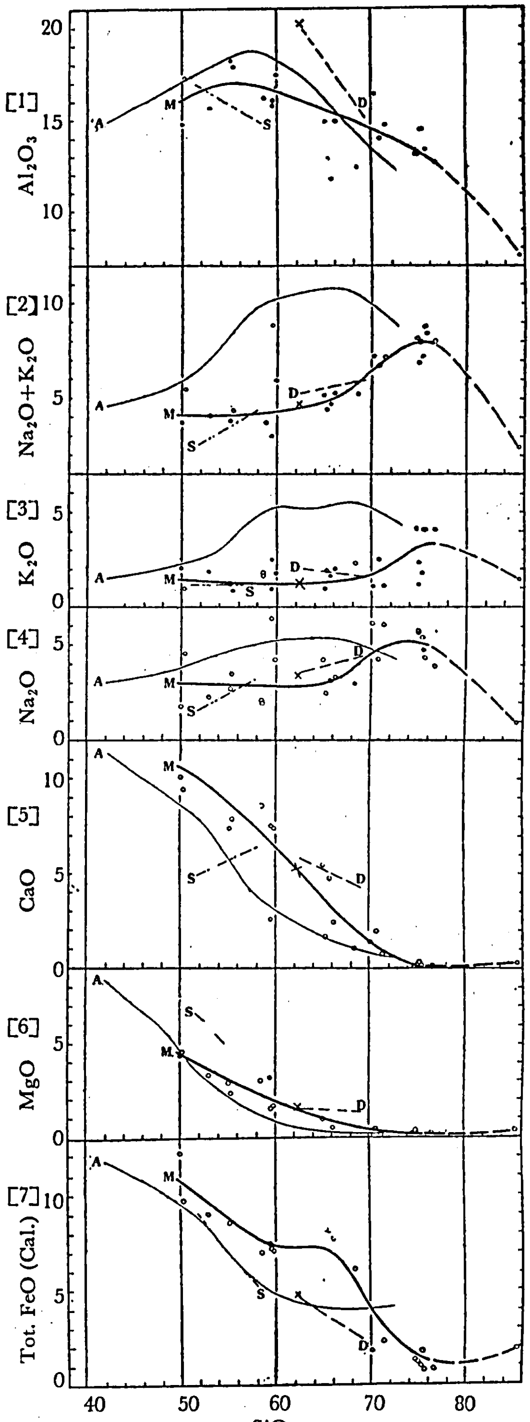
The values are generally normal, but those in the acidic part show an upward inclination.

C. Ratios of two components :—Fig. 4

The distributions and the ratios of two components contained in each volcanic series are here discussed. Values of the ratios for each series seem to be distributed within each considerably limited area on the diagrams showing the respective characteristics. Because the chemical components of rocks are generally used to depend on SiO_2 contents, all the data for the specimens have conveniently been separated into two groups with the boundary of 65% in SiO_2; One is the basic (basaltic) to intermediate (andesitic) group containing less than 65%, and the other, the acidic (dacitic to rhyolitic) including more than 65%.

a. Ratios of K_2O to Na_2O;–more than 65% in SiO_2 :—Fig. 4–1

The sums of K_2O and Na_2O contents for 15 specimens referring to the Miocene



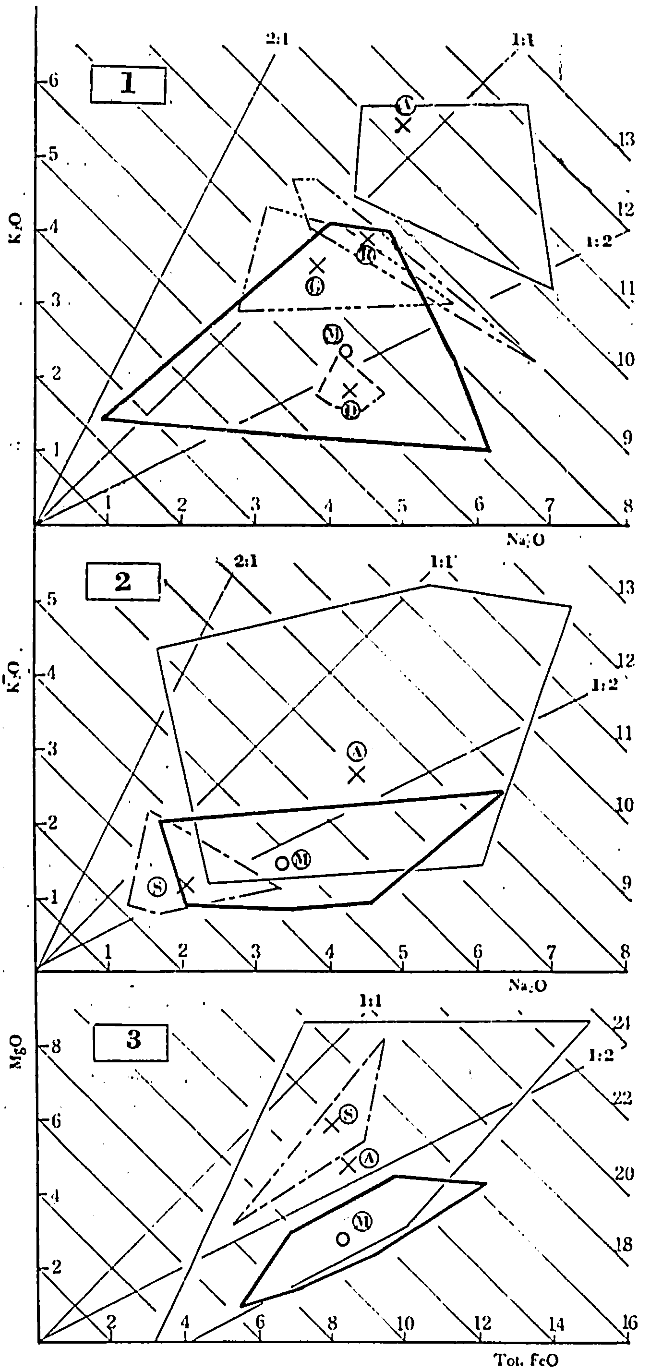
volcanic rocks indicate the variation ranging from 2% to 9% and their mean value is estimated 6.5%. Contents of Na_2O are evidently larger than those of K_2O in their mean value and the ratio of K_2O to Na_2O is about 1 : 2. On the other hand, the sums of K_2O and Na_2O contents for 6 specimens concerning the alkaline suite are in the range from 8% to 13% and their mean value is 10.4%, and the ratio of Na_2O to K_2O is nearly equal to 1 : 1. The sums for 5 specimens relating to the Daisen zone vary from 5% to 7% and the mean value is 6.0%, and Na_2O is quite larger than K_2O, resulting in 1 : 2 in their ratio. For reference, the data for the pre-Miocene granitic rocks and the pre-Miocene rhyolites collected from Chūgoku province are compared. The sums of K_2O and Na_2O for 8 specimens pertaining to the pre-Miocene granitic rocks indicate the variation from 5% to 9% and the mean value is 7.3%, and their mean ratio is nearly 1 : 1, indicating their difference from those obtained for the Miocene rocks. The sums for 4 specimens belonging to the pre-Miocene rhyolites are ranging from 7% to 9% and the mean value is 8.4%, and their mean ratio is nearly 1:1. Conclusively, remarkable differences are noticed in the sums of two components and their ratios for each acidic rock.

b. Ratios of K_2O to Na_2O; less than 65% in SiO_2 :—Fig. 4-2

Fig. 3 Normal Variation Diagrams

Abbreviation

M : For the Miocene rocks
A : For the alkaline suite
D : For the Daisen zone
S : For the Shimonoseki rock
X : For the Wakura andesite



The sums of K_2O and Na_2O for 10 specimens representing the Miocene rocks are ranging from 3% to 9% and the mean value is 4.8%, indicating 1:2 in their ratio. Those for 16 specimens belonging to the alkaline suite show the variation from 3% to 13% and the mean value is 7.0%, indicating nearly 1:2 in their ratio. The sums for 4 specimens corresponding to the Shimonoseki rocks are ranging from 2% to 5% and the mean value is 3.2%, and their ratio becomes 1:2. Noticeable difference is observed in the sums for each rock series.

c. Ratios of MgO to total iron oxides; less than 65% in SiO_2 :—Fig. 4–3

The sums for 10 specimens concerning the Miocene rocks are variable from 6% to 17% (11.0% in the mean),

Fig.4 Distribution-diagrams

Abbreviation

- O M : For the Miocene rocks
- × A : For the Alkaline suite
- × D : For the Daisen zone
- × S : For the Shimonoseki rocks
- × G : For the pre-Miocene granites
- × R : For the pre-Miocene rhyolites

and their ratio is less than 1 : 2, while those for 16 specimens belonging to the alkaline suite are ranging from 3% to 24% (13.2% in the mean) and their ratio is more than 1 : 2, and those for 4 specimens of the Shimonoseki rocks are ranging from 8% to 18% (13.8% in the mean) and their ratio is nearly 1 : 1. These chemical differences in the sums and their ratios seem to imply the characteristics for each series.

D. Relation among three components:- Fig. 5

Mutual relations among three components of the Miocene volcanic rocks are hereunder discussed for the purpose of determining the types of magmatic evolution.

a. Relation among An–Ab–Or :–Fig. 5–1

The trend of the 1st (the Hata) volcanic cycle runs parallel with that of the Circum-Japan Sea alkaline suite: that is, the former falls into the category of "normal" given by T. TOMITA. On the other hand, the trend of the 3rd (the Ômori) seems to fall under the "abnormal". Accordingly, from T. TOMITA's view, the trend of magmatic evolution of the Miocene volcanism suggests a tendency ranging from orthomagmatic to contaminated type in the course of geologic age from the 1st to the 3rd cycle.

b. Relation among MgO–FeO + Fe_2O_3–total alkalies :–Fig. 5–2

All values of the 1st cycle fall within the scope of the pigeonitic series shown by Kuno's

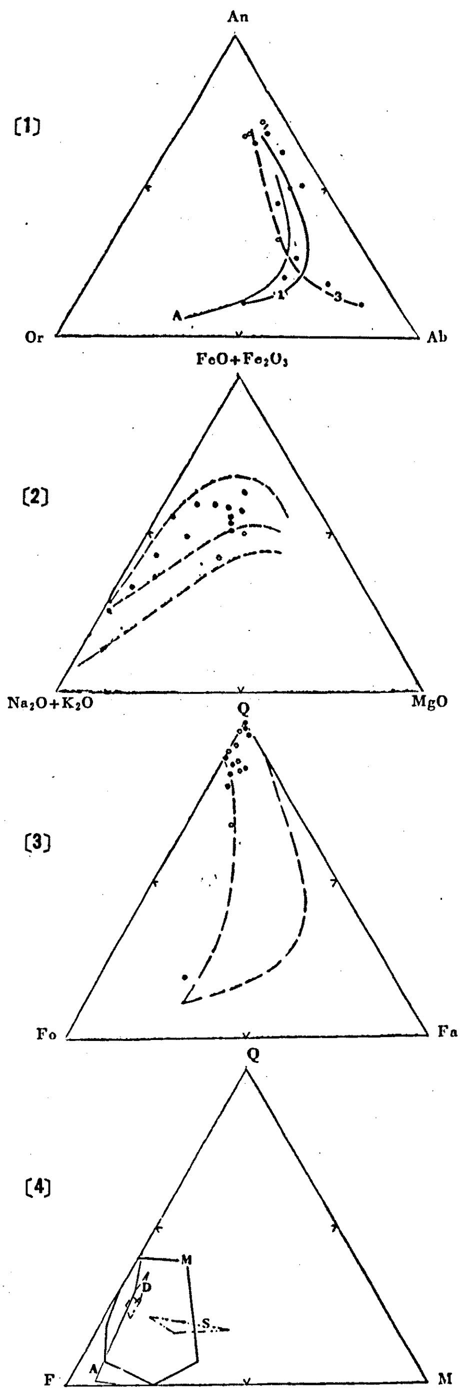


Fig. 5 Triangular diagrams

Abbreviation

● : For the 1st cycle
○ : For the 3rd cycle
M —— : For the Miocene volcanic rocks
A —— : For the alkaline suite
D – – : For the Daisen volcanic rocks
× : For the andesite from Mt. Wakura
S —·— : For the Shimonoseki Volcanic rocks

category (1950), while those of the 3rd cycle are spread over both areas of the pigeonitic and hypersthenic series, and the author however thinks that the 3rd cycle is adaptably included in the hypersthenic series. This interpretation is also possibly derived from the mineralogical data concerning these two cycles.

c. Relation among Q–Fo–Fa :—Fig. 5–3

The trends for the 1st and the 3rd cycles seem to fall similarly on a single curve, suggesting the "abnormal and hornblende" type given by T. TOMITA. Therefore, the Miocene rocks in the San-in Nepton might have been produced not from a simple course of differentiation of a parental magma, but from somewhat contaminated resources.

d. Relation among Q–F–M :— Fig. 5–4

The diagram referring to the relation is thought to indicate the proportion of mineral assembledges corresponding to the mode. The alkaline suite has an inclination toward F, and the Miocene rocks are apt to be widely scattered and relatively rich in M and Q, while the Daisen rocks show a tendency toward Q and F, and those from the Shimonoseki rocks, toward M.

4. *Petrographical characteristics of Miocene volcanic rocks*

In the Miocene volcanic rocks are included various kinds of lavas and pyroclastic rocks such as two-pyroxene-basalts, two-pyroxene-andesites, dacites and plagioliparites, associated with intrusions of gabbros, dolerites and quartz-porphyries. In general, they are mineralogically characterized with their contents of pyroxenes and plagioclases, usually accompanying no olivine and no primary amphiboles in the basic and intermediate varieties, and no quartz-phenocrysts in the acidic parts with some exceptions. The mineralogical features mentioned above as to the Miocene volcanic rocks indicate a remarkable contrast with those of the alkaline suite characterized with thier contents of olivines and alkaline minerals, and with those appeared in the Daisen zone characterized with hornblende, biotite and quartz. The Miocene rocks appeared in the lst cycle contain no rhombic pyroxenes but pigeonitic augite in the groundmass and thus are regarded as a member of the pigeonitic series, while the rocks representing the 3rd cycle contain two-pyroxenes in the groundmass and thus are considered to be a member of the hypersthenic series. Petrochemically, the alkali-lime index for the Miocene volcanic rocks are 63.5% in SiO_2 and 4.5% in CaO, and that for the alkaline suite, 53.1% in SiO_2. The Miocene rocks are therefore clearly belonging to a part of the calcic series. The lst cycle indicates a trend for the normal type in the diagram of An-Ab-Or, the abnormal and hornblende type in that of Q–Fo–Fa, and the pigeonitic type in that of MgO–Fe_2O_3-alkalies respectively, while the 3rd cycle indicates a tendency for the abnormal, the abnormal and hornblende, and the hypersthenic types, respectively. Hence, the Miocene calcic volcanism seems to show the variation from the normal and pigeonitic to the abnormal and hypersthenic one in the course of geologic age.

VI. DISCUSSION ON VOLCANOSTRATIGRAPHY OF San-In NEOGENE

In this chapter, the geology appeared in each main area situated in the San-in Neogene sedimentary basin, the general volcanostratigraphy of the San-in Neogene and the geological relationship among the Cenozoic volcanisms occurred in the so-called San-in mixed province are volcanostratigraphically discussed. From inspection of the results attained for almost all the main areas in the San-in province, it has become clear that the volcanostratigraphical correlation in this basin was of due significance and even most helpful for scrutinizing the geology scattered in the very area without any contradictions against certain data obtained from ordinary methods. Generally, the reality is that the eruptive violency in volcanic activities appeared throughout geologic age is possibly to be corresponding to the volume of pyroclastic rocks as well as their areal distribution, and hence a thickly stratified volcanic formation intercalating pyroclastic rocks and lavas in large amounts may represent a violent period of volcanism. Although the San-in Neogene sedimentary basin is relatively small-scaled and distributed locally as a geologic unit, several volcanic formations scattered within this province are rich in various kinds of characteristics and should be considered to be geologically important as one of the "Green Tuff" regions. On the other hand, it is also significant to inspect the localism of volcanism geochronologically and dimensionally in relation to sedimentation and geotectonical agencies within a sedimentary basin. In the light of these problems, the author wants to discuss on the stratigraphies observable in the related areas and generally on the San-in Neogene.

1. *Stratigraphies of some main areas*

The San-in Neogene province is geotectonically divided into two districts: one is the periphery of the basin represented by the main-land and the other, the central part occupied by the Shimane peninsula. Furthermore, the former is reasonably subdivided into the Hamada City area, the Ômori area, the Izumo City area, the southern coast area of Shinji lake and the southern area of Matsue City, and the latter, into the western, the central and the eastern areas.

(1) The Hamada City area: —Pls. 22–1 and 24

The Neogene geology of the area concerned has, to remarkable extent, been clarified from the results of investigations executed by S. IMAMURA, G. KOJIMA and some students of Hiroshima University. The author has also re-investigated the same area and summarized the data in good correlation to those obtained from the Izumo City area. The Cenozoic geology of this area can be classified into the Kokubu[1] subgroup (F_2), the Tôgane[2] formation (F_3), the dolerites (G), the Tsunozu formation (I_1), the nepheline-basalts (I_2) and the Kokubunji bed (J) (S. IMAMURA, 1957), among which the first is regarded as a chief volcanic formation.

1) Kokubu 國府 2) Tôgane 郷鋼

According to the author's view, following interpretations for the Cenozoic volcanism in this area are surely possible. The Kokubu subgroup is subdivided into the lower and upper main parts, respectively, including the Kokubu volcanic complex and the Yatadani[1] formation. The former is believed to have been erupted in ascending succession of two-pyroxene-basaltic andesites, two-pyroxene-leucoandesites in the most amount, dacites and rhyolites in more amount, quartzose rhyolites, plagioliparites and hornblende-bearing andesites, among which, however, geological intervals are not conspicuously observable. Some specimens of andesites included in the collection are clearly considered as a part of the pigeonitic series. On the other hand, the Yatadani formation, lying conformably upon the dacites in the former, consists of shales, tuffs, sandstones and conglomerates with a lot of *Myrica* (*Comptoniphyllum*)-*Liquidambar* flora of Daizima type. The whitish or light reddish tuffs, intercalated in these beds and occupying about 30% in thickness, are assumed to be correspondent to the acidic volcanic rocks in the upper parts of the former complex on the basis of the lower values of their mean refractive indices ($N \doteqdot 1.50$), as to which a method of rapid determination for volcanics was already published by the author. Consequently, the Yatadani formation is thus thought to be a heteropic facies of the upper part of the Kokubu volcanic complex identified as the middle Miocene (F_2). This volcanic complex, resting directly on the pre-Miocene granitic rocks or schists, is also determinable to be the product derived from the first volcanism in the Miocene pertaining to the 1st volcanic cycle. Since volcanism is observable nowhere in the Tôgane formation, the 2nd cycle is not appeared in this area. The two-pyroxene-dolerites, occured as dikes on the wave-cut terrace of Tatamigaura injecting into the Tôgane formation and in some other parts injecting into the basements, are clearly correspondent to a part of the hypersthenic and is correlated with the two-pyroxene-basalts of the Ômori formation belonging to the 3rd cycle in other main areas. The melilite-nepheline-basalts, belonging to a part of the Circum-Japan Sea alkaline suite, cover unconformably the Tsunozu formation and are found under the Kokubunji bed. The geological age of these volcanic rocks may be the Pleistocene and correlative with one of the 2nd olivine-trachybasalts demonstrated by T. TOMITA in Dôgo, Oki Islands.

(2) The Ômori area: —Pls. 22-2 and 24

The Cenozoic geology of the Ômori area has hitherto been investigated by S. IMAMURA, H. YOSHIDA and some other collaborators. As for the related region, the author has taken part merely in the petrographical study on the specimens collected by the co-workers. The Ômori area is supposed to be a best example of the great embayments geotectonically named by H. YOSHIDA (1952) and at the same time, to be closely connected with one of the inland-basins in the San-in Neogene sedimentary basin by Y. TAI (1957). Consequently it is also believed to be a type-area of the San-in Neogene in the

1) Yatadani 谷田谷

main-land district. According to the latest research given by S. IMAMURA and H. YOSHIDA (1955), the Neogene in this area is stratigraphically classified into three groups of Iwami, Izumo in the Miocene and Ôe in the upper Pliocene. The Iwami group is subdivided into the Kimitani[1] subgroup (F_2), the Kawai (F_3), the Kuri (F_3-G) and the Ômori (G) formations in ascending order. The Izumo group in this area consists only of the Kimati member of the Fujina (G) formation. The Kimitani subgroup, the Kuri (the lower part) and the Ômori formations are all composed of volcanic formations. The Kimitani subgroup, distributed typically around the Kimitani village, consists of conglomerates overlying the basements, volcanic rocks such as rhyolites, andesites and rhyolites appeared in the main portion in ascending succession, and hornblende-quartz-diorites injecting into the formers, and contains only some imperfect floras. In this subgroup are included two-pyroxene- and two-pyroxene-dacitic andesites, belonging to a part of the pigeonitic series, and quartzose rhyolite having petrographical features similar to those from the Izumo City area. Accordingly, the Kimitani subgroup, resting unconformably upon the pre-Miocene granitic rocks, is believed to be correspondent to the volcanic formation of the 1st cycle and to be regarded as a part of the middle Miocene (F_2). The Kawai formation in this area is composed of shallow marine sedimentary beds accompanying no pyroclastic rocks and is surely identifiable with a part of the middle Miocene (F_3) on the basis of marine molluscs such as *Siratoria siratoriensis* ÔTUKA etc. (S. IMAMURA, 1952). The Kuri formation (F_3-G), conformable to the former, consists of pyroclastic rocks and lavas of andesites and plagioliparites in the lower part and black shale in the upper part. Inasmuch as some specimens of andesites are defined as a member of the pigeonitic series and plagioliparites have petrographical characters similar to those from other main areas, the volcanism in this formation is believed to correspond to one of the 2nd cycle. The gypsum deposits in the northern part of this area seem to be situated stratigraphically in the alternation zones near the upper and lower boundary horizons of pyroclastic rocks in the lower part of the formation concerned. Petrographical and petrochemical characteristics for some specimens of andesites and plagioliparites belonging to this formation have already been described in the former chapter. The Ômori formation is a sort of volcanics, consisting of conglomerates in the base and a large amount of pyroclastic rocks and lavas intercalated with shales, sandstones and conglomerates. In the related facies are included two-pyroxene-basalts, two-pyroxene-dolerites, dacites and leucoandesites, clearly regarded as a part of the hypersthenic series, and thus the formation concerned corresponds surely to one of the 3rd cycle occurred in the Izumo City area. Conclusively, it is proven that, in the Ômori area, all cycles of the Miocene volcanism are ascertainable in good accordance with volcanostratigraphy observed in the Izumo City area. The Ôe group (I_1) consists of fresh-water sedimentaries inter-

1) Kimitani 君谷

calated in the upper part with tuffs which show the characteristics resembling those of the specimens obtained from the Daisen volcanic zone, and in the surroundings of Mts. Ôe-takayama, where some lava-domes belonging to the Daisen zone rest conformably upon the group concerned. In consequence, the earliest activity in the Daisen volcanic zone is clearly recognized to have started in the upper horizon of the Ôe group in the uppermost Pliocene (I_1). In the eastern environs of this area is situated Mt. Sambe as one of the volcanoes belonging to the Daisen volcanic zone.

(3) The Izumo City area: —Pls. 22–3 and 24

As the Neogene geology in this area has already in 1954 been reported by the author, the outline is hereunder discussed again from the standpoint of dimensional observation throughout the San-in Neogene with introducing the new names of formations revised by the research group in 1957. The Neogene concerned is divided into the Iwami and the Izumo groups. The one is subdivided into the Hata subgroup (F_2), the Kawai (F_3), the Kuri (F_3-G) and the Ômori (G) formations, respectively corresponding to the Hata group, the lower and upper beds of Tamatukuri group and the Ômori formation described in the former paper. The other is represented only by the Fujina formation, neglecting the Kimati formation, whereas the latter is rather interpreted merely as the basal part of the Fujina formation. The Hata subgroup, the Kawai formation together with the Kuri formation and the Ômori formation, volcanostratigraphical representatives of the type-formations appeared in the San-in Neogene, are correspondent respectively to the 1st, the 2nd and the 3rd cycles of the Miocene volcanism. The Hata volcanic complex, the main part of the very subgroup, resting directly upon the pre-Miocene granitic rocks, consists of various kinds of volcanics ranging from basic (augite-basaltic and two-pyroxene-andesitic) to acidic (dacitic and rhyolitic) properties, indicating a series of magmatic differentiation. These volcanic rocks are clearly belonging to a member of the pigeonitic series as are described in the former chapter. The Nabeyama formation, considered as a heteropic facies of the upper part in the subgroup, is, on account of its content of *Myrica (Comptoniphyllum)-Liquidambar* flora of Daizima type, believed to have been formed in the middle Miocene (F_2). In the middle parts (considered as F_3 in age) of the Kawai and Kuri formations are observed some tuffaceous beds of andesitic, dacitic and plagioliparitic varieties. Since the basic tuff-breccias in the uppermost part of the Kuri formation are, because of their petrographically similar characteristics and from the data for dimensional observation, preferably considered to have been a forerunner of two-pyroxene-basalts appeared in the lowest part of the Ômori formation, the author's view has recently inclined to interpret that the stratigraphical relationship between these two formations is adaptably conformable in spite of the intervention of some volcano-tectonic intervals. The Ômori formation (G) containing rarely marine molluscs is composed chiefly of volcanic rocks ranging from basic (two-pyroxene-basaltic and two-pyroxene-andesitic) to acidic (leucoandesitic and dacitic) in their features, indicating a series of magmatic differentiation. Some type-specimens from these volcanics evidently indicate the characteristics as a member of the hypersthenic series, as have been referred to already. Conclusively, the volcanism in this area is believed to be a typical one in the San-in Miocene and divided into three volcanic cycles characterized with a petrological variation ranging from the pigeonitic to the hypersthenic series and having the respective relations to the sedimentation in the course of geological age.

(4) The southern coast area of Shinji lake: —Pls. 22–4 and 24

The Cenozoic geology of this area have been researched in detail by T. TOMITA and E. SAKAI (1939). This area is situated on the "peninsula" called by H. YOSHIDA geotectonically and an outer periphery of the San-in Neogene sedimentary sub-province designated by Y. TAI. The earliest formation corresponding to the Hata subgroup is not appeared in this area and the younger formations than this subgroup are formed. The age of the Tamatukuri formation taken originally as the lower Miocene is recently ascertained as the middle Miocene (F_3-G), in correlation to the Kawai and Kuri formations, but most recently in correlation only to the Kuri formation by Y, TAI (1957) from the data for microfossils. The volcanic rocks appeared in this formation such as apo-andesites, dacites, basalts and liparites investigated by T. TOMITA and E. SAKAI are most possibly assumed to have been produced in the 2nd cycle. Although the Ômori formation was in the original definition confined to the sedimentary beds intercalated unconformably between the basalts at Higashi-yama and the two-pyroxene-andesites at Kasen-zan, it seems better to be revised as a single volcanic formation including all of these two volcanic rocks intercalated disconformably with the sedimentary beds composed chiefly of pyroclastic materials. Accordingly, the redefined Ômori formation is surely considered to have been produced in the 3rd cycle (G), as is similarly recognized in other areas. The olivine-trachybasalts and hornblende-trachybasalts identified by T. TOMITA and E. SAKAI with the products of the earliest volcanism in the Circum-Japan Sea Alkaline Suite are included in the Matsue fromation (H_1) defined by Y. TAI (1952, 1956 d) on the basis of molluscs such as *Turritella saishuensis* YOKOYAMA etc.. It thus follows that only the 2nd and the 3rd volcanic cycles are surely observed and the 1st cycle has not been appeared in this area, while, on the other hand, the 1st activity of the alkaline suite has started surely in the lower Pliocene (H_1) after a quite long and calm interval represented by a thick bed (700m$\pm$) of the Furue mudstone member or the Fujina formation from the close of the Miocene calcic volcanism.

(5) The southern area of Matsue City: —Pls. 22–5 and 24

The Neogene geology in this area studied already by S. IMAMURA, M. MUKAE and some students in 1956 is divided into the Iwami and the Izumo groups. The former is subdivided into the Kyôragisan subgroup, the Tamatukuri and the Ômori formations and furthermore the latter, into the Fujina and the Matsue formations. The Kyô-ragisan subgroup, the Tamatukuri and the Ômori formations are composed of volcanics erupted in the 1st, the 2nd and the 3rd cycles respectively. The first subgroup, resting directly upon the pre-Miocene granitic rocks, consists of a large amount of pyroclastic rocks and lavas including rhyolites, dacites, two-pyroxene-basaltic andesites, two-pyroxene-andesites, rhyolites and basalts, in ascending succession, accompanied with tuffs and tuffaceous shales. *Myrica* (*Comptoniphyllum*)-*Liquidambar* flora of Daizima type are contained in the intercalated tuffs and tuffaceous shales, and the petrographical characters of some specimens collected from the very subgroup are certainly believed to be a part of the pigeonitic series, as are shown similarly in the specimens from the Hata subgroup, while there are obviously considerable differences in their succession of extrusion. Accordingly, the subgroup in question is reasonably correlative to the Hata subgroup in the middle Miocene (F_2). A large amount of pyroclastics, composed mainly of plagioliparites having the petrographical characters similar to those appeared in the 2nd cycle, are included in the Tamatukuri formation, being correlated to those in the southern coast area. Notes on some specimens in these two cycles have previously been alluded to. Some chalcopyrite-bearing quartz veins associated with galena, zincblende, barite and so forth are contained in the plagioliparitic tuffs concerned and now being worked by the miners of the Hômanzan mine. The Ômori formation, covering disconformably the former, consists only of volcanic rocks such as rhyolites, andesites, dacites, two-pyroxene-andesites and basalts in ascending succession, among which some specimens are surely competent to a part of the hypersthenic series in their features. The activity in the Ômori formation, hence, is surely believed to have taken place in the 3rd cycle. It must be noticed, however, that the order of eruption of volcanics varying from acidic to basic is entirely reverse to those appeared in the Izumo City area. Some thin layers of tuffs occurred in the lower part of the Fujina formation seem to imply the weakness in activity as a tail of the 3rd volcanic cycle. Geotectonically, noticeable fact is that the Fujina formation in this area covers unconformably the older formations, as is indicated on Pl. 24. Besides the Neogene volcanic formations mentioned above, the lava flows of olivine-basalt are found scattered unconformably over the Neogene in this area. Some of tuff beds having biotite and hornblende insert these lava-flows and are petrographically considered to be congruent with the pyroclastics from Volcano Daisen. These lava-flows are geochronologically not determinable, but may be correlated to those of the 2nd olivine-trachybasalts of Dôgo, Oki Islands. It thus results in that the Miocene volcanism appeared in this area shows their good correspondence to all three cycles.

(6) The western peninsular area: —Pls. 22–6 and 24

The Neogene geology in the area concerned, studied precedingly by R. KATO (1949), Y. KINOSAKI and his co-workers (1949, 1952) and S. NISHIYAMA and his collaborators

(1956), is classified into the Taisha, the Tadaura, the Aishiro, the Wanibuchi and the Furue formations in ascending order (S. NISHIYAMA, 1956) and correlative to the stratigraphies in the central peninsular area by Y. TAI (1952) and to those in the southern coast area by T. TOMITA and E. SAKAI (1939). The basements are not observable within the area. The former four formations are composed of volcanics. The author supports generally the bio- and litho-stratigraphy given by S. NISHIYAMA with exception of several points concerning the volcanostratigraphical correlation. The volcanic activities, characterized with the so-called "Green Tuff" varying from intermediate (andesitic) to acidic (dacitic and plagioliparitic) properties and appeared in the Taisha and the Tadaura formations, are rather in good competence merely to the 2nd cycle in the Kawai and the Kuri formations of the main-land district, and the quartz-porphyries and quartz-keratophyres, injecting into the lower parts of the formations mentioned above, may, on the basis of the similarity in their characteristics, be accountably treated as the intrusive equivalent for the plagioliparites occurred in the very activity. The two-pyroxene-basalts included in the uppermost part of the Tadaura formation, in spite of their disconformable relation to the Aishiro formation, must be rather included in the latter as a member of volcanic formation produced in the 3rd cycle, because of an intimate relation to the hypersthenic series in their characteristics. Certain kinds of intrusive rocks such as gabbros, dolerites, diorite-porphyrites and porpyrites injecting both the Taisha and the Tadaura formations may be regarded as the intrusive equivalent for various kinds of volcanic rocks occurred in the Aishiro formation. The Aishiro formation as a volcanic formation consists of miscellaneous volcanic rocks ranging from basic (basaltic and two-pyroxene-andesitic) to acidic (dacitic and rhyolitic) properties, accordingly, indicating a series of magmatic differentiation, and is surely related to the hypersthenic series in their features. Hence, the formation in question is certainly correlative to the Ômori formation, as was already shown by S. NISHIYAMA. In the Wanibuchi formation, some beds of pyroclastic rocks are intercalated in coarse-grained sedimentary beds and the author has considered them as a tail of activity in the 3rd volcanic cycle. In this area are there some famous mines of gypsum and "Kuroko" deposits as are appeared in Wanibuchi Mine and Udô Mine etc. and the main ore-bodies worked at present are situated in or near the boundary horizon between the lower part of oil shale and the upper part of acidic pyroclastic rocks in the Tadaura formation, while, as an exceptional case in the San-in province, the ore-bodies found in the closed Ôtoshi gallery in Wanibuchi Mine is clearly situated within the horizon of the acidic pyroclastic rocks assumed as the uppermost part of the Aishiro formation, as is indicated similarly in the closed gallery of Nonami in the eastern area of the peninsula. As far as the Miocene volcanism in this area is concerned, it is proven that only two volcanisms appeared in the 2nd and the 3rd cycles were valid, and this result also is in good identity with the data biostratigraphically obtained.

(7) The central area of the peninsula: —Pls. 22–7 and 24

Generally, the Neogene developed in the peninsula is considered as the central part of the San-in Neogene Nepton and to have been subjected to severe folding and disturbance. The basements are here not cropped out. After Y. TAI, (1952–1955), the Neogene in the central area is believed to consist of a cycle of sedimentation called the Shinji group, and classified into the Koura, the Furue and the Matsue formations in ascending order. Two members of the Koura sandstones and the Ushikiri alternation are both volcanic formations. The volcanic rocks showing the variation from intermediate to acidic properties, appeared either in the Koura sandstone member or partly in the Jôsôji shale member, contain plagioliparites, and thus must be more reasonably correlated to those included not in the 1st cycle but in the 2nd cycle without any contradiction in volcano- and bio-stratigraphics. The Koura formation, therefore, is more reasonably correlative to the Taisha and the Tadaura formation in the western area, and the Kawai formation and the lower part of the Kuri formation (only F_3) in the main-land district, while the Jôsôji shale member must be correlated to the so-called "oil shale" in the upper part of the Tadaura formation and, at the same time, to the black shale in the upper part of the Kuri formation (only G). Hence, it seems from areal observation more suitable to consider that the intermediate and acidic volcanic rocks mentioned above are correspondent to pyroclastic rocks of the 2nd cycle. The Ushikiri alternation member may be competent to the Aishiro and partly the Wanibuchi formation, and also to the Ômori formation. On the other hand, the Kawatsu member in the Matsue formation is characterized with volcanic rocks belonging to the alkaline suite, and the age of the Matsue formation is recently identified with the lower Pliocene (H_1) by Y. TAI (1956 d) on the basis of some worthy molluscs and foraminifera such as *Turritella saishuensis* YOKOYAMA etc., and consequently, in the San-in province, it must attentively be revised that the earliest activity of the Circum-Japan Sea Alkaline Suite had started in the lower Pliocene (H_1) age of the Matsue formation. The hornblende-bearing cristobalite- andesites appeared around Mts. Wakura and Dake cover unconformably the Matsue formation and are believed to be a member of the Daisen volcanics in their mineralogical and petrochemical charcters. Conclusively, the author has a view that, in the central area of the peninsula, two volcanisms of the 2nd and the 3rd cycles of Miocene calcic series are surely ascertainable, and as to the earliest activity of the alkaline suite, the result mentioned above are to be remarked.

(8) The eastern area of the peninsula: —Pls. 22–8 and 24

According to T. ONDÔ's view (1951), the Neogene distributed in the central area is classified into three conformable formations of the lower shales associated with pyroclastic rocks, the Honjô alternation and the upper pyroclastic complex. Some intrusive rocks such as quartz-porphyries, augite-dolerites and augite-quartz-gabbros etc. injecting the lower formation, are found scattered here and there in this area. The quartz-porphyries shown by T. ONDÔ may be reasonably considered as the intrusive equivalent for plagioliparites occurred in the 2nd cycle from petrographical similarity in their charcteristics, whereas there remain certain geotectonical questions; while the basic intrusive rocks may be suitably included in the intrusive equivalent for two-pyroxene-basalts extruded in the 3rd cycle owing to their characters congruent to the hypersthenic series. The upper pyroclastic complex also is included in the hypersthenic series occurred in the 3rd cycle. The stratigraphy distributed in the easternmost area of the peninsula merely has been briefly studied by the author. The geology in question consists of volcanic formations containing chiefly a large amount of pyroclastic rocks varying from intermediate to acidic properties and black shales in the upper part. Non-marine and marine fossils occur rarely in tuffs and black shales. These volcanic formations may be correlated to the Koura formation, and the black shales, to the Jôsôji member. As a result, it is confirmable that the volcanic activites observed in this area are closely related to the 2nd and the 3rd cycles.

(9) The Dôgo area, Oki Islands: —Pls. 22–9 and 24

Details of the Cenozoic geology concerned have been investigated and made public by T. TOMITA (1927–1936). For reference, a sort of geochronological correlation revised lately by the research group is shown on Pl. 22–9.

(10) The other areas

Besides the above-mentioned areas, the Neogene sedimentaries are found scattered in the Dôzen islands, Oki, and the Yasuki-Yonago areas. The author has tried to establish a correlation of the stratigraphies distributed in Dôgo area with those given by T. SHIMOMA (1927–1928) in Dôzen area. The data preliminarily obtained by the author and R. ÔTA, a member of the Geological Society of Japan, in the Yasuki-Yonago area are roughly compiled on Pl. 24.

2. *Generalized volcanostratigraphy of San-in Neogene*

Basing on the results syntheticaly obtained from careful scrutiny as to the data in each main area, Cenozoic volcanostratigraphies in the San-in province are generalized in the following conclusion (Pl. 23). The Neogene observed in the related regions indicates one cycle of continuous sedimentation through the period from the middle Micene (F_2) to the lower Pliocene(H_1) in the peninsular district representing the central region of the sedimentary basin, while some geotectonic disturbances appeared repeatedly as un- or dis-conformities during the same period of sedimentation in the main-land district representing the peripheral region. However, it is reasonably recognizable that the succession of sedimentation were under the control of basal topographies and of crustal movement in the respective regions, resulting in local differences in sedimentation or happenly in removal of sedimentary basin throughout this period. Now, the author will discuss on the problems concerning the peripheral region. The relationship between the Iwami and the Izumo groups is believed to have been disconformable in the light of the following proves obtained from observation in the whole areas.

a. The chief materials composing the basal conglomerates in the Fujina formation, namely, rounded boulders and pebbles of andesitic rocks and matrices of volcanic rocks are thought to have been derived directly from the Ômori volcanic formation corresponding to the upper part of the Iwami group.

b. Remarkable differences concerning the distribution and the geological structure between these two groups are observable in that the Iwami group indicates the individually separated inland-basin, while, on the contrary, the Izumo group has a trend of continuously extending basin.

c. In the eastern area of the main-land district, the Izumo group lies directly upon several formations earlier than the Ômori formation.

d. The lower part of the Fujina formation clearly contains the large-sized boulders and pebbles indicating shallower facies compared to those of the Ômori.

Accordingly, it is deducible that some difference in the crustal movements might have occurred since the stage of the Fujina formation in the San-in Neogene sedimentary basin.

Discussions on the volcanostratigraphical data obtained for the San-in Neogene stratigraphy are hereunder introduced in more details. Basing on the interruption or violence of activities and their petrographical characteristics, the Miocene volcanism of the calcic series can be divided into the 1st, the 2nd and the 3rd cycles. The intervals between these cycles seem to have been relatively long and peaceful in activity because of no pyrolastic rocks intercalated in the sedimentary beds. In each cycle are appeared various kinds of rocks, varying from basic to acidic characteristics, which are mineralogically and petrochemically believed as the derivatives from a singular resource in the depth. The succession of eruption are not always similarly appeared both in each eruption and in each place, but show a sort of regularity and marked resemblance in most places. The Hata subgroup (F_2) produced in the 1st cycle is appeared only in the peripheral inland-basins and rests almost directly upon the pre-Miocene basements and, as an exceptional case, has conglomerates on its base only in the Ômori area. Owing to that the basements are not observable in the peninsular district, the subgroup may be suggested to have not been appeared. The succession of volcanic rocks appeared in the very subgroup is summarized to have changed from basic (basaltic, however, scarcely with olivine, two-pyroxene-andesite and andesic)to acidic (dacitic and rhyolitic) properties, indicating a series of magmatic differentiation and clearly a member of the pigeonitic series. Because fresh-water sedimentary beds containing fossils of plants or fish-bones are intercalated in the upper part in some area, the 1st cycle in this district is presumed to have been active on the land-surface or under the fresh-water in the later stage. The volcanism of the 2nd cycle is believed to have been active during the stage of the Kawai, the Kuri and the Koura formations (F_3) throughout two districts, and its succession of eruption shows generally the variation ranging from intermediate (andesitic and propylitic) to acidic (dacitic and plagioliparitic) characters. In the stage of this cycle are surely observed the quartz-porphyries intimately related to the plagioliparites. This cycle might have been active under the sea in the stage of the earlier transgression in the San-in Neogne province, because almost all of volcanic rocks are intercalated in the marine sedimentary beds. Some rocks in this cycle are considered to have been in close relation to a part of the pigeonitic series. Almost all deposits of "Kuroko" and gypsum are situated near the uppermost horizons of plagioliparitic tuffs, although some exceptional cases are rarely observed. Most probable is that the 3rd cycle might have been continuously active during the stage of the Ômori formation (G) overall the sedimentary basin, and the succession of eruption shows generally the variation from basic (two-pyroxene-basaltic without olivine and two-pyroxene-andesitic) to acidic (dacitic and rhyolitic) in properties with some exceptions such as those remarkable in the eastern area, and the rocks demonstrate an apparent inclination toward the hypersthenic series. From the fact of accompanying some marine sedimentary beds with fossils of marine molluscs etc., the cycle represented by the Ômori formation is believed to have been active under the sea, and a tail of the activity seems to have prolonged until the stage of the lowest part of the Fujina and the Furue formations. In the stage of this cycle are appeared various kinds of intrusive rocks such as gabbros, dolerites, diorite-porphyrites, especially in the central region of the very basin. As an exceptional case, some deposits belonging to the Kuroko type in small scale are really situated in the upper horizon representing the latest stage of this volcanism. In the main part of the Furue and the Fujina fromation, no volcanism are found intercalated. The sub-alkaline volcanism during the stage of the lower Miocene (F_1) such as the Futomiyama group found in the Toyama province is not yet observable in the Shimane prefecture.

3. *Geological relationship between Cenozoic volcanisms in the so-called San-in mixed province*

As far as the Cenozoic volcanisms are concerned, volcanostratigraphical inspection illustrates that the volcanism relating to the calcic series might have been active from the middle(F_2) to the upper(G) through the Miocene period, associated with the transgressive sedimentation but with no activity of the alkaline suite, as is ascertainable in the San-in basin, while, on the other hand, the volcanism relating to the Circum-Japan Sea Alkaline Suite might have been so through the period from the lower Pliocene (H_1) to probably the Recent, and those relating to the Daisen volcanic zone, through the period from the upper Pliocene (I_1) to the Recent. It is also surely presumed that the Miocene calcic volcanism might have started in the earlier stage seemingly in the peripheral region of the sedimentary basin and almost directly upon the eroded surface of the pre-Miocene before the beginning of the Neogene transgressive sedimentation, and thereafter spread violently overall the basin toward the central region of the basin. An important fact is that the volcanisms of the alkaline suite might have started at the latest stage of the San-in Neogene subgeosynclinal sedimentation after a considerably long and silent interval from the close of the Miocene calcic volcanism, and have been active especially along the peripheral region of the San-in Neogene sedimentary basin through the period of the Pliocene and outerside of the basin in the later stage. Accordingly, these two volcanisms are surely considered to have been active in geochronological unduplication within the same geographical province. Furthermore, it is considered that the volcanism in the Daisen volcanic zone was being active along the southeastern and outermost periphery of the San-in Neogene sedimentary basin from the age of the latest Pliocene around Mts. Ôe-takayama to the Recent almost directly upon the pre-Miocene and apparently in no direct connection with the crustal movements of the San-in Neogene Nepton. Among the volcanic rocks comprised in these three series, some remarkable differences are petrographically noticed, as was already described in the preceding chapter.

VII. SUMMARY

1. The Neogene of the San-in Nepton geologically investigated by S. IMAMURA and his collaborators of the research group in Hiroshima University is stratigraphically divided into two groups of the Iwami and the Izumo in the main-land district situated on the periphery of the San-in Neogene sedimentary basin, among which the former is subclassified into fours of the Hata (F_2) subgroup, the Kawai (F_3), the Kuri (F_3–G) and the Ômori (G) formations in ascending order, and the latter, into two formations of the Fujina (G) and the Matsue (H_1). On the other hand, the Neogene is a continuous nepton of the Shinji group in the Shimane peninsular district situated in the central part of the very basin and subclassified into three formations of the Koura (F_3), the Furue (G) and the Matsue (H_1).

2. It has been volcanostratigraphically enlightened by the author from compilation of the San-in Neogene geology that the activities of the Miocene calcic series separable into three volcanic cycles were active during the period of the Miocene sedimentation in the San-in basin, while those of the Circum-Japan Sea Alkaline Suite defined by T. TOMITA might have started in the lower Pliocene (H_1) after a considerable long and calm interval from the close of the former, and those of the Daisen volcanic zone, in the latest Pliocene (I_1) in the geographically same province.

3. The Miocene volcanic rocks consist of various kinds of lavas and pyroclastic rocks such as two-pyroxene-basalts, two-pyroxene-andesites, pyroxene-andesites, dacites and plagioliparites accompanying some kinds of intrusive rocks such as gabbros, dolerites and quartz-porphyries etc.. Mineralogically, they are generally characterized with contents of monoclinic or/and rhombic pyroxenes usually with almost no olivines and

no primary amphiboles in the basic and intermediate varieties. Their mineralogical features also indicate a remarkable contrast either with those of the alkaline suite characterized with contents of olivines and alkaline minerals or with those of the Daisen volcanic zone characterized with contents of hornblende, biotite and quartz. Among the Miocene volcanic rocks, those appeared in the 1st cycle are used to contain no rhombic pyroxenes but monoclinic ones in the groundmass and thus are considered to be included in the pigeonitic series, while those belonging to the 3rd cycle are apt to include two pyroxenes in the groundmass and thus are considered to be a member of the hypersthenic series.

4. The petrochemically conspicuous reality is that the alkali-lime index for the Miocene volcanic rocks shows 63.5% in SiO_2 and 4.5% in CaO, and that for the alkaline suite, 53.1% in SiO_2, and thus the Miocene volcanic rocks are surely regarded as a member of the calcic series. The bulk compositions of the Miocene rocks are generally similar to the data of the Cenozoic volcanic rocks of Japan given by S. TANEDA (1950). But there are certain specialities observed in the Miocene rocks appeared in the region concerned comparing with other suites in the San-in province. The trend of specimens obtained from the 1st cycle indicates an accordance with the normal type on the diagram for An–Ab–Or, the abnormal and hornblende type on that for Q–Fo–Fa, and the pigeonitic type on that for $MgO–Fe_2O_3$–alkalies, while certain specimens from the 3rd cycle evidently indicate the tendencies for the abnormal type, the abnormal and hornblende type, and the hypersthenic type, respectively. The conclusion is that the Miocene calcic volcanisms are presumed to have been variable from the normal and pigeonitic to the abnormal and hypersthenic types during the stage concerned.

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EXPLANATION OF PLATE

PLATE 18

The Rocks belonging to the lst (the HATA) cycle

FIG. 1. Olivine-bearing augite-basalt (B_1): No. 0–540801, Atodani, Mitoya-chô, Iishi-gun.
FIG. 2. Augite-basalt (B_1): No. 51–58, Yoshino, Kubota-mura, Hikawa-gun.
FIG. 3. Two-pyroxene-andesite ($2PA_1$): No. 53–42, Kakeya-chô, Iishi-gun.
FIG. 4. Two-pyroxene-andesite ($2PA_1$): No. 56–819, Higashiiwasaka, Yagumo-mura, Yatsuka-gun.
FIG. 5. Augite-andesite (PA_1): No. 53–19, Yaeyama, Hata-mura, Iishi-gun.
FIG. 6. Biotite-augite-dacite (Da_1): No. 52–67, Maeneba, Hiebara-mura, Hikawa-gun.
FIG. 7. Rhyodacite (Da_1): No. 53–17, Yaedaki, Hata-mura, Iishi-gun.
FIG. 8. Quartzose rhyolite (Rhy_1): No. 53–63, Nishiyamanaka, Nishisusa-mura, Hikawa-gun.

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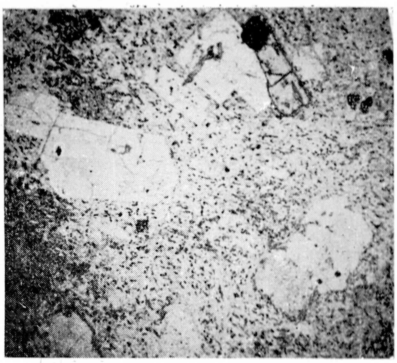

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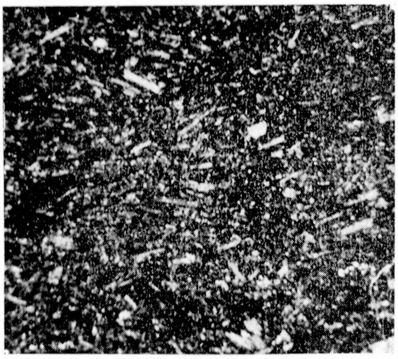

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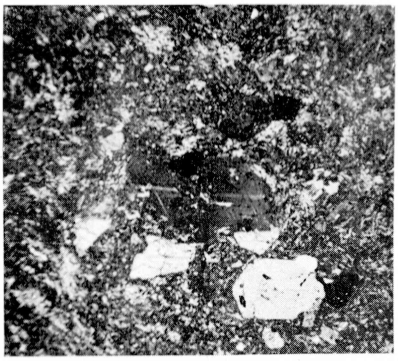

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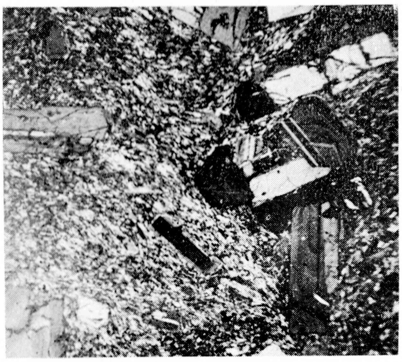

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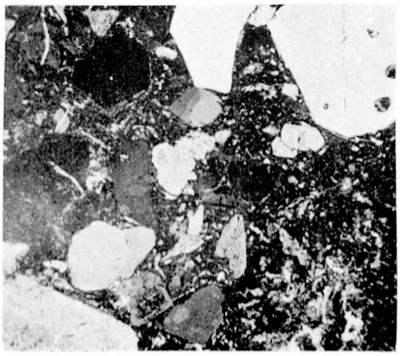

Explanation of Plate

Plate 19

The Rocks belonging to the 2nd (the KAWAI and KURI) cycle

FIG. 1. Propylite (PA_2): No. 0–5052401, Kannonzaki, Chikumi–mura, Yatsuka-gun.

FIG. 2. Two- pyroxene-dacitic andesite ($2PA_2$): No. 56-15, Isotake, Ôda-city, Nima-gun.

FIG. 3. Plagioliparite (Rhy_2): No. T–10263, Jôsôji, Furue-mura, Yatsuka-gun.

FIG. 4. Plagioliparite (Rhy_2): Ibid.

FIG. 5. Plagioliparite (Rhy_2): No. T–50111, Takadatôge, Ikuma-mura, Yatsuka-gun.

FIG. 6. Plagioliparite (Rhy_2): No. 56–16, Yamakuraji, Shizuma, Ôda-city, Nima-gun.

FIG. 7. Plagioliparite (Rhy_2): Ibid.

FIG. 8. Plagioliparite (Rhy_2): No.56–19, Sarugahana, Shimoubeo, Mihonoseki-chô, Yatsuka-gun.

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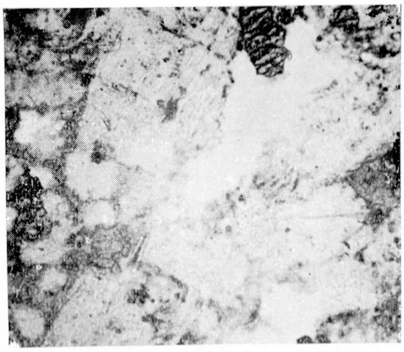

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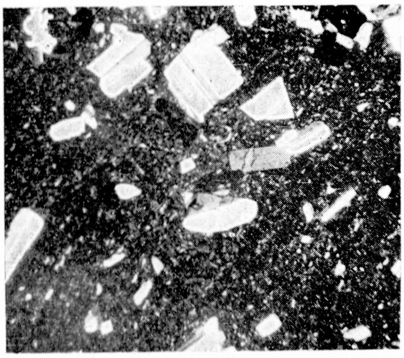

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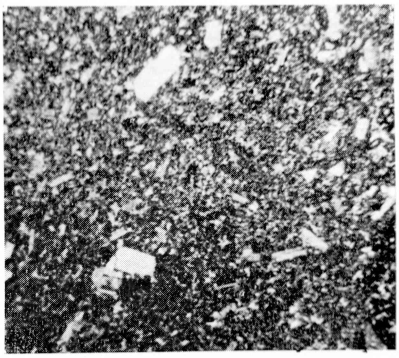

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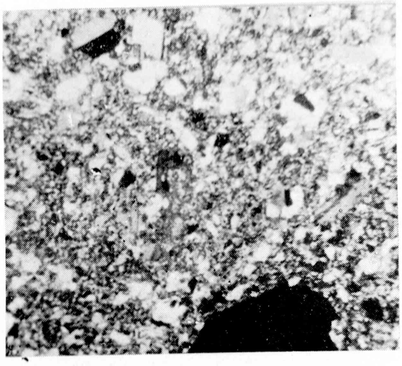

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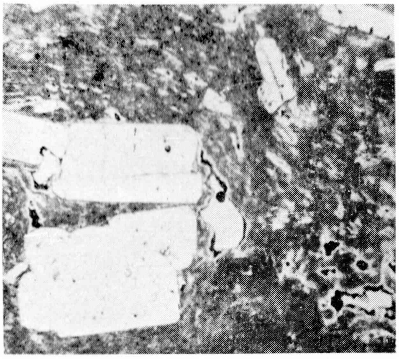

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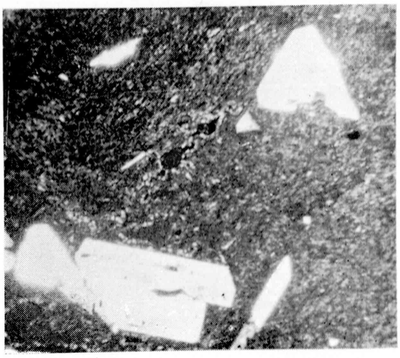

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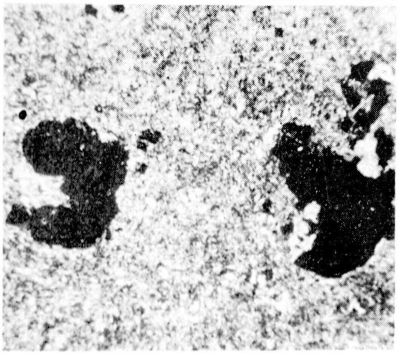


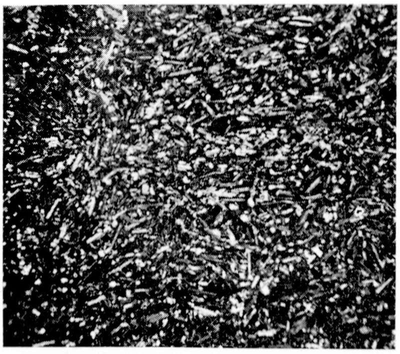
EXPLANATION OF PLATE

PLATE 20

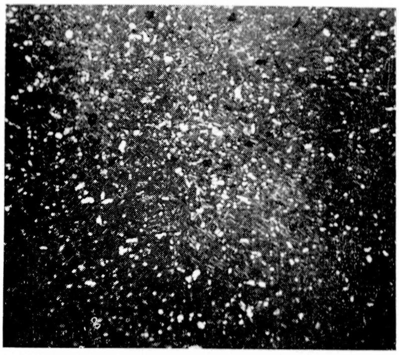
The Rocks belonging to the 3rd (the ÔMORI) cycle

FIG. 1. Two-pyroxene-basalt (B_3): No. 52–4, Kanetsuki, Hiebara-mura, Hikawa-gun.
FIG. 2. Two-pyroxene-basalt (B_3): No. 51–59, Yahatabara, Kubota-mura, Hikawa-gun.
FIG. 3. Two-pyroxene-andesite ($2PA_3$): No. 51–60, Yahatabara, Kubota-mura, Hikawa-gun.
FIG. 4. Two-pyroxene-andesite ($2PA_3$): No. 51–31, Kentabara, Asayama-mura, Hikawagun.
FIG. 5. Dacite (Da_3): No. 52–6, Mimigu, Asayama-mura, Hikawa-gun.
FIG. 6. Augite-leucoandesite ($2PA_3'$): No. 51–1, Sugezawa, Oda, Kikû-mura, Hikawa-gun.
FIG. 7. Dacite (Da_3): No. 52–36, Maki, Asayama-mura, Hikawa-gun.
FIG. 8. Rhyolite (Rhy_3): No. 56–12, Ôtoshi-Inome, Kawashimo, Hirata-city, Hikawa-gun.

0 1 2mm

1


2


3


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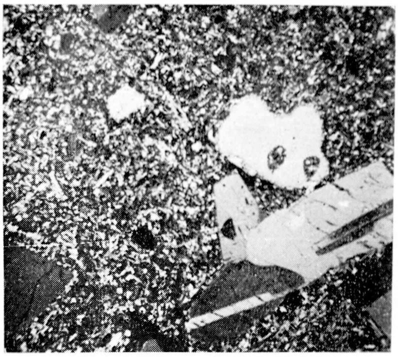

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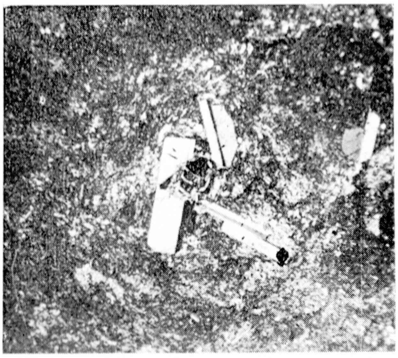

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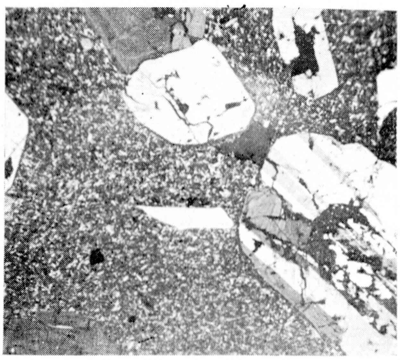

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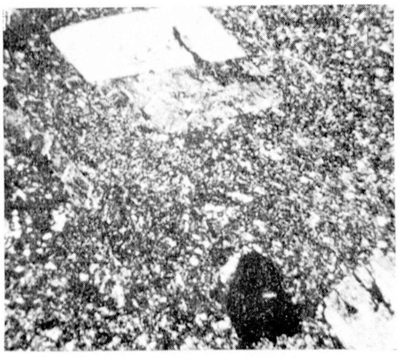
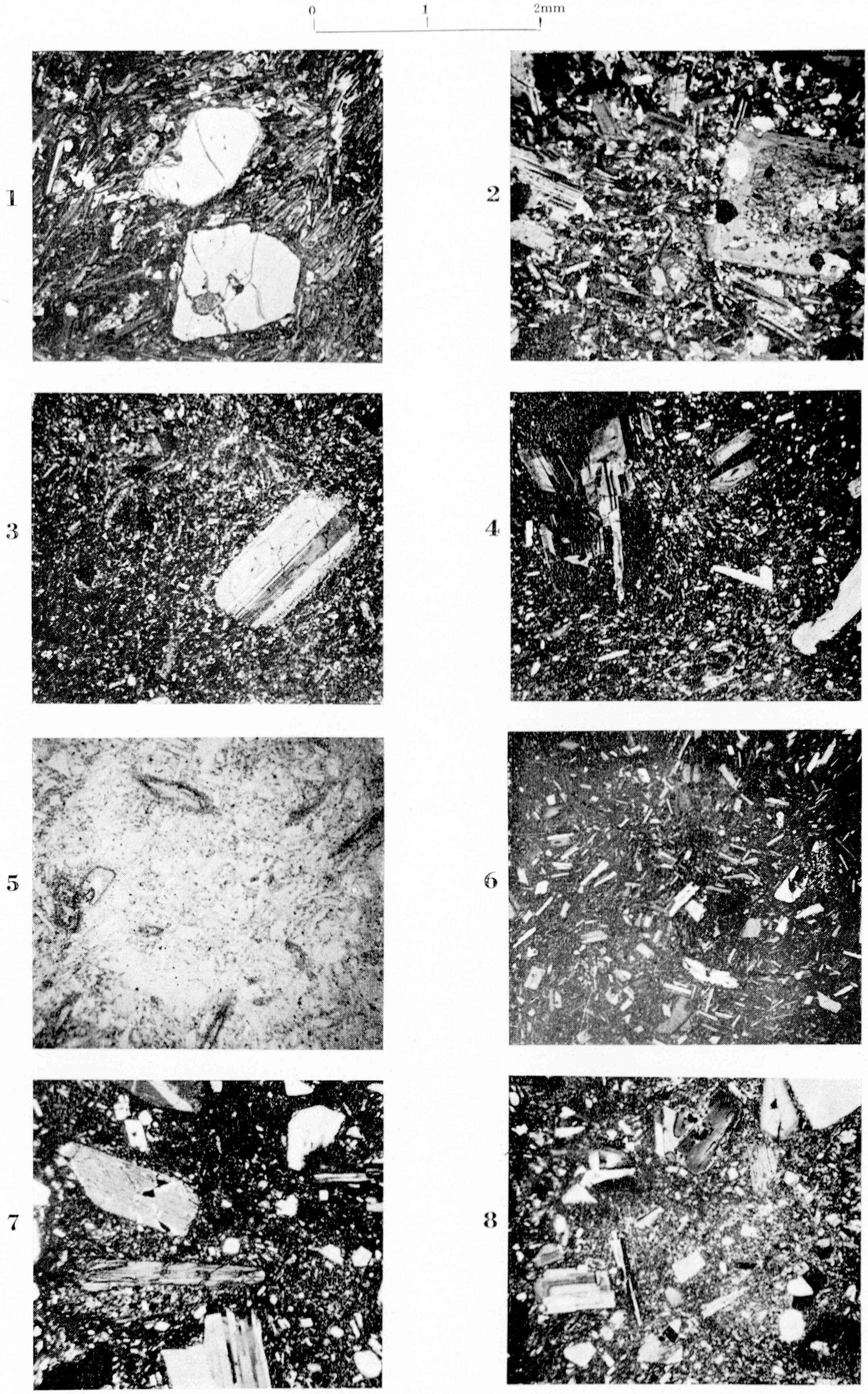


Explanation of Plate

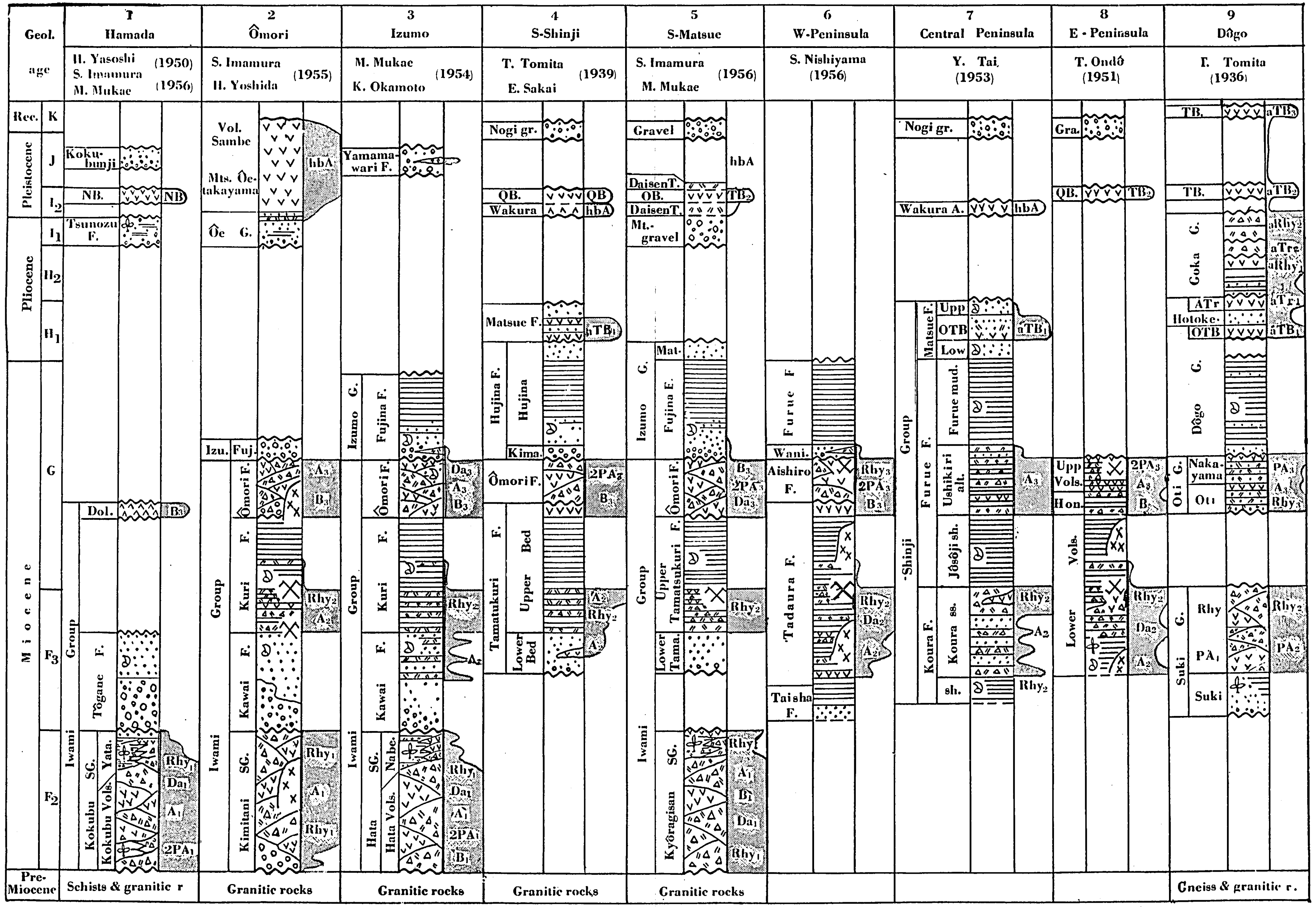
Plate 21

The Rocks unrelating to the Miocene volcanism

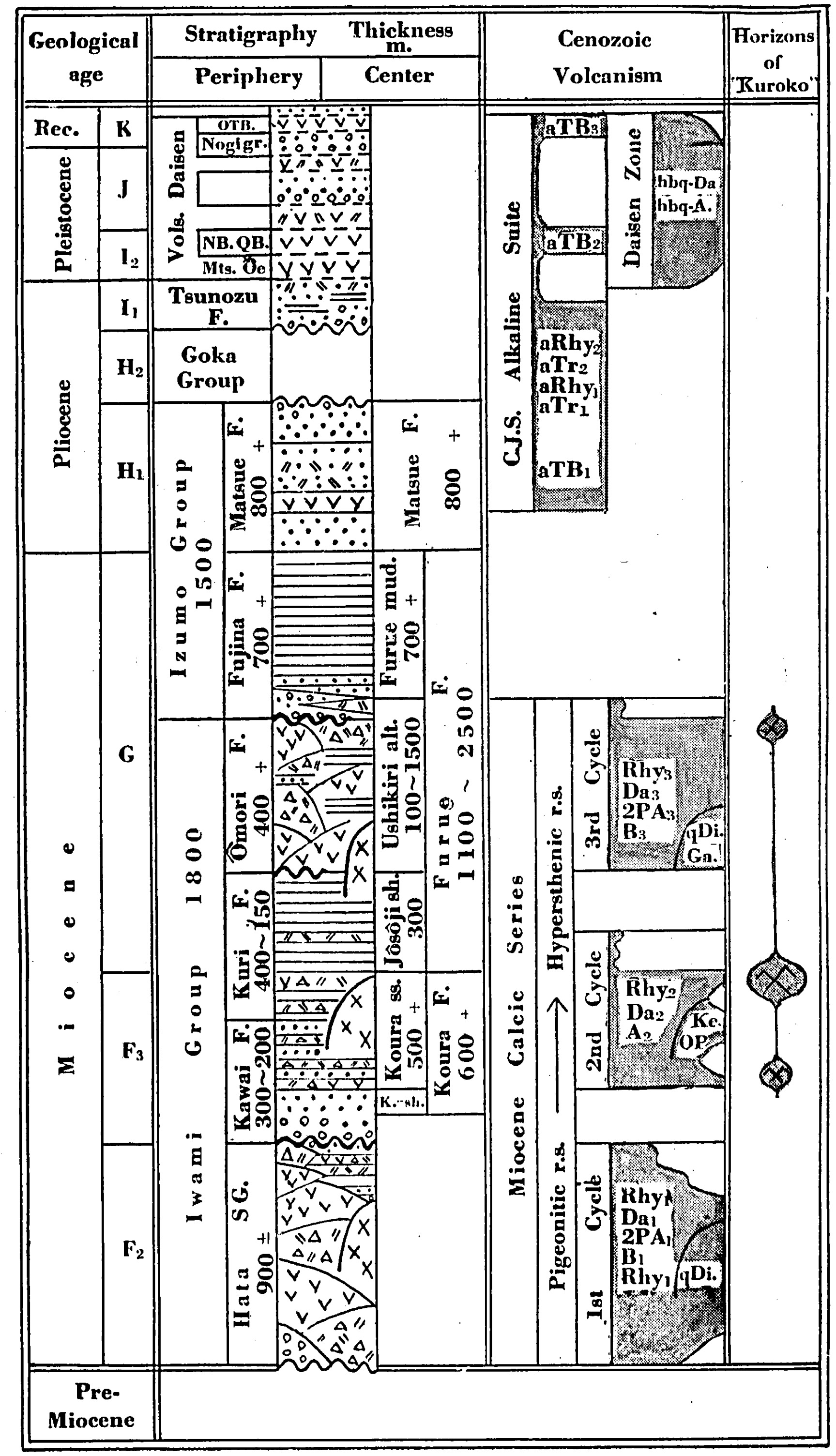
Fig. 1. Olivine-trachybasalt (OTB_1): No. T-830-2, Koshibara, Matsue-city.
Fig. 2. Olivine-trachybasalt (OTB_1): No. T-271016-1, N-Ichinari, Matsue-city.
Fig. 3. Olivine-augite-basaltic andesite (aPA_1): No. T-26924-2, Ichinari, Matsue-city.
Fig. 4. Olivine-augite-basaltic andesite (aPA_1): No. 53-1, Gakuzan, Matsue-city.
Fig. 5. Hornblende-bearing cristobalite-andesite (dA): No. 53-13, Ômisakibana, Matsue-city.
Fig. 6. Cristobalite-andesite (dA): No. T-269233, W-side of Mt. Wakura, Nange, Matsue-city.
Fig. 7. Biotite-hornblende-dacite (dDa): No.I-5105244, Yadaki-Nishida Yuzatô-mura, Nima-gun.
Fig. 8. Biotite-hornblende-dacite (dDa): Ibid.

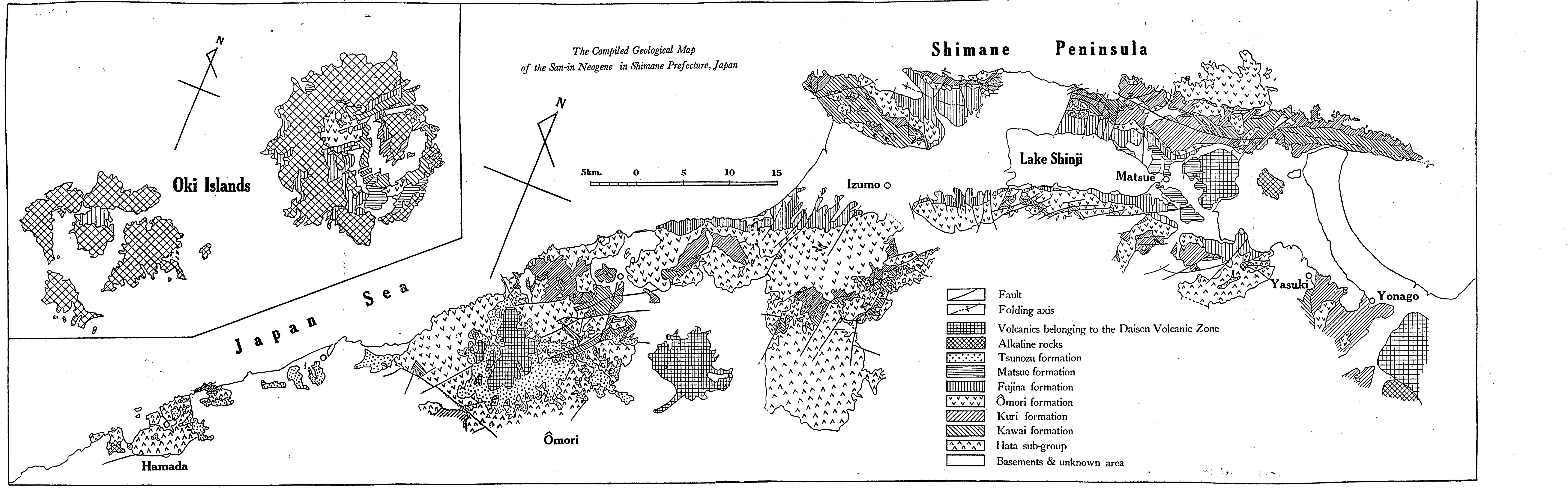

0
1
2mm
1
2
3
4
5
6
7
8

Volcanostratigraphical correlation for the stratigraphies in some main areas



Generalized volcanostratigraphy of the San-in Neogene




The Compiled Geological Map
of the San-in Neogene in Shimane Prefecture, Japan
Oki Islands
N
N
Shimane Peninsula
Lake Shinji
Izumo
Matsue
Yasuki
Yonago
Japan Sea
Hamada
Ômori
5km. 0 5 10 15
Fault
Folding axis
Volcanics belonging to the Daisen Volcanic Zone
Alkaline rocks
Tsunozu formation
Matsue formation
Fujina formation
Ômori formation
Kuri formation
Kawai formation
Hata sub-group
Basements & unknown area