Volcanic Geology of the Cenozoic Alkaline Petrographic Province of Eastern Asia

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Introduction

The writer published the following two views concerning basaltic magma in 1932. (1) There are two types of basaltic magma: basaltic parental magma of the alkaline rock series and a basaltic parental magma of calcalkaline rock series. (2) Of these two types, the first is considered primordial or original magma. This is juvenile magma, while the second is a secondary magma produced under the effect of sialic substances which constitute xenoliths of sedimentary origin and the walls of reservoirs in the circum-Pacific tectonic zone (TOMITA, 1932).

After having advocated the above hypothesis, the writer has been striving for years to verify and express it distinctly. Meanwhile, foreign geologists who entertain the same view have increased in number (RITTMANN, 1936; BARTH, 1939; WALKER and POLDERVAART, 1949; MACDONALD, 1949). However, this view is still hypothetical and is not conclusive enough to be supported by many geologists, and there are a number of geologists who oppose the hypothesis. Nevertheless, in the writer's opinion, this is an important petrographic and geologic problem which must be solved. The importance of the problem should not be denied on the ground that it cannot be solved at present. We should make a concerted effort toward its satisfactory solution.

At present, the writer is at a disadvantage, because he lost in the war specimens collected in Eastern Asia, their sections, field-books, unclassified materials, unpublished geologic maps, field photographs, and sketches. It has been absolutely impossible for the writer to carry out the research he had planned.

The writer is very dissatisfied, feeling that he is obliged to write the present paper under such circumstances. Nevertheless, it may not be useless to prepare a paper on the basis of knowledge which he still retains in his mind. It is hoped that this paper may be of help to future investigators.

The present paper consists of the following three parts: (I) volcanic geology, (II) rock-forming minerals, and (III) petrogenesis. In Part I, Cenozoic volcanic activities in North China, Manchuria, the circum-Japan Sea region, and the inner zone of southwestern Japan are correlated, and their volcanological characteristics are discussed. In Part II, the natural history of rock-forming minerals of the Cenozoic alkaline petrographic province of Eastern Asia is described. In Part III, the classification of the evolution types of olivine-basaltic magma is attempted, and the mode of magmatic differentiation is made clear. In addition, a mechanism of formation of special rocks is discussed.

The writer's thanks are due to Prof. Tateiwa for his assistance on the detailed geology of Korea.

1. History of Research and Problems

According to Dr. Kotō, the petrographic province of Eastern Asia (1915), or the Eastern Asiatic petrographic province (1916) is the region where Cenozoic basalts are distributed in Eastern Asia. Basalt distribution centers around Korea, Manchuria and Mongolia, and extends to Siberia and the coastal districts of Southeastern China. Kotō thinks that the southern margin of this petrogaphic province reaches the inner zone of Japan and he plotted the southern boundary on a map.

On the other hand, since 1905, with the progress of geologic surveys in Cheju-do and Ullŭng-do in Korea and in Matsushima, Kakarajima and the Oki Islands in Japan, it has been discovered that alkaline volcanic rocks are distributed on these islands. All these rocks belong to the Cenozoic. Hereupon, a doubt arose as to whether the region bordering on the Sea of Japan including southwestern Japan and the Korean peninsula was to be included in the alkaline petrographic province. This was around 1910.

In those days A. Harker's (1896, 1909) view of the Atlantic suite and the Pacific suite was dominant. Immediately after his publication of a map showing the distribution of the suites the alkaline petrographic province came to be questioned in Japan. Therefore, it was extremely important to describe in detail and publish the lithologic character of the alkaline rocks discovered in the petrographic province in question. The achievements of Dr. Kōzŭ (1911, 1912, 1913; Kōzu and Seto, 1926) who singlehandedly carried out the research on these rocks are really meritorious. A report on the feldspathoid volcanic rocks from Ullûng-do presented by Dr. Tsuboi (1920), further confirmed the peculiarities of the petrographic province in question. The localities which had been known up to that time were mostly insignificant volcanic islands, and the quantity of alkaline volcanic rocks was very small. As to their origin, most geologists seemed to believe that Daly's theory (1910, 1918) was applicable, that is, alkaline rocks are produced in small quantities as a heteropic facies of differentiation of basaltic magma.

However, the discovery of an enormous amount of alkaline rocks (trachyte or rhyolite) in the Kilchu—Myŏngch'ŏn district, Hamgyŏngpukto, Korea, (Yamanari, 1925) not only confirmed the circum-Japan Sea alkaline petrographic province but also furnished us with important problems on petrogenesis: (1) Alkaline effusive rocks from the circum-Japan Sea alkaline petrographic province may possibly have been derived from basaltic magma as a result of crystallization differentiation, that is, as a result of crystallization differentiation of basaltic magma. Alkali-trachytes and alkali-rhyolites may have been produced, and on the other hand, feldspathoid effusive rocks such as nepheline-bearing and leucite-bearing rocks and limburgite may have also been produced. (2) The above mentioned basaltic magma may be essentially different from basaltic magma (represented by miharaite) which is considered the parental magma of andesites of the Japanese type. Though both are called basaltic magma, when examined in detail there may be at least two kinds of basaltic magma, one of the alkaline rock series and the other calc-alkaline rock series. (3) The difference in the period of activity between the basaltic magma of the alkaline rock series and the basaltic magma of the calc-alkaline rock series may have been caused by different geologic environments (geotectonics and crustal movements) or other factors.

In order to try to solve these problems, it was necessary (1) to confirm whether the explanation of genesis based on crystallization differentiation of the alkaline effusive rocks from the circum-Japan Sea alkaline petrographic province is proper or not; and (2) to clarify whether the basalts from KOTŌ's Eastern Asiatic petrographic province are different from those of the Japanese type, and to attempt geologic comparison between the petrographic province in question and the petrographic province of Japan.

Intending to solve these problems, the writer began to study Dōgo in the Oki Islands. In his first report (1922–1932) he disclosed the following points: (1) through the evolution of feldspar, olivine, alkali-augite, and alkali-hornblende, volcanic rocks such as alkali-trachyte and alkali-rhyolite were doubtless derived from olivine-basaltic magma through crystallization differentiation; (2) two-pyroxene andesites found in the same place as alkaline rocks differ from alkaline rocks in age of effusion—effused prior to alkaline rocks—and in their parental magma; (3) the parental magma of andesites of the Japanese type is siliceous basaltic magma, as the parental magma of the alkaline volcanic rock series is olivine-basaltic magma and the parental magma of the calc-alkaline volcanic rock series is siliceous basaltic magma; (4) the parental magma of all volcanic rocks has the nature of basalt belonging to the alkaline rock series. The parental magma of the calc-alkaline series was produced as a result of parental magma being contaminated by xenoliths of sedimentary origin (alumina and quartz); (5) opportunities of capturing xenolith are given by crustal movements; zones of orogenic folding are subject to disturbance of the earth's crust; therefore, the parental magma of the calc-alkaline rock series is likely to form; (6) basalts which represents KOTŌ's petrographic province of Eastern Asia belong to the same series as basalts of the circum-Japan Sea alkaline petrographic province. Consequently, the petrographic province of Eastern Asia may be called the Cenozoic alkaline petrographic province of Eastern Asia. In other words, the circum-Japan Sea alkaline petrographic province is included in the Cenozoic alkaline petrographic province of Eastern Asia and is a region where centers of magmatic differentiation are densely concentrated.

In spite of these conclusions, many problems remain unsolved. Further geologic and chemical studies will be required to explain the genesis of geologic phenomena such as (4) and (5) mentioned above. The problem of the true nature of magma cannot be clarified unless it is pursued not only from the viewpoint of mineral constitution but also chemically and quantitatively. The results of the writer's systematic study in these lines were published in a series (1935, 1936A; TOMITA and SAKAI, 1938). Alkaline rocks from various places in the circum-Japan Sea alkaline petrographic province have been reported, though fragmentally, by other geologists.

Now, let us turn to the eastern Asiatic continent. Alkaline rocks from the continent reported up to about 1933 were as follows: Nepheline basalt (KOTŌ, 1912) from Ying-e-men, Ch'ing-yüan-hsien, Feng-t'ien Province; olivine gray pseudo-basalt and limburgite (LACROIX, 1928, 1919) from Manchuria, Jeho, Mongolia, and Shan-tung; and barkevikite and monchiquite (OGURA, 1933) from Feng-t'ien and Kuan-tung Provinces. However, the writer predicted that still more alkaline rock localities would be discovered (1935, p. 298). A new locality at that time was where a leucitic rock had been found in Wu-ta-lien-ch'ih volcano. After that, surveys were made of the volcanoes in Manchuria, and it was found that the basalts in Manchuria belong to the alkaline rock series. In addition, leucite basalt was reported from Erh-k'o-shan in Lung-chiang Province (OGURA and MATSUMOTO, 1939) and Ch'i-hsing-shan (OGURA, SAWATARI and MURAYAMA, 1939) extending from Feng-t'ien Province to South Hsing-an Province. Quite recently HARUMOTO (1949A) disclosed that the basalts in Hsi-hsia-hsien, Shan-tung Province, are all nepheline basalt.

Moreover, in southwestern Japan, HARUMOTO (1949B) discovered that melilite basalt occurs in the vicinity of Nagahama, Shimane Prefecture (famous as a locality of nepheline basalt).

With the progress of the studies described above many rock types were discovered. At present, in the Cenozoic alkaline petrographic province, a variety of petrographic types ranging from acidic dike rocks such as paisanite and grorudite to the so-called typical alkaline volcanic rocks such as leucite basalt, nepheline basalt and melilite occurs. But it must be emphasized that the problems of the petrographic province do not differ at all from those which the writer considered at the time he set about to study the province. (1) Many rock types were produced by differentiation of the olivine-basaltic parental magma. What is the process of differentiation? (2) What is the geologic age of magmatic activity in the Cenozoic alkaline petrographic province of Eastern Asia and how has the activity changed? (3) Of what type was the magmatic activity in the Cenozoic calc-alkaline petrographic province of Japan which occurred at the same time as the activity in Eastern Asia? (4) What is the genetic relation between olivine-basaltic magma, which the writer assumes to be one of the parental magmas of igneous rocks, and siliceous basaltic magma of the Japanese type (the writer's Mihara magma), which the writer provisionally considers to have been produced secondarily from olivine-basaltic magma (mostly by assimilating "sial" substance)?

2. Outline of Volcanic Geology

The Cenozoic alkaline petrographic province of Eastern Asia is very extensive. In order to comprehend its extent, its geographic distribution will be described, without regard to geologic age. The eastern margin of the province is the marginal part (or the continental shelf) of the eastern Asiatic continent. In northeastern and central Japan, the margin of the province seems to barely touch the coastal districts of the Japan Sea (in Hokkaidō and Sakhalin). In the Chūgoku district (Okayama, Hiroshima, Yamaguchi, Tottori and Shimane Prefectures) and northern Kyūshū, the margin penetrates deep into the Japanese islands and reaches the so-called Median Tectonic Line. Islands on the continental shelf include the following: the Oki Islands, Takeshima, Ullŭng-do, and small islands belonging to the San'in district in the Japan Sea; Ikishima, Kakarajima, Matsushima, and Madarashima on both sides of the Iki Strait; Gotō and Cheju-do west of the above islands; the southern islands, in the region extending from the northern end of Taiwan to P'eng-hu-Tao; farther south, the region including the northern part of Hainan Island and the Lei-chou Peninsula; and Wei-chou Island (YAGI, 1949)[1] situated west of the above region. The northern half of the Korean peninsula exhibits the characteristics of the alkaline petrographic province. The Soviet Maritime Province is also considered to belong to the alkaline petrographic province. It is beyond question that North and South Manchuria, the Mongolian plateau, and Jeho belong to the same province. This petrographic province extends probably as far as Siberia and is contiguous with the area of the arctic basalt described by WOLFF (1914).

In the Japanese Islands, there is a volcanic zone lying along the island arc (a) and another volcanic zone crossing the island arc (b). Arc a is divided into the outer volcanic zone and the inner volcanic zone. Petrographically, the outer volcanic zone generally belongs to the pyroxene andesite series and the inner volcanic zone to the hornblende andesite series (sometimes accompanied by biotite). Arc b is represented by the Fuji and Norikura volcanic zones. In these volcanic zones, the pyroxene andesite series occurs near the Pacific and the hornblende andesite series near the Japan Sea —the side relatively near the continent. The volcanic zones, which parallel each other and extend north and south, constitute a volcanic zone on the west Pacific side in the circum-Pacific andesite zone.[2]

However, an olivine-basaltic region—in other words, the Cenozoic alkaline petrographic province encompasses a great area closer to the continent than the

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[1] In Tung-ching Bay; 21°N, 109°E.

[2] The relation between an active volcanic zone and a deep-focus earthquake plane (thrust plane) is very important, but is not discussed in this paper.

inner volcanic zone, which is represented by the above-mentioned hornblende andesite series.

In southeastern Asia also, this distribution is remarkable. There is an outer pyroxene andesite zone and an inner hornblende andesite zone in the andesite zone in Java and Sumatra. Indochina and Borneo, which correspond to a more continental part as compared with the Java—Sumatra arc, belong to a region where olivine basalt—alkaline volcanic rocks—occur. LACROIX (1933) compared the Cenozoic basalts from Indochina with those from Manchuria, Jeho, Mongolia, and Shantung.

As mentioned in the beginning of this chapter, the above description was made without regard to geologic changes. The present condition, however, is the result of innumerable changes which occurred from the beginning of the Tertiary to the present. The changes of the petrographic province which took place in the inner zone of southwestern Japan are particularly noteworthy. It is no exaggeration to say that it is impossible to discuss the problem of parental magma without knowing of such changes.

As mentioned above, the Cenozoic alkaline petrographic province of Eastern Asia occupies a very extensive region, the greater part of which has been a continent since the Mesozoic; the Tertiary formation is lacking in many cases. It was found that the circum-Japan Sea alkaline petrographic province (one of the sub-petrographic provinces of the Cenozoic alkaline petrographic province of Eastern Asia) is the most suitable region for the study of geologic disturbances. However, the changes throughout the Cenozoic cannot be revealed just on the basis of the data of this sub-petrographic province. In order to fully clarify the mode of changes, comparative study is necessary, and the significance of each region must be clarified.

Table 1 shows a tentative correlation of each typical region. This table is not conclusive but is published for reference and also as a foundation on which studies in this line can be made easier in the future.

Any one who examines this table will notice many interesting facts about volcanic geology and petrogenesis in the petrographic province in question. For convenience' sake, the volcanological history is divided into seven periods, and the principal characteristics of each period will be described, in the sequence of older to younger.

(1) The first period of volcanic activity (Paleogene to earliest Miocene)

Volcanic activity in the Paleogene has not been clarified at all except in the vicinity of Fu-shun in South Manchuria, the Mongolian plateau, and the vicinity of Fan-chih in Shan-hsi Province. These three areas are characterized by basaltic activity.

In Fu-shun and Fan-chih the basaltic lava flows are intercalated by black shale beds, which yield fossil plants. The fossils had been considered (particularly by Chinese geologists) Oligocene, but, according to ENDŌ (1931), they belong to Upper Eocene. The basalt from Fu-shun is called *kokuhangan* (black porphyry) by some Japanese geologists, but it is unnecessary to use such a special name. From this basalt, Dr. SUGI (1940) discovered a plagioclase, the optic axis of which is abnormally small, and he explained that the optical abnormality is caused by twinning. Plagioclase-like feldspar with a similar optical abnormality is frequently found in the groundmass of basalts effused after the last period of Miocene in the Cenozoic alkaline petrographic province of Eastern Asia. The writer (1931A) has called it "potash andesine." As is evident from the name, the writer attributed the optical abnormality to molecules of potash feldspar which are more abundant than in common plagioclase (neutral feldspar). Potash andesine is a metastable feldspar, and it was thought that such a metastable type was produced because a homogeneous crystal could not be formed as it was too rich in potash feldspar to crystallize as plagioclase. Even now the writer has not given up this idea. MACDONALD (1942) discovered in basalt from Hawaii a feldspar which closely resembles the writer's potash andesine in optical property and mode of occurrence (it seems to be the anemousite inferred by BARTH, 1930); thus supporting the writer's view concerning the cause of optical abnormality, MACDONALD named it "potash-oligoclase." In short, potash andesine and potash-oligoclase are quite different from the abnormal feldspar which was described by Dr. SUGI. Basalt that contains these minerals in its ground mass is rich in potassium (sometimes it is associated with anorthoclase, but not always) and belongs to a very basaltic type. This is a characteristic of basalts of the Cenozoic alkaline petrographic province. This is noteworthy not only for researchers of these rocks but also, taking into consideration that it is present in basalt of the Inner Pacific Ocean, for those studying the evolution of feldspar.

Basalt of the Mongolian plateau is one of the so-called plateau basalts. The basalt forms lava flows several hundred meters thick, consisting of many lava sheets. These thickly accumulated lava flows may not have been effused in the same age. Actually, north of Ta-t'ung, there are volcanic cones similar to the Ta-t'ung volcano group (Late Pleistocene). It is beyond doubt that the basaltic lava flows effused from the volcanoes of this age overlie the Paleogene lava flows. However, the Pleistocene lavas are not very abundant, so it is not a great mistake to consider most of the basaltic lava flows in the Mongolian plateau Paleogene.

The basaltic lava flow found in the vicinity of Fan-chih in Shanhsi Province is composed of many sheets and is intercalated by black shale, which yields fossil plants. The genera and species of the fossil plants are the same as those from Fushun. Therefore, Chinese geologists consider them the same age.

The chemical composition of the basalt from the Mongolian plateau is quoted from LACROIX's report (1928, p. 48) and is shown in Table 2. In this table's notes the petrographic name adopted by Lacroix is shown. However, it is more reasonable to call it analcite olivine-basalt than 'basanitoid.'[3] Mongolian basalt is

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[3] A basalt which is chemically basanite but does not contain nepheline (i.e. a basalt in which *ne* is calculated in the norm but is not contained in mode) is called basanitoid by Lacroix. His

generally rich not only in analcite but also in other zeolites. In parts of the lava flows, the lava is highly porous or amygdaloidal. In such a rock type abundant zeolite is macroscopically noticeable and sometimes well-formed crystals of natrolite are found. Some rock types have fine veins of zeolite. Even in a rock type in which zeolite cannot be easily detected with the naked eye, zeolite filling the interstices is usually discernable under a microscope.[4] If we re-examine Table 2 with this knowledge, we shall notice that in the rock type which contains more than the norm amount of *ne*, the amount of H_2O associated with Na_2O increases. By this fact it is understood that norm *ne* is attributable to analcite and natrolite. The presence of a fair amount of analcite basalt in the basalts of the first period of volcanic activity described in this chapter is not limited to the Mongolian plateau basalt but is found universally throughout the entire petrographic province. Since this fact is significant volcanologically, it is especially noteworthy. Examples will be cited below.

The Yongdong alkaline basalts in the Kilchu—Myŏngch'ŏn district, Hamgyŏng-pukto, Korea—These basalts form a thick layer of lava flows. Though their relation to the overlying P'yŏngnyuk-tong beds is an erosional unconformity, the longer lava flow, 1,000 m thick, extends over 50 km and disappears where cut by a fault. The other flow is also cut by a fault or sinks into the ground. Its extent is therefore unknown, but judging from the above figures, it may be thought a huge lava sheet. Several places in this lava flow are agglomeratic; hence it is known that there were many effusion centers. It was probably a large volcano of the Hawaiian type in the earliest stage of the Miocene. A rock type (effusive rock type in the relatively early period) in this basaltic lava flow is analcite basalt (TOMITA, 1933B), and samples containing macroscopic well-formed crystals of analcite can be collected in some localities. However, as a matter of course, the Yongdong alkaline basalt is not entirely composed of analcite basalt. Generally speaking, it is olivine-trachybasalt having many olivine phenocrysts; chemically speaking, one of its characteristics is that it is rich in potassium. Its chemical composition is shown in Table 3.

The Ŏil basalts associated with the Ŏil beds in the Yongil area are also olivine basalt, but their lithologic character has not been ascertained. Though both are altered, the original Shimonagu basalt developed on the west coast of Dōgo in the Oki Islands and the Higashiyama basalt on the south side of Lake Shinji are inferred to be undoubtedly olivine-basalt from the presence of pseudomorphs. In the

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calculation of *ne* is based on the fact that the ground mass is rich in *ne* or that the Carnegie molecule is contained in plagioclase (that is, anemousite). The writer does not agree with his opinion on anemousite. (TOMITA, 1933A, P. 26).

[4] Besides zeolite, chalcedony is found in the pores of these rocks. With respect to zeolite, there is the following literature: MATSUZAWA, I., 1940, On the natrolite from the vicinity of Shen-wei-t'ai, Inner Mongolia: *Bull. Orient. Archaeol.*, Ser. B, v. 2, 'Mongolian Plateau', P. 29–31.

It is said that the basalts in this region are accompanied by trachyandesite and trachyte. (MATSUZAWA, I., and IWAO, S., A geological study of several rocks developed in the Mongolian Plateau, *ibid.*, p. 1–28.)

Shimonagu basalt there are large and small pores, which are filled with zeolites and green earth; the zeolites, analcite, natrolite, and chabazite are distinguishable (TOMITA, 1926, 1931B).

The basalt which has suffered thermal metamorphism by the Takayama gabbro in Yamaguchi Prefecture is considered to be of the same age, that is, of the first period of volcanic activity. A geologist who studied this thermal-metamorphosed basalt supposed that this basalt was the same age as the Takayama gabbro (NOJIMA, 1941). However, as a problem on an extensive geologic phenomenon such as volcanic activity, it may be reasonable to choose a correlation common to an extensive region.

It is thought that there was a time lag between the active period of the Mongolian plateau and that of the regions east of it. That is, Mongolian basalt was effused in the early Oligocene (or in the beginning of Eocene), but the effusion occurred in the end of the earliest period of Miocene in the Yongil area in South Korea and in the San'in district, Japan. In the Kilchu—Myŏngch'ŏn area, the active period was between the above two activities, that is, in the beginning of the earliest Miocene (or beginning in the end of the Oligocene).

It is very interesting that in Japan the activity in the earliest Miocene is represented by the calc-alkaline rocks (pyroxene andesites and rhyolites), while there was no activity of those rocks in the region extending from the Kilchu—Myŏngch'ŏn district to the continent. The only exception is the Yongil area which belongs to the petrographic province of the Japanese type. This remarkable contrast did not appear in the Tertiary but had existed from the Cretaceous (though the extent of the petrographic province was somewhat different).

The next problem which is worthy of notice is that of the Miocene alkaline rocks in the Fossa Magna zone in the central part of Japan. In the writer's opinion, the age of the famous teschenites in Takagusayama was the end of the first period of volcanic activity; the volcanic activity represented by the Misaka beds is older than the age of the above teschenites (during the earliest Miocene). If this correlation is correct, the following petrographic province can be recognized: the basaltic province that surrounds Japan and, through the present San'in district and the Hokuriku district, extends to the Pacific via the Fossa Magna. In this petrographic province alkaline trachyte was produced under favorable conditions. An example may be seen in Ryūsōzan north of Shizuoka City (MAKIYAMA, 1950). The differentiation tendency observable in this example is not only the same as that of the above-mentioned Mongolian basalt but also as that of the alkaline volcanics formed in the end of the Tertiary. Thus, part of the features of the Cenozoic alkaline petrographic province of Eastern Asia had already appeared in the earliest Miocene.

(2) The second period of volcanic activity (Early and Middle Miocene)

This is actually a period of no alkaline volcanic activity. On the Chinese continent it was a long erosion period and in the last stage the Shanwang series (probably a lacustrine deposit, famous for abundant yield of fossil plants) was deposited.

In Hamgyŏng-pukto, Korea, it was the period of deposition of the P'yŏngnyuktong, the Hamjindong, and the Manhodong beds. Though there was some basaltic activity in Hamgyŏng-pukto, it was inconsequential compared with the scale of other magmatic activities apparent when the Cenozoic alkaline petrographic province of Eastern Asia is viewed in the light of ages and regions.

In spite of such tranquil conditions on the continent, the petrographic province of Japan experienced a period of prominent igneous activity; volcanic rocks were formed and plutonic rocks were intruded.

The first activity in the petrographic province of Japan in this period is represented by rhyolites, and the effusion of the rhyolite was followed by the eruption of two-pyroxene andesites. Prominent volcanic activities that occurred in this sequence were accompanied unquestionably by tuff and agglomerates, and tuffite was formed in the areas of deposition; the rocks are distributed almost throughout Japan (though their petrographic characters differ in different areas).

The first activity in this period was a disturbance which occurred in the Early Miocene. From the end of the Early Miocene to the beginning of the Middle Miocene there was a calm period of erosion and deposition which continued for some time, and then volcanic activity again became prominent (about the middle of the Middle Miocene). No rhyolite was erupted in this period, but in the Inland Sea zone, peculiar biotite andesite and amphibole andesite was formed. Similar rocks are found in the San'in district. Andesite of the same period is found in Dōgo, but it is only two-pyroxene andesite. Exceptionally, in the south shore area of Lake Shinji, no volcanic activity occurred. The Kimachi and the Fujina beds were deposited. (It seems that a strait which may be called the Shinji Strait, was formed during this period.)

A great episode in this period was the intrusion of the Tertiary plutonic rock mass, examples of which are observable in various places in Japan. The Takayama gabbro mass which has been well-known for a long time belongs to this period. Aplite occurs on the northwestern side, cutting the mass. This fact suggests the formation of acidic rocks during the same period. Actually, concerning the examples in the San'in district only, in Tamasakimura, northeast of Susa, dikes of granite porphyry traverse the Miocene series and in Dōzen, the Oki Islands, nordmarkite cuts the Miocene series. This Miocene series is thought to belong to the Early or Middle Miocene.

The Tertiary plutonic rocks in the Fossa Magna zone and those in Tanzawayama are probably of the same period. Moreover, in the granites of the outer zone, granite, apparently of the same period, occurs.5) The granite mass in the Chūgoku district is more questionable. This mass seems to be a fairly involved complex of rock masses, and it is supposed that granites of this period may be contained in the complex. It is expected that future study will solve the problem.

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5) T. Kobayashi infers that the granite mass traversing the Cretaceous formation in Uwajima, Shikoku (Takatsuki granite mass) intruded in the Miocene: Kobayashi, T., 1950, Regional geology of Japan (Shikoku district): Asakura Shōten, Tōkyō, p. 59.

In short, in Japan this period indicates a pure calc-alkaline petrographic province, extending as far as the Yongil area, South Korea, while on the continent it was a period of dormant volcanic activity.

The Yongil area, Korea, is particularly worthy of notice. This area kept in step with the petrographic province of Japan in the second period as it did in the first period. That is, the area was calm in the second period and was in a geologic environment quite different from that of the alkaline petrographic province. The area, however, was calm in the Pliocene when the alkaline petrographic province became active. Thus, the Yongil area, though geographically located at one end of the Korean Peninsula, geologically belongs to the Japanese islands, which seems to suggest that the Korean peninsula was connected with the Japanese islands in the Pliocene and had similar geotectonics.

When the second volcanic activity gradually subsided, a period of erosion and deposition continued for some time in Japan also, and from the end of the early stage of the Late Miocene a great diastrophism occurred in Eastern Asia.

(3) Third period of volcanic activity (Late Miocene)

The period's great diastrophism was the activity of olivine-basaltic magma in the beginning of the period, which extended at least over the northern half of Eastern Asia. In Taiwan Miocene olivine basalt occurs in the vicinity of Ma-wu-tu in Hsin-chu Prefecture (the present Hsin-chu district, Hsin-chu Prefecture) (YEN, 1949). This basalt may be an effusive rock of the same period.

The activity of basaltic magma in and after this period modified the features of the Cenozoic alkaline petrographic province of Eastern Asia and complicated the relation between the Cenozoic alkaline petrographic province of Eastern Asia and the andesitic province of Japan. Therefore, in a study of the Cenozoic alkaline petrographic province of Eastern Asia, special attention should be paid to the activity of basaltic magma. For convenience' sake, the basalts of this period are named B_1.[6)]

The chemical composition of B_1 basalt is shown in Table 4. As is evident in the table, the basalt from Wei-ch'ang in Jeho Province (Nos. 11–13) is poor in *an* and rich in *or* in the norm. Basalt of a similar type occurs in Dōgo. These belong to basalts in which differentiation has progressed. Nos. 14, 15, and 17 from Japan contrast sharply with the above basalt. These are rich in *an* and relatively poor in *or*. Nos. 14, 15, and 17 closely resemble one another in chemical composition (particularly remarkable in the feldspar constituent in the norm). In spite of that, it is interesting that their localities— Dōgo, Kaho in Fukuoka Prefecture, and Shōdoshima in the Inland Sea,— are relatively far apart.

In many petrographic provinces and comagmatic regions in the world, basalts of very similar character were effused in various places throughout extensive regions and during a relatively short period. The writer calls such basalts "areal

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[6)] For the same reason, the basalts after this period are abbreviated as follows: Early Pliocene basalts: B_2; Older Pleistocene basalts: B_3; Younger Pleistocene basalts: B_4; and alluvial basalts: B_5. This nomenclature of B_1–B_5 is used for geologic units and not for types.

basalts" (1951). The above-mentioned nos. 14, 15, and 17 are good examples of areal basalts. The "areal" does not imply a mode of occurrence like the so-called 'plateau basalts.' Rather, the basalts form sometimes a lava flow covering an extensive area (the Deccan basalts), sometimes a group of dikes (the Scottish basalts), and sometimes they occur sporadically (Hawaiian basalt). In general, extensive lava flows are apt to attract attention, but if, in sporadic occurrences, the rocks closely resemble one another in lithologic character, that resemblance must be an important characteristic.

Nos. 14, 15, and 17 lack macroscopic phenocrysts, and it is understood that the chemical composition shows the constituents of original magma. Therefore, not only petrogenetically but also geologically the rocks are very significant. The writer, as a result of various petrogenetical studies, regards no. 15 as representative of the parental magma of various alkaline volcanic rocks. It is thought that the parental magma of alkaline volcanic rock series in the Cenozoic alkaline petrographic province of Eastern Asia is also the magma of olivine-basalt of a similar character.

That alkaline volcanic rocks were formed through differentiation from such olivine-basaltic magma is known by the presence of rocks of a type intermediate between trachybasalt and alkaline trachyte in various types, summarized by the geological term basalts. In Dōgo, the Oki Islands, the first alkaline trachyte (AT_1) was effused. This AT_1 is mainly plagioclase-bearing anorthoclase-trachyte, and, when the evolution system of feldspar is traced, shows evidence of magmatic evolution from trachybasalt to alkaline trachyte. There was a period of erosion and deposition after the effusion of B_1, and the Hotokedani beds were deposited in Dōgo. The eruption of AT_1 seems to have begun with violent explosions in the course of the deposition of the Hotokedani beds, and a thick pumice bed of AT_1 directly covers the upper part of the Hotokedani beds. In some places the basal part of the AT_1 lava flow forms an obsidian cliff, indicating that it was a lava flow which flowed into the water.

Table 5 gives a chemical analysis of AT_1 from Dōgo. As is evident in the table, though the amount of silica varies considerably, the constituents of norm feldspar fall within fairly definite limits. Moreover, the minimum value of the constituent *an* is within the limits of 6–8. This minimum limit may be regarded as almost fixed. This datum is highly serviceable when the evolution of feldspar is discussed, but further discussion is omitted from this paper.7) In short, it is fortunate that rocks which are significant petrogenetically occur in our petrographic province.

Volcanic rocks correlated with AT_1 of this nature have not been discovered in other areas in this petrographic province. An important discovery, however, was a pumice bed found intercalated in the Matsue beds, in the vicinity of Matsue, on the mainland across from Dōgo. The discovery that the white pumice constituting

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7) The writer considers it appropriate to determine the boundary between the "plagioclase" province and the "orthoclase" province in the feldspar composition diagram by the rocks containing plagioclase and anorthoclase or the rocks containing the crystals of zonal plagioclase and anorthoclase.

this pumice bed is of the same composition as the pumice which is the early ejecta of AT_1 in Dōgo played a more important part in the correlation of the two areas than did fossils (TOMITA and SAKAI, 1938). The writer believes that it is necessary to apply this correlation method in stratigraphical studies.

In the third period of volcanic activity, the first eruption of sanukitic andesites occurred in the Inland Sea zone (at least in Shōdoshima). The geologic age of the eruption was probably the end of the Miocene and the age has been correlated with the age of AT_1. The following phenomenon is interesting: in the early part of the third period olivine-basalt (areal basalt) of a similar lithologic character was effused both in Dōgo and Shōdoshima. However, in Dōgo, which is the inner area of the petrographic province where the evolution of olivine-basaltic magma progresses, alkaline trachyte was formed, and in the Inland Sea zone, which is the marginal part of the petrographic province, a peculiar rock of sanukitic andesites was produced.

Whether the difference in formation is related to the difference of geologic environments becomes a problem. Study of this problem is interesting and very important volcanologically, and I would like to suggest the following conclusions.

(1) The crust of the Inland Sea zone is a fractured zone and its geologic structure is very complicated. (This can be partially inferred from the features in the vicinity of the Nagatoro metamorphic rock zone in the Chūbu district). (2) Into such a crust olivine-basaltic magma intruded from a deep subterranean area. During intrusion and in a magma reservoir after intrusion, the nature of the magma changed as crustal substances were supplied to the magma from the magma conduit and the wall of the magma reservoir. (3) From such secondary magma sanukitic andesites differentiated and were formed by crystallization.8) (4) In the inner part of a petrographic province like Dōgo, the subterranean geologic structure is relatively simple, and magma which may rightly be called secondary magma was not formed or was formed only slightly. Hence, crystal differentiation may be regarded as having occurred directly from juvenile magma.

In short, by the third volcanic activity, the features of volcanic rock formation exhibited by the second volcanic activity had changed completely. In particular Dōgo in the Oki Islands, which had belonged to the calc-alkaline petrographic province, changed to the alkaline petrographic province. There are in the world several instances of an area which belonging to a certain petrographic province in some period changing into an area belonged to an entirely different petrographic province in another period. The writer has called this phenomenon "petrographic revolution" (1936). This is an extreme magmatic cycle. I should point out that genetical studies of igneous rocks without any conception of magmatic cycle or petrographic revolution frequently breed careless error.

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8) In my opinion, xenoliths which we can collect as samples were captured in the period when the assimilation of magma declined. The nature of the magma had been considerably changed in this period. The mode of change in xenoliths due to magma has been studied and reported, but the research must be accumulated. Current knowledge indicates only a part of the changes in the nature of magma and may not deal thoroughly with the formation of secondary magma.

A prominent geologic phenomenon in the final stage of the third period of volcanic activity was peneplanation. A good example of this phenomenon is found in Hamgyŏng-pukto, Korea. In this region, gneisses which are the bedrock border on the Miocene series by a remarkable fault, and after the region was peneplained the lava flow of the Chaedŏksan basalt was effused. This remarkable fault (Yamanari's great Kilchu—Myŏngch'ŏn fault) was formed after the deposition of the Middle Miocene series and before the peneplanation. No fault which can be assigned to this period has been discovered in other regions. The level plane underlying the Laohotingtzu basalt in the P'aektu-san region is thought to be the same age as the peneplain in question. It is said that a similar level plane is found also in Manchuria. The eastern part of the Shan-tung Peninsula is famous for the development of old topography, and a level plane is found at the bottom of the basaltic lava flow in this district. In Japan, a level plane in the Kitamatsuura Peninsula, northern Kyūshū, recently pointed out by the writer, is a good example. In this peninsula also the level plane has been preserved by a covering basaltic lava flow. The lava plateau topography exhibited by the basaltic lava flow can be attributed to the underlying peneplain. Furthermore, the low-level peneplain in the Chūgoku districts is also of this age. The conclusion is that this peneplanation occurred extensively in at least the northern half of the Cenozoic alkaline petrographic province of Eastern Asia. On the other hand, there were also areas of deposition. In short, the third volcanic activity completely subsided with the end of Miocene.

(4) The fourth period of volcanic activity (Pliocene)

The volcanic activity of this period also began with the eruption of basalts. Generally speaking, the basalts (B_2) formed a typical lava plateau; the eruption is typed as a fissure eruption.[9] Of course the lava plateau has been cut into buttes by later fluvial erosion. The great lava plateaus in the western part of North China, Manchuria, North Korea, and Shan-tung belong to this age. In these regions, the lava plateaus lie on the peneplanes, and their flat surface is partly attributable to the fact that they flowed onto the peneplanes.

In Japan, B_2 has preserved plateau topography in the southwestern part of northern Kyūshū. The remarkable level plane of the Higashimatsuura Peninsula is attributable to a basaltic lava flow, and the level plane has been preserved under the lava flow. B_2 in the Chūgoku district is exceedingly eroded and dissected. In some areas basaltic blocks lie scattered on the summits or lie sporadically in the cultivated farmlands. Therefore, the original mode of occurrence is not known at all.

B_2 is composed of various basalts. Compared with B_1, the variation in the basalts is remarkable. In certain lava flows (actually several lava sheets in layers), the type of variation is macroscopically distinguishable from the lower part upward. Since there is type variation in different areas, it is difficult to summarize the character-

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[9] B_3 which will be described below exhibits a similar topography. In the field, B_2 cannot be distinguished easily from B_3. In the northern part of Korea and South Manchuria, there are several examples where B_3 flowed down the valleys and developed in the B_2 lava plateaus.

istics of B_2. However, a general characteristic is that the porphyritic type is predominant, and phenocrysts of pyroxene and plagioclase are conspicuous. As a geologic unit, these are customarily described simply as basalt, but strictly speaking, they belong to olivine trachybasalts. There are very few chemical data for the rocks (Table 6).

We should note that special alkaline rocks, that is, limburgite, nepheline basalt, and melilite basalt, are contained in the basalts belonging to B_2.

Limburgite has been reported from Ch'i-hsing Shan (part of T'ai Shan), T'ai-an Hsien, Shan-tung Province, Ōgusoyama, Shimane Prefecture, and Sukumozuka in the vicinity of Tsuyama, Okayama Prefecture, but the mode of occurrence is not known for any locality. It probably occurs in small rock bodies like volcanic necks. Limburgite was also described from Chi-lin Province (Mu-tan-chiang Province) Manchuria, Mu-ling-ho, the area southwest of Lin-hsi-hsien, Jeho Province, and Ta-li-po, Chin-p'eng-hsien, Jeho Province (Hsing-an Province). The geologic age of these examples is unknown. For convenience' sake, limburgite is described in this paper together with the above-mentioned rocks. Their chemical composition is shown in Table 7.

Nepheline basalts occur in Ts'ao-shih-erh, Ying-e-men, Ch'ing-yüan Hsien, Feng-t'ien Province; in the vicinity of T'ang Shan, Hsi-hsia Hsien, Shan-tung Province; and in Nagahama, Shimane Prefecture. The nepheline basalts in Ying-e-men and Shan-tung form lava plateaus. The manner of occurrence of the nepheline basalts in Nagahama is not known. Melilite basalt occurs as a type of lava in the vicinity of Takano. A chemical analysis of nepheline basalts from Eastern Asia is shown in Table 8. The basalt in which the magmatic water is contained was nepheline basalt from Nagahama. The same problem arose in the basalt from the Kitamatsuura coal field in Kyūshū, which in the writer's opinion is also a B_2 basalt.

These peculiar alkaline rocks are distributed in areas where neutral or acidic alkaline volcanic rocks (alkaline trachyte, pantellerite, comendite, etc.) are not found. Furthermore, they have not been discovered in areas where neutral or acidic volcanic rocks do occur. Hence, one may conclude that at least in the Cenozoic alkaline petrographic province of Eastern Asia, limburgite and nepheline basalts (including melilite basalt) do not occur associated with neutral or acidic alkaline volcanic rocks. It is thought, therefore, that those peculiar alkaline rocks were formed through an entirely different process—though the original magma of both was the same.

The climax of the fourth period of volcanic activity is represented by the eruption of neutral or acidic alkaline volcanic rocks. This was an astounding event throughout this petrographic province. It was a remarkable contrast to the very slight volcanic activity in the Japanese Islands at this time. It is noticeable that sanukitic andesites (the second eruption of the rocks) were formed in the Inland Sea zone and the Kyūshū district which are on the margin of this petrographic province.

There were only a few centers of activity of neutral or acidic alkaline volcanic rocks:

P'aektu-san: The description of this volcanic body has been omitted as it is not within the province of this paper. The eruption of alkaline volcanic rocks began with alkaline trachytes, gradually progressing through lava of high acidity, and at last ending in comenditic lava. This sequence is the same as that in the Kilchu—Myŏngch'ŏn district in Hamgyŏng-pukto, Korea, and Dōgo in the Oki Islands. The chemical composition of those lavas is shown in Table 9.[10)]

P'aektu volcanic zone: Sobaek-san, Pukp'ot'ae-san, Changgun-bong, Hwang-bong, Kwandu-bong, P'aeksa-bong, Namsŏl-lyŏng, and Turyu-san which rise in a row toward the SSE or SE from P'aektu-san are composed of alkaline trachyte or alkaline rhyolite. That is, according to YAMANARI (1928), Hwang-bong and Kwandu-bong are composed of alkaline rhyolite and the others are of alkaline trachyte. According to KINOZAKI (1932), Turyu-san is composed of alkaline trachyte (chemical composition: Table 10, no. 3). These mountains, consisting of alkaline volcanic rocks, were named by KAWASAKI (1927) the P'aektu volcanic zone. He considered that this volcanic zone extends farther towards the southeast; that is, he thought that Ch'ilbo-san in Kilchu-myŏn, Ŭngdŏk, Kapsan (in Hamgyŏng-namdo; chemical composition: Table 10, nos. 79 and 83), and even Ullŭng-do in the sea belong to the P'aektu volcanic zone. Developing this view, HOMMA (1930) established an arcuate alkaline rock volcanic zone including the Oki Islands and trachyte forming the hills between Tsuiyama and Kinosaki in Hyōgo Prefecture.

If such a volcanic chain or zone is recognized, a volcanic zone including the Oki Islands, Matsushima and Kakarajima in northern Kyūshū, and Cheju-do must be recognized. However, it is highly questionable whether the distribution of alkaline volcanic rocks may be treated within the concept of a so-called volcanic zone.

Kilchu—Myŏngch'ŏn district, Hamgyŏng-pukto, Korea (see Table 1): The eruption sequence of alkaline volcanic rocks (TATEIWA's Ch'ilbosan group) in this district has not been thoroughly disclosed in spite of the detailed survey by YAMANARI and TATEIWA and the writer's supplementary survey. The reason is that the alkaline volcanic rocks are widely distributed and some groups are isolated. Most of the rocks, however, are correlated with those of Dōgo. The varieties which do not occur in Dōgo are the Chaedŏksan basalt, the Namyangdong beds, and AT_1 (Kal-san, Mokchin, and Sangam-san alkaline trachytes), which belong to a series of groups having the genesis of the above order. Since the Chaedŏksan basalt belongs to B_2, these varieties are older than the alkaline volcanic rocks in Dōgo; in other words, they correspond to the lowest part of the Ch'ilbosan group.

If this correlation is correct, the eruption cycle in this district proceeded from neutral rocks to acidic rocks and was repeated twice. It occurred only in the Pliocene, but in Dōgo it was a long-range event extending from the Late Miocene to the Pliocene, and there are some differences in lithologic character (the difference of AT_1 in the above two areas is particularly remarkable). Generally speaking, however, not only the geologic disturbances but also the lithologic characteristics

[10)] For comparison purposes Table 9 includes the chemical composition of Pleistocene ejecta.

in the two areas closely resemble each other. Sometimes it is very difficult to determine from which of the two areas a sample was collected.

The chemical composition of alkaline trachyte and alkaline rhyolite in this district is shown in Table 10. For purpose of comparison with the above rocks, the chemical composition of the Turyusan alkaline trachyte (no. 73) and comendite (nos. 79 and 83) from Kapsan in Hamgyōng-namdo is also shown in the table.

Data already published are shown in Table 11. Generally speaking, these rocks are richer in alumina than silica. It cannot be readily concluded whether this fact is due to a peculiar rock type different from the general chemical characteristics of the rocks in this district shown in Table 10 or whether it is an error in analysis. (For various reasons the writer supposes it to be the latter. At any rate it is shown as an appended table for future reference but is not used as a datum for genetical discussion).

Dōgo, Oki Islands: Dōgo is a match for the above-mentioned Kilchu—Myŏngch'ŏn district in the occurrence of many rock types. As described above, B_2 has not been discovered in Dōgo and rock formations corresponding to the Namyangdong beds and Kalsan, Mokchin, and Sangamsan trachytes developed in the Kilchu—Myŏngch'ŏn district are also lacking on the island. Hence, the oldest Pliocene series there is the Nakajima beds, which are correlated with the Naesandong beds in the Ch'ilbosan group. Later formations are essentially the same as those developed in the Kilchu—Myŏngch'ŏn district, and the types of alkaline volcanic rocks in the two areas strikingly resemble each other. One outstanding example which the writer observed during his survey will be described immediately below. Lava corresponding to the Puhyang alkaline rhyolite (Table 10, no. 78) in the Kilchu—Myŏngch'ŏn district is not found on the surface in Dōgo, but an ejected block was discovered in the Washigamine beds in Dōgo. Their similarity is unquestionable from a comparison of the chemical compositions of the two rocks. The chemical composition of the ejected block in Dōgo is listed in Table 12, no. 95.

Worthy of special mention concerning the volcanic geology of Dōgo is the fact that peculiar alkaline dike rocks were intruded after the eruption of comendites. The dike rocks are partly paisanite and grorudite, which may be called alkaline quartz porphyry, and partly tinguaite porphyry, which may be called a phonolitic trachyporphyry. The time sequence of these rocks is not known. My view is that these dike rocks represent the final stages of the cycle of alkaline magma activity in Dōgo, that is, there was no eruption of Pleistocene alkaline neutral and acidic rocks in Dōgo.

Table 12 lists the chemical composition of the alkaline trachyte and later differentiated types of Dōgo. Many analyses of alkaline rhyolites are contained in the table, because various types of rocks were analyzed in order to ascertain that there are two types in the evolutional system of the rocks there.

Dōzen, Oki Islands: The oldest rock formation in Dōzen is the Tertiary formation (probably Early or Middle Miocene) and quartz syenite body[11] which traversed the Tertiary and contact-metamorphosed it. This plutonic rock body may be correlated with the Takayama gabbro and the Tamasaki granite porphyry in the San'in district. It may be a body that intruded in the end of the Middle Miocene.

The volcanic rocks of Dōzen were described by Kōzu (1913) and Shimoma (1928). According to Kōzu, there are (K_1) trachybasalts, (K_2) olivine-bearing glassy trachyte (chemical composition shown in Table 12, no. 109), (K_3) hornblende trachyte, (K_4) biotite trachyte, (K_5) hornblende-bearing plagioclase trachyte (chemical composition shown in Table 12, no. 109), and (K_6) aegirine augite trachyte. According to Shimoma, (S_1) trachybasalts and basalts, (S_2) andesite, (S_3) trachyandesite, (S_4) plagioclase-bearing biotite-augite trachyte, (S_5) biotite-augite trachyte, (S_6) hornblende trachyte, (S_7) olivine-bearing biotite trachyte, and (S_8) comendite occur in Dōzen.

When the Dōzen types are compared with those from Dōgo, some types are seen to resemble each other and others are quite different. Andesite does not belong to the eruption cycle of alkaline volcanic rocks, but probably to the pre-alkaline volcanic rocks. Trachybasalts and basalts are roughly divided into two groups on the basis of the period of eruption, pre-alkaline trachytes and post-alkaline trachytes. Alkaline trachytes which traverse the former are developed in a radial dike group with Takuhiyama at the center. This development is a remarkable example of radial dike groups in Eastern Asia. From their geological relation, the trachybasalt and basalt of the pre-alkaline trachytes unquestionably belong to B_1, and those of the post-alkaline trachytes to B_3. The presence of those belonging to B_5 has not been established.

Many of the trachytes from Dōzen contain plagioclase (andesine or oligoclase) and also hornblende and biotite. These probably correlate with AT_1 in Dōgo. However, a type (K_6) described as aegirine-augite trachyte belongs to AT_2, and comendite (S_8) is comenditic. Therefore, though few in number, they distinctly show that they passed through a cycle of formation of alkaline volcanic rocks.

In short, it is hoped that geologists will study in detail the volcanic geology and volcanic rocks of Dōzen just as they have studied the adjoining island of Dōgo. The rock types from Dōzen are very interesting petrogenetically.

Matsushima, Kakarajima, and Madarashima, Nagasaki Prefecture: The three islands, Kakarajima, Matsushima, and Madarashima, between Iki Island and the Higashimatsuura Peninsula, that is, in the Iki Strait, are composed of basalts and alkaline trachyte. In Matsushima alkaline trachyte is predominant (chemical composition: Table 13, nos. 111 and 112) and is well-known since olden days (Ōtsuki, 1910, Kōzu, 1911). The time sequence of the alkaline trachyte and the basalt has not been confirmed. According to Ōtsuki, dike-like basalt is found on the northeast coast of Matsushima, so the eruption of the alkaline trachyte may be

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[11] Kōzu calls the quartz syenite "kurokigan" (Kōzu, S., 1914, Igneous rocks in the Oki Islands; *Bull. Geol. Surv. Japan*, no. 1, p. 83)

prior to the eruption of the basalt. If this observation is correct, this dike-like basalt was effused after the Pliocene and may belong to B_3 of the Pleistocene.

The alkaline trachyte of Madarashima is more acidic than that of Matsushima and is a variety close to alkaline rhyolitic rock. In this island the time sequence of this rock and basalt is unknown (personal communication from N. Aoyama).

Iki Island: This island has not been considered an alkaline volcanic rock area. However, quite recently, the writer, judging from reported related findings, thinks it highly possible that volcanic rocks belonging to the alkaline rock series may be present on the island.

It is said that in some localities the liparite reported by Ōtsuki (1910) occurs as dikes in the basalt and in other localities as xenoliths captured by the basalt. If the basalt is correlated with B_2 and B_3 respectively, the eruption period of the liparite will be the same as that in Dōgo. In addition, from Ōtsuki's description, the liparite closely resembles platy alkaline rhyolite from Dōgo. Next, the rock described as hornblende andesite closely resembles in lithologic character a variety of trachyte from Dōzen, and it was effused before the basalt. This basalt may reasonably be regarded as B_3. On the other hand, as the basalt erupted before and after "the younger Tertiary," it is clear that it erupted at least twice. Though one may question whether the so-called younger Tertiary is the younger Tertiary or Pleistocene, generally speaking, the geologic history of Iki Island coincides with that of the Oki Islands, and the lithologic character of these rocks shows a remarkable similarity.

Cheju-do: Alkaline trachyte (chemical composition: Table 13, nos. 113 and 114) on the summit of Halla-san in Cheju-do contains fayalite and closely resembles a rock of a similar type (Table 9, nos. 51, 52, and 53) found on the summit of P'aektu-san. According to Haraguchi (1931) the alkaline trachytes from Cheju-do are the oldest effusive rocks among the volcanic rocks of the island and are older than the sedimentation of the Sŏgwip'o beds (oldest Pleistocene). Consequently, it would be no great error to think that the eruption of the alkaline trachytes occurred at the end of the Pliocene. That is, one may presume that the alkaline trachytes erupted in the same period as those of P'aektu-san, the Kilchu—Myŏngch'ŏn district, and Dōgo.

It is said that the trachyandesites and basalts of this island are younger than the Sŏgwip'o beds. For convenience, the chemical composition of the trachyandesites is included in Table 13.

As described for the eight sites considered above, volcanic activity occurred in the Cenozoic alkaline petrographic province of Eastern Asia in the Pliocene. The volcanic activity of this period was the most remarkable event in this petrographic province and the rocks produced were generally neutral and acidic alkaline volcanic rocks. Only in Dōgo, residual-magmatic dike rocks such as alkaline quartz porphyry and tinguaite have been found. In short, the center of eruption was the center of magmatic differentiation.

(5) The fifth period of volcanic activity (Early Pleistocene)

After the end of the fourth period of volcanic activity this petrographic province entered a period of calm sedimentation. It is very interesting that a remarkable gravel bed was formed in each region. The gravel beds in the continental region are particularly noticeable. There was a period of gravel bed formation after the Paleogene, and gravel beds correlated with the Sanmen gravel bed are extensively distributed in the drainage basin of the Huang Ho. In Japan, thick gravel beds containing shingles are found in the mountainland of the Chūgoku district. These gravel beds may be of the same period. The sand and gravel bed (intercalated in the basaltic lava flow) in the Sasebo coal field district, northern Kyūshū, may be no exception. The sedimentation of such great gravel beds calls to mind the so-called Pleistocene heavy rainfall period, but it is difficult to prove positively that there was actually a period of heavy rainfall. Regardless of the existence of such a climatic factor, we may reasonably suppose that epeirogenetic movements occurred in the extensive region.

The volcanic activity of this period also began with the eruption of basalts (B_3). The rocks are rich in a type which lacks phenocrysts and resembles a similar B_1 type. However, when compared in detail, it is found that the B_3 of this period does not have as greasy a luster or as scintillating a feldspar ground mass. Generally, plagioclase basalt is abundant. Phenocrysts other than plagioclase include pyroxene and olivine (the latter is generally small in quantity). Some types contain kaersut-hornblende and biotite.

The chemical compositions of basalts from P'aektu-san, Dōgo, the San'in district, and northern Kyūshū are listed in Table 14. In Cheju-do, the activity of this period was that of hornblende trachyandesites, and its chemical composition is shown in Table 13. In Ullŭng-do, basalts occur in the lowest part of the peculiar alkaline volcanic rocks. According to HARUMOTO (1948), the basalts form lava flows, agglomerate and frequently occurring dikes, and include many types. Though there is not enough field evidence to determine their geologic age, from a consideration of their volcanologic characteristics and lithologic character, the basalts of this island are considered a product of this period. The chemical composition of the basalts is indicated in Table 15 together with that of peculiar alkaline volcanic rocks.

There are many cases in which the basalts appear in the form of plateau lava flows. The form of eruption gives an impression of fissure eruption, but the basalts were not always effused in that form. The eruption in Ullŭng-do was a central eruption, and, in P'aektu-san, the basalts were effused like parasitic cones on the great volcanic body of alkaline trachytes. The lavas were highly fluid, however, and flowed copiously down along the former river beds. The lava flow meandering along the Namdae-ch'ŏn in Hamgyŏng-pukto, Korea, is a good example. The Changdŏk basalt may have reached the lowland.

Because of the long-distance flowing, there is no lava plateau in the San'in district and northern Kyūshū. Lava plateaus due to fissure eruptions are commonly found on a small scale. However, in such an eruption, it seems that there were conduits of the central eruption at the points of eruption, or it may be reasonable to assume that the final stage of fissure eruption took the form of a central eruption.

Most lava plateaus do not consist of a sheet flow of lava. Generally speaking, basalt which was effused in the early period is black and that which was effused in a later period is gray or white. Basalt from the later period has remarkable platy joints (columnar joints are also well developed) and horizontal interstices are in which biotite (actually phlogopitic brown mica) or sometimes brown hornblende is found frequently developed.

Tholeiitic basalt is frequently present among the basalts of this period. Quartz-basalt (quartz captured as xenocrysts) is also found occasionally, and in the Yongilman district in Korea and in the southern part of northern Kyūshū (the southern part of the Shimabara Peninsula), a type suggesting the development of two-pyroxene andesite occurs. These examples indicate that two-pyroxene andesite is formed from olivine-basaltic magma by a certain action, a very important fact petrogenetically.

The period of volcanic eruption was followed by a period of subsidence, which continued for some time. In the latter period, erosion was active, and in some areas sand and gravel beds (the Kŭmsan beds in the Kilchu—Myŏngch'ŏn district and the Obama beds in the Shimabara Peninsula) were deposited. Then volcanic activity revived. In P'aektu-san, pumice (Table 9, nos. 71 and 72) was ejected with a great explosion, and at the same time blocks of trachybasalt (Table 9, no. 69) and nordmarkite (Table 9, no. 70) were hurled out. In the Kilchu—Myŏngch'ŏn district, there was some feeble activity of alkaline trachyte. The activity on Ullŭng-do is particularly interesting. Though various alkaline trachytes were erupted, it is noteworthy that a peculiar alkaline volcanic rock having nepheline (phonolite) was formed at that time.

Of further note was the formation of hornblende andesite in Japan. The type locality is Unzen volcano, and both Kinugasa lava and Kusembu lava belong to it. Numerous blocks were captured by these lavas.[12] Hornblende andesites of the same period occur in the following localities: Taradake, Sannotake, and Ninotake of Kimpōsan; Kuradake and Tawarayama on the western shoulder of Aso volcano; Kurodake, Hanamureyama, Ryōshidake, Kuroiwayama, and Sensuisan in the Kujū area; and Fukumayama, Okoshiyama, Bunsekiyama, Tobidake, Minakuchiyama, and Takasakiyama in the Yufu—Tsurumi area. The area where these volcanoes are distributed is a zone about 25 km wide extending from the Shimabara Peninsula through Aso volcano to Beppu Bay. It was hitherto believed that the area belongs to the inner volcanic zone in southwestern Japan. But in the writer's opinion, based on considerations of the petrographic province, the area corresponds to the marginal zone of the region of B_3 activity in the Cenozoic alkaline petrographic province of Eastern Asia. Considered with the fact that sanukites were formed in the marginal zone of the region of B_1 and B_2 activity, it is very inter-

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[12] The captured blocks are so numerous it is no exaggeration to say that they appear at every blow of the hammer in field surveys.

esting that hornblende andesite is present (hornblende andesite containing abundant captured rock fragments as described above). The area where the activity of olivine trachybasalt had taken place was reduced to the coastal zones of the San'in district and northern Kyūshū in the Holocene epoch. This will be discussed later.

At the end of the fifth period of volcanic activity, older alluvial fans, sand and gravel beds, and terraces were formed.

(6) The sixth period of volcanic activity (Late Pleistocene)

The first event in this period was a great faulting, which was followed by the activity of B_4.

North China: The formation of the Tat'ung volcano group was remarkable. About eleven small volcanic cones lie scattered in the area more than 10 km east of the capital of Ta-t'ung Prefecture, Shanhsi Province. Craters still remain in several cones. Large and small bombs can be collected from some cones. The volcanic activity began with an outflow of black compact olivine-basaltic lava[13] during the deposition of loess near the end of the Middle Pleistocene. The final stage of this activity is represented by the formation of small cones consisting of scoriaceous lava, and the eruption was accompanied by many explosions. After the formation of the volcanic bodies, these were covered partially or entirely by loessic loam due to aeolian migration. The fact that the original form of the volcanic bodies has not been remarkably eroded and dissected is attributed to the porosity of the lava constituting the cones, the resulting prominent permeability of the lava, and the arid climate.

Similar small conical volcanoes rise sporadically NNW from Ta-t'ung. Aerial photography revealed these cones on the Mongolian plateau. The regular arrangement of the cones suggests that they consist of lava which erupted along a geotectonic line such as a fissure, but there is no confirmative evidence for this view. There is a possibility, however, of interpreting them as the results of volcanic activity promoted by faulting movements that accompanied the epeirogenetic movements in Eastern Asia.

The above-mentioned epeirogenetic uplifting movements (which caused the formation of older alluvial fans, sand and gravel beds, and terraces described in the foregoing paragraph), and the faulting movements that accompanied them were a large-scale phenomenon throughout all of Eastern Asia. That is, until that time, the Japanese arc and the islands in the West Pacific had been connected with the continent, but as the peripheral sea (continental shelf sea) came into being as a result of the large-scale faulting movements of this period, the islands were separated entirely from the continent, and broke off into an arrangement which has barely changed up to the present. Consequently, faults of this period have important geologic significance and are found even in the parts which are still land.

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[13] This lava is highly fluid and reaches as far as the Sang-ch'ien Ho. Several parts have the appearance of ropy lava. A thorough petrographic study of this lava has not been attempted by the writer or other scientists. The lava which occurs as dikes in the adjoining gneiss is olivine trachydolerite that contains purple pyroxene.

(In Japan, the Chijiwa fault in the Shimabara Peninsula and faults traversing the so-called Pleistocene gravel beds in various areas are examples.) Depressions and collapse on a large scale in volcanic bodies (for example, P'aektusan, Ullŭng-do, etc.), are not just local volcanic events, the writer believes, but are local manifestations of the areal geologic phenomena mentioned in this paragraph.

Paektu Volcano: Ch'ŏn-ji, crater lake of Paektu-san, is 3–4 km in diameter and 375 m in maximum depth. (The distance between the highest peak and the lake bottom is 863 m.) This lake is a gigantic caldera. It seems not unreasonable to think that the formation of this caldera is associated with the great explosion of pumice, which we have discussed above. It is questionable, however, whether the gigantic caldera was formed at the time of the great explosion. The writer doubts that it was formed at that time. Probably the crater formed in association with the pumice ejection is, so to speak, the embryo of the present caldera, and may have been enlarged by later collapses. The writer is inclined to consider collapse as an effect of crustal movement (particularly the crustal movements that affected the whole region of Eastern Asia).

In the sixth period of volcanic activity in the end of the Pleistocene, Paektu volcano also became active. Alkaline trachytic mud lava was discharged and poured down on all sides. This outpouring of mud lava was subsequent to the development of the present scale caldera. It is confirmed by mud lava attached to the crater wall.

It is not known whether lava or ejecta were discharged in the later eruptions (recorded in historic times).

Kilchu—Myŏngch'ŏn district: The two basalts of Ŭngdŏk and Kuktong and the later alkaline trachyte are the representatives of the volcanic activity of this period in this district. Though the center of eruption of the lavas is not known, it is inferred from their lithologic character (particularly the glass basis) that the lavas were not a lava flow which ran down from a distant place but a local product. The lavas include many varieties,[14] and it is interesting that there is a hypersthene-bearing variety. In the Ŭngdŏk basalt, sporadic large crystals of feldspar are frequently found as phenocrysts, and captured assemblages of pyroxene and plagioclase are also enclosed.

The large crystals of feldspar are potash andesine, and it is noticeable that they exhibit a reverse zonal structure (Itō, 1935). On the other hand, xenoliths consisting of assemblages of pyroxene and plagioclase are considered cognate xenoliths. Generally speaking, olivine spherulite is not rare, regardless of its age of eruption, in the basalts of the Cenozoic alkaline petrographic province of Eastern Asia. It is frequently present, particularly in the Pleistocene basalts (B_3 and B_4), and there is no example of the above-mentioned cognate xenoliths except in the Pleistocene basalts. The writer believes that this is a noteworthy fact from a petrogenetical point of view.

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[14] This is also one of the general characteristics of local basalts.

The chemical composition of Ŭngdŏk basalt is shown in Table 6 (no. 146). This is the only reliable analysis of the basalt. It is noteworthy that the basalt has quartz in the norm.

Central Korea: Of the vast amount of Pleistocene basalt in North Korea, the one which is regarded as Late Pleistocene (B_4) is the Ŭngdŏk basalt. The lava flows (Kinozaki, 1937) in Central Korea which are described next are considered Late Pleistocene lava.

The basaltic flow distributed along the graben running NNE between Wŏnsan and Kyŏngsŏng was effused after the development of the normal fault associated with the formation of this graben. The direction of this graben is parallel to the coast line at the southeast end of the Korean Peninsula and the extended trend of Tsushima Island. In Japan, the direction determines the extended trends of southern Kyūshū and the direction of the zone connecting the two volcanoes, Aso and Kirishima. In the writer's opinion, the direction was determined by the great crustal movements at the end of the Middle Pleistocene.

There are at least two localities regarded as the eruption center of the Ch'uga-ryŏng graben basalt: one is 680 m upland and the other is Ap-san (452.5 m). Both retain the original form of a volcano of the *aspite* type. The lava which flowed out of the former crossed over Ch'uga-ryŏng, reached as far as Anbyŏn, and stopped in the vicinity of Pokkye in the south. The total length of the lava flow was about 60 km. The lava which issued from the latter, though it was stopped in the vicinity of Pokkye in the north, reached as far as Ch'ŏlwŏn in the south, and its total length is about 30 km. These two lava flows meet in the vicinity of Pokkye, so the Ch'uga-ryŏng basalt forms a narrow lava flow extending as far as 90 km. In Ap-san, there is not only a crater (about 200 m in diameter and about 20 m deep) but are there also more than twenty small protuberances which resemble parasitic cones, and volcanic topography still remains fresh.

It is interesting that basaltic activity in the early period of Pleistocene took the form of fissure eruptions, and that the activity of the later period was a central eruption.

The writer is inclined to believe that the basalts found on the east side of the Ch'uga-ryŏng, namely, the basalt in the vicinity of T'ongch'ŏn (which closely resembles the Ŭngdŏk basalt), that in Hoeryŏng County, and that in the vicinity of Kŭmhwa east of Ch'ŏlwŏn (Table 16, no. 145) erupted in the same age.

There is a great basaltic flow west of the Ch'uga-ryŏng graben and distributed along the geotectonic line running parallel to this graben. This is the basalt of the Koksan—Singye district. The lava flow is about 45 km N-S and a maximum of about 20 km E-W. Though it is small compared with the basalt flow in the Ch'uga-ryŏng graben, this is one of the largest lava flows (including the andesitic lavas in Japan) in Eastern Asia. The original form of volcanic topography (*aspite*) has not been considerably eroded. I regret to say that I have no knowledge of the lithologic character of these basalts.

Ullŭng-do: As described above, a central eruption occurred in Ullŭng-do in the fifth period of volcanic activity, and the eruption was followed by the outflow of alkaline trachytes (including phonolite). The volcanic body thus produced was shattered by faulting movements in the end of the Middle Pleistocene. Then the sixth volcanic activity began, and Nan-bong was formed on the summit which had sunk and collapsed. This Nan-bong is noted for being composed of leucite trachyandesite (Table 15, nos. 137 and 139). At the same time alkaline syenitic ejecta were thrown out. The island remained entirely calm after that.

Cheju-do: All the trachyandesites in Cheju-do were thought to be of the fifth period of volcanic activity. The writer, however, doubts that all may have been effused in this period.

The foregoing paragraphs are an outline of the condition of the continental region and Korea. It is very interesting, by way of comparison, to consider the volcanic activity in the Japanese Islands during this period.[15]

As described above, the volcanic activity of this period commenced after the great crustal movements (the crustal movements by which the Japanese Islands were entirely separated from the continent). The Chijiwa fault in the Shimabara Peninsula and the graben in the Yufu-Tsurumi area were formed in these crustal movements. The San'in type hornblende andesites were the effusive rocks in this period of activity. Of these, the principal ones are: the Fugendake lava in Unzen volcano, the lavas of Ichinodake in Kimpōsan volcano, Kujūsan, Kujūdake, Ōfunayama, Yufudake, and Tsurumidake, the hornblende andesite on the summit of Futago volcano, and the lavas of Aonoyama, Sambesan, and Daisen in the Chūgoku district. These lavas frequently contain oxidized biotite as well as oxidized hornblende, and quartz and feldspar are mixed as captured crystals (SUGI, TANEDA and YAMAGUCHI, 1948).

There is considerable evidence that the activity of olivine basaltic magma helped form these San'in type hornblende andesites. According to HOMMA (1936), peculiar rocks in which olivine and quartz coexist are found in the volcanic rocks of Unzen volcano. The peculiar rocks are found not only in the lavas of the Fuken period in question but also the above-mentioned lavas of the Kinugasa—Kusembu period (belonging to the fifth period of volcanic activity) and the Holocene lavas (Furuyake and Shin'yake), which will be described later. HOMMA published an interesting genetic opinion on the Furuyake lava (erupted in 1657), stating that the Furuyake lava originated from a mixed magma which was formed by intermixing olivine basaltic magma with quartz-bearing biotite hornblende andesitic magma. Although HOMMA's opinion needs to be explained in some detail, the writer agrees with its main points.

In addition, a lava flow of olivine basalt was recently discovered in the Yufu—Tsurumi area (T. KASAMA, personal communication). This is called Bateisan lava and is probably an effusive rock of this period of activity.

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[15] In this paper the only volcanic activity in the inner zone of southwestern Japan which is in a close geologic relation with the Cenozoic alkaline petrographic province of Eastern Asia is sketched.

The final display of this period was the great eruption of the Aso lava and the formation of the Aso caldera. The lithologic character of the Aso lava has not been thoroughly studied. The embryo of the Aso caldera probably formed before the eruption of the Aso lava and probably was later enlarged to its present size. The formation of this embryo is thought to have been in the above-described period of great crustal movements. In short, in the same period, a caldera was formed in P'aektu-san in the north and then alkaline trachytic mud lava was effused, and a caldera was formed in Aso volcano in the south. A great eruption of the Aso lava also occurred. This contrast is very interesting and significant. It cannot be overlooked that, though the lavas of Aso volcano are pyroxene andesite, the alkali content is too high to be classed as a Japanese-type pyroxene andesite.

(7) The seventh period of volcanic activity (Holocene)

The beginning of the Holocene was a calm sedimentation period. In the continental region, loessic sand beds were formed by the erosion and resedimentation of the loess bed, and the weathering of the loess bed itself progressed considerably. In particular, as the Japanese Islands were completely separated from the continent, the coast line advanced inland to its present position, and thereby Shan-tung Province came to be controlled not by an inland climate but by a littoral climate. In the writer's opinion, the brown earth found in the eastern part of Shan-tung Province was produced by the weathering and metamorphism of the loess bed due to this climatic change, in turn caused by a topographic change.

Meanwhile, epeirogenetic movements on a grand scale progressed. The isostasy of the earth's crust was kept in defined zones by faulting movements. The activity of basaltic magma was induced. Volcanic activity in the resulting so-called tension area was begun in the interior of the continent. The inland volcanic activity of Wu-ta-lien-ch'ih volcano and Erh-k'o volcano in North Manchuria and the Ch'i-hsing volcano group in South Manchuria, and others went through such conditions.

Wu-ta-lien-ch'ih volcano: This volcano is located north of the capital of Te-tu Prefecture, Hei-lung-chiang Province, and is composed of fourteen small volcanic cones. This volcano has been called "Wünhordongui" volcano since olden times. Of the fourteen cones, Lao-hei Shan and Huo-shao Shan were formed in the 1720 eruption (Ogura *et al*, 1936).

The basement rocks of this volcano group are granite, Cretaceous formation, and Pleistocene formation. On the flat plateau formed by these basement rocks, alkaline basic volcanic rocks were erupted in the following order: (1) hilly plateau lava, (2) shield-like plateau lava, (3) older volcanic cone lava, (4) Shihlung lava, and (5) younger volcanic cone lava (effused in the 1720 eruption). The chemical composition of the rock types belonging to each lava is tabulated in Table 18 (nos. 168–186).

The mode of activity of this volcano group and the kinds of volcanic rocks erupted during the activity are regarded as representative of the inland type of volcanic activity. The volcanology of this group will be briefly mentioned.

The hilly plateau lava of the first eruption is trachyandesite of the Banak type. There were several centers of eruption, and the area where the lava is distributed attains about 500 square kilometers.[16] The flat topography became hilly due to the eruption of this lava. Moreover, the height of the hills increased due to the second eruption. (The kind of lava is much the same as the lava of the first eruption.) However, the maximum height (in the center of eruption) is only 120 to 130 m. In the third eruption, 12 small volcanic cones of the homate type were built up on the hilly plateau lava flow. These cones are on a very small scale: the average base is several hundred meters in diameter and the height is less than 100 m. These cones are composed of stratified lava flows and scoria. However, as each cone has an explosion crater on the summit, it is known that the activity was relatively violent in the final stages of the activity. However, the ejecta are found scattered only around the crater, so the volcanic activity is regarded as having been fairly gentle.

With the above activity one cycle of volcanic activity came to an end, and later the second cycle began. The first stage of the second cycle was represented by the outflow of the Shihlung lava. This activity occurred in the central part of the volcanic district where there was no center of eruption from the first cycle. Lava flowed down on all sides and toward the south it flowed along the narrow valley. The lava flow is eight km long, though it is several hundred meters wide, and it has a form like a huge snake, hence the name 'Shih-lung' (stone dragon).[17] After the relatively gentle outflow of the Shihlung lava the younger volcanic cones of the fifth period of volcanic activity were formed. A reliable old record indicates, beyond doubt, that this was the eruption which built up Lao-hei Shan and Huo-shao Shan (Wu, 1721). The age of the outflow of the Shihlung lava previous to the above eruption is not known but it is inferred that the outflow occurred in historic times.

A noticeable fact concerning the activity of Wu-ta-lien-ch'ih volcano is the outflow of lava containing leucite during and subsequent to the period of formation of older volcanic cones (see Table 18). Other examples of volcanic rocks containing leucite and occurring in the interior of the continent are known elsewhere in the world. The Tertiary volcanic rocks in Yellowstone National Park are suitable for a comparative study with those from North Manchuria. It is believed to be unquestionable that those in the above locality belong to Tertiary, though they are known only as post-Eocene, but those in North Manchuria are the Holocene lavas. This is a very noteworthy fact from the volcanological and petrogenetical point of view.

In addition, it is not rare that accidental xenoliths are present in the lavas of this volcano. That is, granite, quartzite, and sandstone are found as xenoliths, and quartz and orthoclase have been known as captured crystals. The lavas of this volcano are a special instance in the Cenozoic alkaline petrographic province of

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[16] The area is almost equal to the area of the inside of the Aso caldera.

[17] In Japan, advancing lava-flows were also likened to dragons. In ancient records on volcanic eruptions such accounts are found from time to time (Example: the 1783 eruption of Asama volcano).

Eastern Asia, in the sense that the lavas contain frequent accidental xenoliths. Lavas containing accidental xenoliths have been found in few other volcanoes. This is in remarkable contrast to the case of the andesites in Japan.

Stressing the presence of accidental xenoliths, particularly in the presence of granitic xenoliths, GORAI (1940) explained by selective assimilation (of basaltic parental magma) the genesis of leucitic volcanic rocks from Wu-ta-lien-ch'ih Volcano and Erh-k'o volcano, which will be mentioned later. Though this is an interesting explanation, many difficult points are contained in it. OGURA (1951) does not agree with Gorai's opinion, and it seems that he attributes the chemical characteristic of rich potassium to crystallization differentiation, but a detailed discussion has not yet been published.

Erh-k'o volcano: This volcano is located about 70 km south of Wu-ta-lien-ch'ih volcano, and is composed of three small cones. Tung Shan, the highest cone, is 110 m high (700 m in diameter at the base) and Hsiao-k'o Shan which is the lowest is only 18 m high (210 m in diameter at the base). Another cone called Hsi Shan, is 75 m high (550 m in diameter at the base). All are very small cones, but each cone has an explosion crater on its summit (OGURA and MATSUMOTO, 1938).

The basement rocks of this volcano are Cretaceous and Pleistocene. Being in a flat plain, it is said that Erh-k'o volcano, though it is small, can be viewed from scores of kilometers away in the plain area.

The volcanic activity was divided into two periods. In the first period leucite basanite (Table 17, no. 168) was erupted and formed a shield-like plateau. The area covered by the lava is 33 square km. The second lava was erupted on the first lava and formed volcanic cones. The lava constituting these volcanic cones is also leucite basanite (Table 17, no. 169), but it is mostly vesicular and scoriaceous.

There are no geologic data concerning the age of activity of Erh-k'o volcano except that it is younger than the Pleistocene formation in this area (yellowish brown clay bed and grayish white clay bed, and in places sand and gravel bed and yellowish brown or yellow sand bed). The age of activity probably correlates with the first cycle of activity of Wu-ta-lien-ch'ih volcano. There is no evidence that erosion and dissection took place.

In short, Erh-k'o Shan is a very small scale volcano and the area covered by the lava flow of the first eruption is estimated at only 33 square kilometers. Because of the occurrence of volcanic rock containing leucite, however, it is of great geologic significance.

Ch'i-hsing Shan volcano: Seven volcanic cones rising around Ling-yuan (Cheng-chia-chun), an important town in the center of the Manchurian plain, are collectively the Ch'i-hsing Shan volcano. Poli Shan, which is the highest of the seven cones, is 110 m high and Nao-pao Shan, which is the lowest, is 30 m high. Hence, this is also a small volcano. No cone, however, has a crater like that of Wu-ta-lien-ch'ih Volcano or Erh-ko Shan volcano. It is questionable whether some of them may be called volcanic cones. They may belong to the tholoide type of volcano. There is no evidence that the cones displayed an explosive activity. There is also no geologic evidence concerning their age. A clay bed and a sand bed, which seem to be younger Pleistocene or older Holocene are found in the vicinity of the cones. It is said that they form the basement of this volcano group (OGURA, SAWATARI and MURAYAMA, 1939).

The lavas of this volcano group are essentially the same. Generally speaking. the lavas are olivine basalts; leucite basanite occurs only in Nao-pao Shan. Their chemical composition is shown in Table 18. The lithologic character also differs from the lavas of Wu-ta-lien-ch'ih and Erh-k'o Shan volcanoes.

Lung-wan volcano group: This volcano group is located about 150 km WNW of Pai-t'ou Shan, and is composed of more than 35 volcanic cones lying scattered on the west side of the Lung-kang Mountains. Some of them have crater lakes. The cones consist mainly of scoriaceous lava and lava flows that were poured out before the formation of these cinder cones. There are four large lava flows which are 6, 8, 9, and 35 km long. The longest is a large lava flow which attained a maximum width of 5 km.

This lava flowed down the present valleys. This fact shows that the age of the activity was Holocene. The lithologic character also shows characteristics of Holocene basalts (Table 19).

The fact that there is a volcanic cone in which ejected granite blocks are found is very interesting. Furthermore, the basement of granite is exposed in parts of the crater bottom or crater wall. Hence, this is a fine example of volcanic activity displayed in a pure granite area. In this volcano, there is no leucite basalt, thereby differing from the Wu-ta-lien-ch'ih and Erh-k'o Shan volcanoes. As described above, a view advocated concerning the petrogenesis of leucite basalts is that of selective assimilation of granite. It is questionable whether or not such assimilation is possible. Even if it is possible, such assimilation does not always occur. It is considered that such assimilation may be limited by certain conditions. These problems are very interesting from the volcanological point of view, and for this study an examination of the lavas of Lung-wan volcano is also necessary. In this sense, this volcano is one of the important members in the Cenozoic alkaline petrographic province of Eastern Asia.

Fourteen volcanic areas, besides the above, have been identified in Manchuria (OGURA *et al*, 1936). Volcanoes in almost all of the above areas consist of basaltic lava. The only exception is Halhin volcano situated on the east side of the Ha-lun-erh-shan spring in the central part of the Great Hsing-an-ling Mountains. Liparite, tuff, and obsidian occur in this volcano (KIYONO and ENDŌ, 1935). It is supposed that the eruption may have occurred in the end of the Tertiary or the beginning of the Pleistocene.

In the Korean Peninsula, lavas which seem to be of Holocene age have not been reported. In Cheju-do, there are small conical volcanoes consisting of basaltic lavas rising in groups from place to place throughout the island. Judging from the geomorphological features, they are considered to represent Holocene volcanic activity. However, it is suspected that some of them may be volcano groups erupted in the Late Pleistocene or so, though there is no supporting geological clue.

The chemical composition of the basalts is shown in Table 20. Of these, no. 18 was previously known as tephrite, but the presence of nepheline has not been confirmed. The basalt was probably named on the basis of its chemical composition. From the chemical composition, no. 199 is also a noticeable rock type, and, in both basalts, the norm *ne* does not exceed 10 percent. As both have a low water content it cannot be considered that their large soda content is due to the presence of zeolites, and nepheline is probably present. The writer hopes to call investigators' attention to this problem in the future. Since the basalts contain olivine, the name tephrite is not appropriate. The writer would rather call them basanite. However, as described above, the presence of nepheline has not been confirmed, so, according to Lacroix's nomenclature, the writer provisionally calls them basanitoid.

The Daimanjisan lava (Table 21, no. 205) and the lava exposed at Misaki, Saigōmachi, both in Dōgo, the Oki Islands, are Holocene basalts. The southern extremity of the Daimanjisan lava reaches Tōgō, Tōgōmura, and faces Saigō Bay. In this locality, the lava overlies an Alluvial gravel bed, from which an ancient water-jar has been unearthed.18) It is said that, judging from the mode of occurrence at the time it was unearthed, the jar had been naturally buried. This discovery serves as an important clue in determining the age of the gravel bed and the age when the Daimanjisan lava was erupted.

Tradition says that Takuhiyama in Dōzen, the Oki Islands, as shown by the name (Takuhiyama means a burning mountain), was in eruption in remote antiquity. On the Japan Sea side such as the San'in and Kinki districts where there is no geologic evidence which supports the above tradition, there are volcanoes such as Takurayama in Yakuno, and Kannabeyama in Hyōgo Prefecture and Kasayama in Yamaguchi Prefecture (Table 21, no. 207). Of these, in Takurayama and Kannabeyama a crater-like topography remains even now, and in Kasayama the topography of a volcanic cone is still evident. A volcanic bomb consisting of basalt was collected from a volcano in Shimonoseki City, and abundant volcanic bombs are found on Ondake and other small volcanic cones on Fukueshima, the Gotō Islands.

Summarizing the above geologic data, there is a volcanic zone consisting of Holocene basalt on the coasts of the Japan Sea including the adjacent islands in southwestern Japan.19) It is noteworthy that in the so-called volcanic zone, very small scale volcanoes erupted sporadically here and there. This forms a remarkable contrast to the eruption of Pleistocene basalt which poured out a vast amount of lava and formed plateaus. The activity of basaltic magma in the Pleistocene is not an exception to the general law that is advocated by the writer. In the first stage,

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18) This jar was kept in the Shimane Prefecture Fisheries and Mercantile Marine School at the time the writer took part in the first investigation party (August 1925).

19) It was mentioned above that Pleistocene plateau basalt is also developed in this region. The basalt and that described in this paragraph must be treated separately from the volcanological point of view.

lava plateaus were formed by fissure eruptions, and in the final stage, the type of eruption changed to local central eruptions.

Taking a general view of the activity of olivine basaltic magma in the inner zone of southwestern Japan after the Miocene, it is very interesting to note that at first the region where volcanic activity played an active part extended as far as the Median Dislocation Line, but eventually the region was reduced to the littoral zone of the Japan Sea where basaltic magma was erupted in a linear arrangement. It is inferred that in the intermediate period, volcanoes had a field of activity associated with the retrogressive tendency. It is believed that this fact shows that the geologic conditions under the effect of which basaltic magma came into being in the lower part of the earth's crust migrated gradually toward the northwest, that is, toward Korea and Manchuria.

In harmony with the retrogressive tendency of the activity of olivine-basaltic magma, the eruption of the San'in type hornblende andesites was inclined to decay. That is, the eruption of the rocks (produced only a) which was relatively active in the Middle Pleistocene was reduced to a very small scale effusion of lava in the volcanoes of Daisen, Sambesan, Futagoyama, Tsurumidake, Yufudake, Kujūsan, Kimpōsan, and Unzendake. In the Holocene, only a very small quantity of lava was erupted from Furuyake (1657) and Shin'yake (1792) in Unzendake. On the other hand in Aso volcano, from which the so-called Aso lava flowed out, extensive activity was displayed in the central cone in the Holocene, and frequent and violent activities have continued up to the present in Kirishimayama, Sakurajima, and the volcanic islands southwest of Kyūshū belonging to the Ryūkyū volcanic zone.

Volcanic activity in the alkaline petrographic province, however, did not subside in prehistoric times. That is, the following volcanic eruptions were recorded in historic times: Cheju-do (1002 and 1007), Paektu-san (1597 and 1702), and Wu-ta-lien-ch'ih (1720). Of these, except in the last-named one, lava did not issue forth and only explosive activity seems to have occurred. In this respect, it is noteworthy that in the activity of historic times the activity has migrated from Cheju-do to the interior of the continent. The formation of leucite basalt in the interior of the continent in the last period seems to be related with the locality and mode of activity and not with the age. At any rate, it is an interesting theme for study.

3. Summary of Volcanic Geology

The writer sketched the outline of the volcanology of the Cenozoic alkaline petrographic province of Eastern Asia in the previous chapter. A detailed description of the general geology of each region is omitted as the limited scope of the present paper does not permit it. Besides the areas described above, there are other volcanic areas which are believed to belong to the present petrographic province. As the geology of these areas has not been studied in detail, the areas were not treated in the previous chapter.

Therefore, in this chapter, only relatively important volcanological matters of this petrographic province will be summarized. Readers should refer to Table 1 while reading this chapter.

(1) Paleogene volcanic activity

The volcanic activity in the Paleogene paleocontinent, with the Mongolian plateau as the center, was very violent from the end of Eocene to Oligocene. The lavas consisted mainly of olivine basalts, with some analcite basalt. This activity extended as far as Fushun, South Manchuria, though it was on a small scale. Then, in the end of Oligocene (probably to the earliest Miocene) a great activity of basalts took place in the Kilchu—Myŏngch'ŏn district, Hamgyŏng-pukto, North Korea. The scale of this activity was far less than the above-mentioned activity of the Mongolian plateau, but it rivaled the activity of the Hawaii Islands (since Pleistocene). The lavas were also olivine basalt and analcite basalt.

In this age, the Japanese Islands, except northern Kyūshū, the San'in district, part of the Kanto district, and the greater part of Hokkaido, were connected with the paleocontinent, but there is no record of volcanic activity like that which occurred in the interior of the continent.

The basalts of this age are doubtlessly basalts of the alkaline rock series, and are typical plateau basalt. The eruption was of the Hawaiian type. Lavas of the remarkable magmatic differentiation type were not erupted, but trachyandesite and trachyte have been reported from the Mongolian region.

(2) Volcanic activity of Earliest and Middle Miocene

In the earliest Miocene, there occurred the above-mentioned activity of basalts in the Kilchu—Myŏngch'ŏn district, and after that the continental region entered a period of calm erosion and deposition. That is, in the Kilchu—Myŏngch'ŏn district, the marine deposites such as the P'yŏngnyuktong beds, the Hamjindong beds, and Manhodong beds were formed.

In Japan, however, it was an age of a complicated mixture of deposition and considerable volcanic activity. The lavas included basalt, andesite, dacite and rhyolite, and the entire calc-alkaline lithologic series. More than one magmatic cycle was repeated. Little local difference is found in the eruption sequence of the layered lavas, as far as the inner zone of Southwestern Japan is concerned.

It is interesting that this calc-alkaline petrographic province of Japan extended to the Yongil district in this age. A similar situation prevailed at the end of the Mesozoic. This resulted in the well-known igneous activity of the Tsushima basin.

The magmatic activity of the Japan type in the inner zone of Southwestern Japan ended with the activity of this age. After that, that is, during and following Late Miocene, the inner zone of southwestern Japan sometimes became a field of activity of the calc-alkaline rock series and sometimes a petrographic province of mixed rocks. It is interesting that, in this respect, the inner zone of southwestern Japan forms a distinct contrast with the Japan Sea side of northeastern Japan.20)

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20) Concerning the igneous activity of the Japan Sea side of North-eastern Japan, the following paper was published after the completion of this paper: Tanai, T., and Shimbori, T., 1951, On

Another interesting fact which should not be ignored is the sporadic distribution of the small intrusions of so-called plutonic rocks such as gabbro and granites in the San'in district in the final period. The formation of small plutonic rock bodies in this period seems to have been a countrywide phenomenon in Japan and arouses our special interest.

(3) Activity of alkaline volcanic rocks from Late Miocene to the Latest Pliocene

The volcanic activity of this age, strictly speaking, is divided into the activity of the Late Miocene and that of the Pliocene. It is during the volcanic activity in Pliocene that remarkable rock types of alkaline trachyte and alkaline acidic rock were produced throughout this petrographic province.

The activity of the Late Miocene commenced with the effusion of areal basalt (B_1). This was the activity of the olivine-basaltic magma, and the area includes the following districts: Wei-ch'ang in Je-ho, Kilchu—Myŏngch'ŏn, Dōgo in the Oki Islands, the vicinity of Matsue, northern Kyūshū, and Shōdoshima in the Inland Sea. Of these, none of the exposures are very large except Wei-ch'ang. Of course, much of this is a result of erosion. According to the writer's petrographical study, this olivine-basaltic magma is inferred to be the parental magma of the neutral rocks which were erupted later. Not only neutral and acidic alkaline volcanic rocks but also basalts which were erupted several times are included. This is certainly one of the parental original magmas.

With this activity of olivine-basaltic magma, the calm age in the Kilchu—Myŏngch'ŏn district down to that time was ended. On the other hand, in the inner zone of southwestern Japan, the calc-alkaline petrographic province changed into the alkaline petrographic province. This phenomenon is, in the case of certain regions, called "petrographic revolution" by the writer.

Volcanic activity in the Late Miocene, however, cannot be said to have been very prominent. In the Kilchu—Myŏngch'ŏn district, after the formation of the so-called great Kilchu—Myŏngch'ŏn fault, an age of peneplanation continued. In Dōgo, trachyandesite and trachyte (potash trachyte) were erupted. In the Inland Sea zone, the first formation of sanukitic andesites occurred. In other districts, namely, in the districts where volcanic activity did not occur, peneplanation or sedimentation progressed.

In the Early Pliocene, basaltic activity extended to a wide region. The basalt (B_2) of this age was mainly plagioclase basalt having the phenocrysts not only of olivine but also of pyroxene and plagioclase. There occurred also limburgite and nepheline basalt. The above basalts were distributed throughout the whole region of the Cenozoic alkaline petrographic province of Eastern Asia, but it was in the Kilchu—Myŏngch'ŏn and P'aektu-san areas that great quantities of basalt were effused. In southwestern Japan, sanukitic andesite was produced.

The most magnificent display of magmatic activity in this period was the eruption of neutral or acidic alkaline volcanic rocks. The areas famous for this magmatic

the Tertiary igneous activity in the Japan Sea side of Northeastern Japan: *Science of the Earth,* no. 5, p. 15–22.

activity are P'aektu-san, Kilchu—Myŏngch'ŏn, Dōgo, Cheju-do, and Matsushima in Kumamoto Prefecture. There are some types belonging to pantellerite and comendite. In Dōgo, grorudite, paisanite, and tinguaite are associated species. It is noteworthy that these rocks which are rarely found elsewhere in the world occur in the region adjacent to the petrographic province of Japan. It must not be overlooked, however, that the alkaline petrographic province, in those days at least, reached the Inland Sea zone in the south.

(4) Pleistocene volcanic activity

The Pleistocene activity is divided into two periods. The eruption of basalt was repeated twice (B_3 and B_4) and formed plateaus. In places quartz-basalts occur and tholeiitic basalt is also mixed in.

In Paektu-san, the Kilchu—Myŏngch'ŏn district, and Ullŭng-do, a small activity of alkaline trachyte accompanied the basalt. On the other hand, in the inner zone of southwestern Japan, hornblende andesites are associated with this activity. In addition, it is noticeable that the hornblende andesites are from an olivine-basaltic magma contaminated by granite or an acidic rock like dacite. The hornblende trachyandesite in Cheju-do is an effusive rock of the same period, but its genesis must be thoroughly considered. In respect to the distribution of the volcanic zone, the writer entertains a doubt that the Dai-sen—Sambe volcanic zone continues to Cheju-do.21)

(5) Holocene volcanic activity

Volcanic activity in this age is known in the San'in district, northern Kyūshū, and Cheju-do. The activity in Manchuria is divided into two types: the activity which is associated with leucite basalt such as Wu-ta-lien-ch'ih volcano, Erh-k'o Shan, and Ch'i-hsing Shan, and that which is not associated with it (Lung-wan volcano is an example). Some geologists consider that the leucite basalt originated due to selective assimilation of granite, but it appears to be a problem for more deliberate study. In the Japanese Islands, it is interesting that small conical volcanoes of Dōgo, Kasayama in Yamaguchi Prefecture, Shimonoseki, Ondake on Fukueshima of the Gotō Islands, etc., are arranged approximately in a straight line. Irrespective of the geologic significance of the plateau, basalt in the Pleistocene was reduced to local activity of a central eruption on a very small scale in the Holocene, and the active region retreated to the zone close to the Japan Sea coast.22)

The volcanic activity in Japan in this age is well known, so its description is omitted in this paper. However, as far as southwestern Japan is concerned, the lavas of Aso, Kirishima, and Sakurajima volcanoes are trachyandesitic, and at

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21) The writer holds a view that, even in the same volcanic zone, according to the geologic environments in the center activity, more or less different types of rock are produced. The writer considers that a volcanic zone is related not to the kind of rocks but to the geologic structure. Therefore, though sometimes there may be a case in which a continuous volcanic zone is represented by similar rocks, it is inconceivable that a volcano belongs to the same volcanic zone only by reason of the occurrence of similar rocks.

22) Note that the activity of olivine-basaltic magma extended to the Inland Sea zone in Late Miocene.

least differ from the pyroxene andesite in Hakone, Izu, and Ōshima, though these rocks have been called pyroxene andesites. In this respect, careful study is needed.

In the petrographic province in question, there have been volcanic activities in historic times. The recorded activities were those of Cheju-do (1002, 1007), Paektu-san (1597, 1702), and Wu-ta-lien-ch'ih Volcanos (1720). Of these, only Wu-ta-lien-ch'ih volcano emitted lava. Though the records on the activities are few, it is of keen interest that the activity in the above region had a tendency to gradually migrate toward the northwest.

(6) Migration of the activity of basaltic magma

There were at least six basaltic magma activities, large and small, in the Cenozoic alkaline petrographic province of Eastern Asia. Of these, the activities in the Paleogene or earliest Miocene are called B_0 and those after Late Miocene B_1 to B_5. B_1 to B_5 are closely related to the formation of neutral or acidic alkaline rocks and feldspathoid volcanic rocks, and they are also closely related to the volcanology of Japan. Therefore, the writer feels a keen interest in this fact.

Of these five activities, B_1 (Late Miocene) and B_2 (Early Pliocene) extended to the Inland Sea zone, but in the Pleistocene, though the activities are considered fissure eruptions forming lava plateaus, B_3 and B_4 were limited to the coastal regions from the San'in district to northern Kyūshū. The Holocene basalt (B_5) formed only small conical volcanoes built up by local eruptions such as Dōgo, Kasayama, Shimonoseki, Ondake in the Gogō Islands, etc.

What is the cause of migration of basaltic magma activity with age? To answer this will be a theme for future study. However, the following fact is one which should be considered in connection with this problem. The sanukitic andesites in the Inland Sea zone and its western extension and the San'in type hornblende andesites occur in the region considered the marginal zone of the continental basaltic magma region. In the writer's opinion, these rocks were produced from a migma of olivine-basaltic magma and the pre-existing rocks, and belong to the same genetic system as quartz basalt and tholeiitic basalt which occur also in the marginal zone.

According to this view, the cause of the migration of the activity of basaltic magma with time is considered to mean the migration of subsurface geologic conditions which produce and erupt basaltic magma. To explain this in greater detail, this means that the environments from which olivine-basaltic magma can be erupted as original magma gradually became nonexistent in the inner zone of southwestern Japan, and the above environments were replaced by the geologic environments which gave rise to secondary magma-like migma.

Pursuing this more closely, this seems to mean that the relatively stable tension region in southwestern Japan gradually evolved into a region of compression having the nature of a changeable zone. This is thought to be the result of a movement in the ocean floor which has underthrust the Japanese Islands from the Pacific side and has had an increasing effect since the Pleistocene or so.[23)]

[23)] This movement was inferred from the distribution of the epicenters of deep-focus earthquakes

(7) Geologic characteristics of the Cenozoic alkaline petrographic province of Eastern Asia

Geologic conditions in specific regions where alkaline rocks are produced has been a problem since HARKER's advocacy (1909) of the regional tension theory.

After HARKER, some scientists, entertained the idea that alkaline rocks occur in a tensional region, and, on the other hand, that calcalkaline rocks occur in a compressional region. They also considered that the occurrence of alkaline rocks in a region of special geotectonics is closely related to their genesis. Those who published their opinions on the petrogenesis of alkaline rocks are BECKE (1903), JENSEN (1908), SMYTHE (1913), STARK (1914), WINKLER (1914), EVANS (1915) and NIGGLI (1925). DALY (1918), on the contrary, published an opinion that alkaline rocks are developed in zones which were subjected to intense lateral pressure, while most calcalkaline rocks are found in a region where radial fissure lines are developed.

In opposition to these opinions, there are scientists who consider that there is no relation between the kind of rocks and geotectonics. SHAND (1938) is one of them. According to him, it is too radical an opinion to consider that alkaline rocks are related to special geotectonic structure, and volcanic activity, without exception, is related to faults.

No advance has been made concerning this problem since NIGGLI. In relatively recent times BOWEN (1938) published the following opinion on the relation between the alkaline volcanic rocks in the African Rift Valleys and the tectonic movements: it cannot be determined whether the zone of African Rift Valleys is a tension region like the former view or a compression region like the later view, since geologic evidence favors both views. We cannot be so bold as to connect such an uncertain fact with the chemical property of lavas.

After having examined the basis of the above views, the writer reached the following conclusion. That is, (1) the rocks should be treated by discriminating between volcanic rocks and plutonic rocks rather than by simply alkaline rocks and calcalkaline rocks. A result of such a treatment would be that it would not give rise to diverse opinions. (2) There is a slight confusion between the conception of a tension region or a compression region as an areal phenomenon and a region where normal faults or thrusts are developed as a local phenomenon. Consequently discussions must be made as to the above-mentioned opinions on the basis of the writer's judgement. In this paper, however, the discussions are omitted; instead, the Cenozoic alkaline petrographic province of Eastern Asia will be discussed.

The facts which can be surely pointed out as geologic characteristics of this petrographic province are as follows:

(a) From the viewpoint of the character of each rock series to which each rock belongs, Cenozoic basalt in the Eastern Asiatic continent belongs to the alkaline rock series almost without exception. Therefore, the Cenozoic alkaline petrographic

and discrimination of 'push' and 'pull' of the initial motion of earthquakes. The chains of active volcanoes in Japan are unquestionably related to this movement.

province of Eastern Asia includes an extensive region ranging from the eastern part of Siberia in the north to the coastal zone of the South China Sea in the south. However, the region where rocks having the characteristics of the alkaline rock series (TOMITA, 1933A) occur is limited to a relatively small region including the circum-Japan Sea alkaline petrographic province and Manchuria.

It has been an object of discussion whether the characteristics of geologic structure of such regions are related to the formation of alkaline rocks. Consequently, in this paper, discussion will be attempted with respect to the above region alone.

(b) In the Kilchu—Myŏngch'ŏn district and Dōgo, there was an age of marine deposition which ended in the Middle Miocene prior to the eruption of alkaline rocks. In the Kilchu—Myŏngch'ŏn district, the age of the marine deposition was followed by a period of upheaval and faulting. This period was followed by peneplanation. On the other hand, on Dōgo there is no evidence of peneplanation. Moreover, from Early to Middle Miocene, Dōgo was a field of volcanic activity in the calcalkaline petrographic province of the Japan Sea side type.

Judging from the results obtained by putting these facts together, the geologic hysteresis previous to the eruption of alkaline rocks is considered to be unrelated to the formation of alkaline rocks. Rather than the problem of this relationship, the problem arises as to under what geologic conditions olivine-basaltic magma—the parental magma of alkaline rocks—can intrude into the shallow part of the earth's crust without having its original condition changed.

(c) An example of deposition occurring to some extent in the course of the activity of alkaline rocks has been reported from the Kilchu—Myŏngch'ŏn district and Dōgo. The deposition, however, was not of the geosyncline type but rather of the inland type, and the deposition was not accompanied by folding movements. In this respect, it is remarkably different from the facts known for the Japan Sea side of northeastern Japan and, hence, must be regarded as of great importance.

However, this does not answer the question of the relation between these facts and the formation of alkaline rocks (alkaline trachyte, pantellerite, comendite, etc.) from the olivine-basaltic magma.

The possibility of the following facts alone is considered to be worthy of note: in the region which lacks deposition of the geosyncline type and folding movements associated with the deposition, that is, in the relatively stable region, olivine-basaltic magma which is the parental magma can work differentiation without suffering external effects (physical and chemical). However, in the disturbed region, the parental magma itself is possibly a secondary magma and the parental magma is liable to suffer external effects in the course of differentiation. As a matter of course, the following case may be included in this idea: according to the condition of the earth's crust, it may be possible that a rock type resembling calc-alkaline rock is produced by external effects in the course of differentiation of the alkaline rock series.

Such a problem is not related to this petrographic province alone, but is also generally related to petrogenesis of igneous rocks, hence it may be premature to come to any conclusion. The problem should instead be studied carefully from all sides.

Supplement

There are alkaline rock localities which were omitted from the correlation table (Table 1) and from the above descriptions because the time of eruption is not known, and for other reasons. These localities are described here for reference.

Otsurumizu in Kōzaki, Ōita Prefecture: This place has been famous for the occurrence of alkaline trachyandesite and a monchiquitic rock for a long time (Kozu, 1914). It is said that the mode of occurrence of these rocks seems to be dikes traversing the so-called Sambagawa system (consisting of chlorite schist, graphite schist and slate). From the facts that alkaline trachyandesite constitutes the main body and that the monchiquitic rock is glassy, these rocks have been inferred to be the marginal facies of the dikes. The chemical composition of these rock types is shown in Table 22 (nos. a and b).

It is not known whether these alkaline rocks from Otsurumizu belong to the Cenozoic alkaline petrographic province of Eastern Asia or are from the Inland Sea volcanic zone.

Hyŏnam, Kuk-tong, Tong-myŏn, Myŏngch'ŏn County, Hamgyŏng-pukto, Korea: With respect to the igneous body traversing the Heiroku-dō (P'yŏngnyuk-tong) beds and Kanchindo (Hamjin-dong) beds in the area, the composite intrusive sheet in Hyŏnam (about 4 km north of Myŏngch'ŏn) is a rare and interesting rock body in the Cenozoic alkaline petrographic province of Eastern Asia.

This rock body was first introduced by Tateiwa (1925) and Itō (1937) later described the details. This rock body intruded into the monoclinal Tertiary formation and is exposed for about 10 km along the river cliff. The distribution of the exposed part on a geologic map is incompletely ring-shaped. The thickness of the rock body exceeds 100 m but it thins abruptly on both ends. One end is cut by a fault and the other end splits into several dikes which pinch out. This rock body mainly consists of syenitic dolerite (Table 22, c and d), but in the vicinity of Hyŏnam, syenite which intruded later (Table 22, f) is found intercalated in the dolerite, and a contaminated rock type was produced in the boundary between both types. Moreover, syenitic aplite (Table 22, g) which intruded later, forms reticulated veins in the dolerite or syenite.

In the Hyŏnam area, several trachytic dolerite dikes, which intruded later than the above rock body, are developed. The dikes described by A. Lacroix (Table 22, e) seem to be those of this kind, and the lithologic character closely resembles that of Pleistocene basalt. It is believed that the rock constituting the Hyŏnam intruded sheet is Tertiary (Pliocene) in age.[24]

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[24] This idea resulted from the writer's study of the evolution types of magma. Its detailed description is omitted in this paper.

Hoeryŏng and Chongsŏng districts, Hamgyŏng-pukto, Korea: In the Hoeryŏng area (ICHIMURA, 1924) and the Chongsŏng district (KŌZU and SETO, 1922) also, as in the above-mentioned Hyŏnam area, trachydolerite and alkaline syenite occur together. Results of chemical analyses of these types are shown in Table 23.

The noticeable type in this Hoeryŏng—Chongsŏng district is sodalite microsyenite. It has been known that a type containing sodalite is also found in trachydolerite (Table 23, k).

The feldspathoid group which occurs in the Cenozoic alkaline petrographic province of Eastern Asia is leucite, nepheline, and melilite, and the occurrence of sodalite minerals has not been reported from other regions.[25] The rocks in the district mentioned here distinctly traverse the Miocene series, and the age when the rocks intruded is considered Pliocene. Therefore, the rocks are members of this petrographic province.

Hence, it can be understood that a detailed petrogenetic study on various types in this district is both highly important and desirable.

P'i-tzu-wo and Ta-sha-ho in Kuan-tung Province and the vicinity of Ta-shih-ch'iao in Feng-t'ien Province, South Manchuria: From these places barkevikitic monchiquite has been reported (OGURA, 1933). The rock in Kuan-tung Province forms dikes traversing gneiss (pre-Sinian); the mode of occurrence of the rock in Kuo-ti Shan in Ta-shih-ch'iao is not known. The chemical composition of barkevikitic monchiquite from P'i-tzu-wo is shown in Table 24 (p).

There are no field data concerning the age determination necessary to confirm that these monchiquites belong to the petrographic province in question. However, according to Ogura's inference, the monchiquite in Kuo-ti Shan, Ta-shih-ch'iao, seems to traverse the quartz porphyry. If this quartz porphyry is of the same age as the Cretaceous monchiquite distributed in Jehol and North China, the monchiquite can be said to be a Cretaceous or post-Cretaceous intrusive rock.

On the other hand, the monchiquite from P'i-tzu-wo belongs from every chemical stand point to the same series as limburgite from Eastern Asia. That is, it is considered that the monchiquite in question and the limburgites belong to the same system of magmatic evolution; the former is a representative of dikes and the latter is a representative of effusive rocks.[26]

According to this view, it is inferred that the geologic age of monchiquite in question is the same as that of limburgites, that is, the Early Pliocene. Of the basalts in this area of the same age, the Pliocene basalts in the Shan-tung Peninsula are distributed from the northern end of the peninsula to Miao-tao and other islands and extend as far as Kuan-tung Province to the north through the neighboring

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[25] The sodalite nepheline syenite in Poksin-san, P'yŏnggang County, Kangwŏn-do, Korea, is a famous example, but the geologic age seems to be the beginning of Mesozoic. (The result of age determination of allanite by means of the lead method is about 200 million years or less—personal communication from N. KOKUBU. Chemical Institute, Fac. Sci., Kyūshū Univ.) In this respect the above syenite does not belong to the Cenozoic alkaline petrographic province of Eastern Asia.

[26] A rock resembling monchiquite from Otsurumizu, Ōita, and alkaline trachyandesite both belong to a quite different series from limburgite.

islands. Hence, it is believed that in Kuan-tung Province also there was activity of basaltic magma in the same age as the Shan-tung Peninsula. Therefore, the above inference is considered reasonable.

Taiwan: Teschenite which occurs in Lu-k'u (the summit of the pass between K'ang-chieh-k'ang, Hsi-chih-chieh, Ch'i-hsing County, and Lu-k'u, Shih ting-chung, Wen-shan County) in the vicinity of T'ai-pei is a Miocene intruded sheet (ICHIMURA, 1929 and 1932) (Table 24, q, r, s).

According to YEN (1945) Miocene olivine basalt and basanite occur in the vicinity of Ma-wu-tu, Hsin-chu Province.

These basalts and the teschenite belong to the alkaline rock series, and it is beyond doubt that the rocks are constituents of the Cenozoic alkaline petrographic province of Eastern Asia as the age is Miocene or post-Miocene. The rocks, however, cannot be exactly correlated with the circum-Japan Sea alkaline petrographic province.

P'enghutao basalt also belongs to the Cenozoic alkaline petrographic province of Eastern Asia (KOTŌ, 1900).

Central China and South China: There are Pleistocene basaltic areas in An-hui and Chiang-su Provinces in the lower stream region of the Yang-tzu Chiang.[27) Of these, Nu Shan situated about 70 km east of Pang-fu, An-hui Province, has been known as a basaltic volcano. Moreover, in the Nan-ching—P'u-k'ou area, many Pleistocene basaltic tablelands (buttes) are distributed (the Fang Shan butte situated south of Nan-ching is most striking). These basalts, to our regret, have not been described in detail.

Concerning the distribution of the basalt, one opinion is that the basalt is a southeastern extension of the row of volcanoes extending from the Ta-t'ung Volcano group to the Mongolian plateau in the north-northwest. It is considered reasonable, however, to regard the area in question as the western extension of the San'in—Cheju-do volcanic zone. That is, it is considered that the zone of Pleistocene basaltic magma activity previous to the formation of the two seas—Huang-hai and Tung-hai—extended through the San'in district and Cheju-do to the lower reaches of the Yang-tzu Chiang.

On the other hand, there is a great lava plateau in the area extending from the Lei-chou Peninsula to the northern part of Hai-nan Tao—a representative in South China of the basalt distributed in the margin of the continent of Eastern Asia. Wei-chou Tao (Lat. 21° N, Long. 109°L) in Tung-ching Bay, an almost circular island 4 to 5 km in diameter, is a shield-like volcano, and there is an explosion crater (1 km in diameter) in the southern part (YAGI, 1949). The volcano consists of trachybasalt. The phenocrysts are olivine, but titanaugite, aegirine augite, and aegirine are found in the groundmass, and not only labrador-feldspar but also anorthoclase is found in the groundmass feldspar. The chemical

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27) The area about 100 km in diameter surrounded by Lake Hung-tse, Lake Kao-yu, Chin-p'u Railway, and the Yangtse River.

composition of the trachybasalt is shown in Table 24 (t). That is, this is an olivine trachybasalt distinctly belonging to the alkaline rock series.

Shan-hsi Province: In Shan-hsi Province, post-Triassic alkaline intrusive rocks occur in places. (It is said that the Triassic-Jurassic complex is traversed by intrusive rocks). The principal rock types are syenites such as åkerite and nordmarkite, but in Tzu-chin Shan, Lin-hsien, nepheline syenite, tinguaite, leucite syenite-porphyry, etc., are associated with the above rocks and in the area east of Lin-fen analcite syenite has been known.

The age of intrusion of these rocks is not exactly known. When NYSTROM (1927) published a synthesis of the alkaline rocks in Shan-hsi Province, he suggested that their age was not the same as the circum-Japan Sea alkaline petrographic province.[28] However, the writer cannot support his opinion for the following two reasons: (a) in Shan-hsi Province, there is no evidence of crustal movement by which igneous activity is considered to have been caused in the Tertiary, particularly in the Pliocene; (b) the Cretaceous crustal movements were remarkable throughout North China and the associated igneous activity was also active. In addition, in association with igneous activity, the intrusion of monzonite and åkerite occurred in the eastern margin of the Shan-hsi plateau (the area southwest of Hsing-t'ai, Ho-pei Province, and in the vicinity of Wu-an, Ho-nan Province). Thus, in the writer's opinion, the age of the alkaline intrusive rocks in question in Shan-hsi Province is Cretaceous and the activity belongs to the igneous activity associated with the well-known Yenshan movements. Therefore, these rocks are considered to have no relation with the Cenozoic alkaline petrographic province of Eastern Asia.

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[28] At that time (1927) this petrographic province had been known through the following paper: YAMANARI, F., 1924, Soda-pyroxene in the Tertiary and post-Tertiary alkaline rocks from the environs of the Sea of Japan: *Jap. Jour. Geol. Geog.*, v. 3, nos. 3–4.

Table 2. Chemical Composition of Mongolian Basalts.

No.	1	2	3	4	No. / Norms	1	2	3	4
SiO_2	42.40	42.56	46.24	47.64	*or*	13.90	10.01	10.01	7.78
Al_2O_3	14.50	14.55	16.19	15.17	*ab*	8.12	14.54	23.06	27.77
Fe_2O_3	3.58	4.70	4.46	8.57	*an*	10.84	15.29	24.19	22.80
FeO	8.57	8.57	6.66	2.85	*ne*	17.75	11.71	2.84	—
MgO	6.17	7.54	7.27	7.63	*hl*	0.12	—	—	—
CaO	9.42	8.72	9.08	10.08	*wo*	11.49	8.93	7.31	8.70
Na_2O	4.90	4.31	3.36	3.28	*en*	6.80	5.70	5.20	11.50
K_2O	2.36	1.72	1.66	1.34	*fs*	4.09	2.64	1.45	—
TiO_2	2.13	2.28	2.02	2.02	*fo*	6.02	9.17	9.10	5.32
P_2O_5	1.31	1.03	0.51	0.65	*fa*	4.18	4.59	3.06	—
MnO	0.24	0.25	0.12	0.18	*mt*	5.34	6.73	6.50	4.18
H_2O+	3.70	2.97	1.37	0.38	*hm*	—	—	—	5.76
H_2O-	0.84	0.93	0.82	0.34	*il*	4.10	4.41	3.80	3.80
CO_2	n.d.	n.d.	n.d.	0.27	*ap*	3.02	2.35	1.34	1.68
Cl	0.07	n.d.	n.d.	n.d.					
Total	100.19	100.13	99.76	100.46	*or*	42	25	17	13
					ab	25	37	41	48
Analyst	Raoult	Raoult	Raoult	Raoult	*an*	33	38	42	39
					Q	14	10	10	21
					fo	51	60	68	79
					fa	35	30	22	0

1. Basanitoid; north entrance of Shen-wei-t'ai, Wan-ch'uan Hsien, Cha-ha-erh Province.
2. Basanitoid; Shan-p'o-pao, Wan-ch'uan Hsien, Cha-ha-erh Province.
3. Labradorite basalt, doleritic; near Han-no-pa pass, Wan-ch'uan Hsien, Cha-ha-erh Province.
4. Porphyritic andesine basalt; same locality as 3.

Table 1. Correlation of Cenozoic Alkaline Petrographic Provinces of Eastern Asia (Tomita, June 1951).

District Age		Manchuria, Mongolia, western part of N. China (Tomita)	Shan-tung (Tomita)	Pai-t'ou Shan (Asano) Lung-wan volcano	Turyu-san (Kinosaki)	Kilchu, Myŏngch'ŏn (Yamanari, Tateiwa, Makiyama, Tomita)	Ullŭng-do (Tsuboi)	Cheju-do (Haraguchi)	Yŏnil (Tateiwa, Kobayashi)	Dōgo (Tomita)	Matsue (Tomita, Sakai)	Southwestern part of San'in (Tomita)	Northern Kyūshū (Tomita)	Setouchi district (Yamanari, Takai)	District Age	
Alluvium	ua	1720 activity Wu-ta-lien-chih volcano, Erh-k'o Shan, and others	Late Alluvium	1702, 1597 activities	Younger fluviatile deposit	Younger fluviatile deposit		1007, 1002 activities Groups of small basalt cones		Late Alluvium Misaki basalt (B_5)	Alluvium	Late Alluvium Kasayama QB (B_5)	Onidake Activities of Unzen, Kujū, and Tsurumi Aso central cone		ua	Alluvium
	la	Loessic sand	Redeposited loess, brown soil	(Lung-wan volcano)	Older fluviatile deposit	Older fluviatile deposit				Tōgō gravel	Nogi formation				la	
Pleistocene	ud	Loessic loam Ta-t'ung volcanic group	Loessic loam Brown loam Loess and brownish gray loam Brown sandy clay	Alkaline trachytic mud flow x	x	Alkaline trachyte (AT_4) Kuk-tong, Ŭngdŏk basalt (B_4)	Lapilli, pumice, leucite trachy-andesite x	x		x	x San'in-type hornblende andesites	San'in-type hornblende andesites	Aso lava San'in-type hornblende andesites Nagasa basalt 3		ud	Pleistocene
	md	Loess		Alkaline trachytic pumice x		Sangho-dong alkaline trachyte (AT_3) Kŭmsan formation	Alkaline trachytes x	Hornblende trachyandesites x			x		Hornblende andesite Obama formation		md	
	ld	Chou-k'ou-tien formation	Light red loam	Yen-chih basalt	Sindong-ni basalt	Ŏrang-ch'ŏn, Changdŏk basalt (B_3)	Trachybasalt	Basaltic agglomerate	2PA Yŏnil basalt	Ōminesan basalt (B_3)	Daikonjima QB	Kitanagato basalt	2PA Kitanagato basalt 2		ld	
	dp	San-men conglomerate	Basal conglomerate	x	Sindong-ni gravel	Namdae-ch'ŏn formation		Sŏgwip'o formation		x		Ōmijima gravel	Ōe formation	Setouchi series	dp	
Pliocene	up	T'aiyu formation: San-men formation Ching-lo formation Upper Yu-she series		Comenditic rocks	x Turyu-san tuff Moto-ri quartz porphyry	x Chungbong, Chuehbong comendite Saam formation			x	Phonolitic trachyte porphyry, grorudite, paisanite, comendites, Washigamine formation x		Hamada group			up	Pliocene
	mp	Lower Yu-she series	x	Pai-t'ou Shan alkaline trachyte	x Turyu-san alkaline trachyte	Ch'ilbosan AGP Puhyang alkaline rhyolite Alkaline trachyte (AT_2)		Halla-san alkaline trachytes		Alkaline trachyte (AT_2) Dakeyama formation Platy alkaline rhyolite Nakajima formation	x	x	Matsushima alkaline trachyte		mp	
	lp	x Hsueh-hua-shan trachybasalt Hsueh-hua-shan, Pao-te formations	Lu-hsi, Lin-ch'u, and Ch'i-hsia basaltic rocks Red clay	x Lao-hei-ting-tzu basalt	x Sŏkp'o basalt	Ŭngbong alkaline rhyolite Naesan-dong formation Alkaline trachyte (AT_1) Namyang-dong formation Chaedŏk-san basalt (B_2)				x	Trachybasalt (B_2) x	Nagahama, Daifunzan basalts	Sanukitic basalt 2 Nagasa basalt 1	Sanukitic basalt 2 Olivine-pyroxene basalt 2 Ikeda formation (upper)	lp	
Miocene	um	x Wei-ch'ang basalt and shale	x			x Manho-dong formation (upper) Manho-dong basalt (B_1)	x		Yŏnil series x	Alkaline trachyte (AT_1) Hotokedani formation x Trachybasalt (B_1)	Matsue formation Hornblende trachybasalt Tsuda formation Trachybasalt (B_1)		Kaho City, Muroyama B	Sanukitic andesite 1 (orthorhombic pyroxene basalt) Olivine-pyroxene basalt 1 Ikeda formation (lower) Shōdo-shima, Kamiura B	um	Miocene
	mm		Shan-wang series			Manho-dong formation (lower) Hamjin-dong formation		x	P'omgong-ni volcanic rocks x	Dōgo formation 2PA (3) Nakayama formation	Fujina formation Kimachi formation	Tamasaki granite porphyry Hornblende andesite 2PA Takayama Gb Karakane formation		Sakate formation Hornblende andesite Mica andesite x	mm	
	lm	x	x	x	Winam-dong formation P'yŏngnyuk-tong conglomerate	P'yŏngnyuk-tong formation			P'omgong-ni group: 2PA Rhyolite Conglomerate	x Ochi group: 2PA (2) Rhyolite Basal conglomerate	x 2PA Ōmori formation	x 2PA Rhyolite x	2PA Yoroigadake lava	Tsuyama series x Ishizuchiyama acidic lava x	lm	
	lmm		Wen-ho gravel and Ch'i-hsia gravel		x Yong-dong basalt	x Yong-dong basalt (BO)			Changgi group: Ŏil basalt and Ŏil formation Nultae-ri volcanic rocks Kamp'o conglomerate	Shimonaku basalt (BO) Rhyolite Andesite (1) Suki formation	Shinji series: Higashiyama basalt Tamatsukuri formation (upper) Andesite Tamatsukuri formation (lower) Koura formation	Takayama metamorphic basalt Aburataniwan group x		Ishizuchiyama series x	lmm	
Oligocene		Meng-ku, Fan-chih, Fu-shun basalts and shale	x		Yong-dong formation	Yong-dong formation						Ashiya group	Sasebo group Pre-Sasebo Paleogene formation			Oligocene
Eocene		x Yuan-ch'u series P'ing-lu series Ch'ang-hsin-tien gravel	Kuan-chuang series		x	x			x	x	x	x		Ube coal-bearing formation x		Eocene
Note				"T'ien-ch'ih" at the top of the mountain seems to have been formed in Pleistocene; it must not be considered contemporaneous with eruption of alkaline trachyte and comenditic rocks.			No reliable data to determine exact geological age. Correlations were made on the basis of lithology and genetic nature of igneous rocks.	At the top of Halla-san is found a crater lake called Paengnok-tam. This crater lake was formed much later than the eruption of the Halla-san alkaline trachytic rocks.	2PA is two-pyroxene andesite.		QB is quartz basalt.	Only the correlatable data were used. Gb is gabbro.	Same as described on the left. "Nagasa" is an abbreviation of Nagasaki-Saga. DC is dacite, and B is basalt.	Little is known on the geology from Late Pliocene to Pleistocene.		

Table 3. Chemical Composition of Yong-dong Alkaline Basalts.

No.	5	6	7	8	9	10
SiO_2	43.48	43.52	44.32	44.90	47.82	49.52
Al_2O_3	16.78	9.83	12.51	18.57	18.85	16.42
Fe_2O_3	2.71	2.48	3.68	7.89	4.96	3.53
FeO	6.20	6.96	5.27	4.20	6.06	5.56
MgO	10.66	14.09	13.98	5.11	4.85	6.52
CaO	10.24	13.36	10.82	8.22	8.52	7.76
Na_2O	3.21	3.22	3.15	3.02	2.52	2.94
K_2O	0.69	0.87	0.80	3.33	2.43	2.35
TiO_2	1.04	1.01	1.18	1.03	1.47	1.32
P_2O_5	1.05	2.63	0.57	0.49	trace	1.09
MnO	0.17	0.17	0.20	0.79	0.14	0.15
H_2O+	2.79	2.23	2.71	1.62	1.60	1.74
H_2O-	0.54	0.31	1.04	0.52	0.95	1.09
Cl	n.d.	n.d.	0.10	n.d.	n.d.	n.d.
SO_3	n.d.	n.d.	0.03	n.d.	0.28	n.d.
Total	99.56	100.68	100.36	99.69	100.45	99.99
Anal.	Teshima	Teshima	Raoult	Ushijima	Geol. Survey, Chōsen	Teshima
Norms						
or	3.89	5.00	5.00	19.46	14.46	13.90
ab	16.77	9.17	11.53	13.10	20.96	24.63
an	29.47	9.73	17.51	27.52	33.08	21.96
ne	5.68	9.80	8.24	6.53	—	—
wo	5.80	16.70	13.57	3.94	3.83	3.83
en	4.10	12.00	10.60	3.30	7.90	16.00
fs	1.19	3.17	1.45	0.13	3.17	5.28
fo	13.11	16.24	17.08	10.15	2.94	0.21
fa	5.00	4.69	2.75	0.61	1.22	0.10
mt	3.94	3.71	5.34	11.37	7.19	5.10
il	1.98	1.98	2.28	1.98	2.74	2.43
ap	2.69	6.05	1.34	1.34	—	2.69
or	8	21	15	32	21	23
ab	33	38	34	22	31	41
an	59	41	51	46	48	36
Q	6	12	11	7	20	28
fo	71	68	77	88	56	53
fa	23	20	12	5	24	19

5 & 6. Olivine-analcite basalt; Yong-dong, Sŏ-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto, Korea (Tomita, T., 1928, *Shanghai Sci. Inst. Jour.*, sect. 2, v. 7, p. 58).

7. Olivine-analcite basalt; (Lacroix, A., 1928, *Geol. Soc. China Bull.*, v. 7, p. 58)

8. Olivine dolerite; Sindong-ch'ŏn, Changbaeng-myŏn, Kilchu-gun, Hamgyŏng-pukto, Korea (Tateiwa, I., 1925, *Geol. Atlas of Chōsen*, no. 4, p. 2).

9. Olivine dolerite; Yongdong-ch'ŏn (near Sindong-ch'ŏn), Changbaeng-myŏn, Kilchu-gun, Hamgyŏng-pukto, Korea.

10. Labradorite-olivine dolerite; Yong-dong (Tomita, T., 1931, *Shanghai, Sci. Inst. Jour.*, sect. 2, v. 1, p. 246).

Table 4. Chemical Composition of B_1.

No.	11	12	13	14	15	16	17	18	19
SiO_2	45.42	47.88	48.16	44.06	47.76	48.40	49.02	50.69	55.25
Al_2O_3	13.10	15.09	14.74	15.17	17.14	16.74	16.38	15.55	13.98
Fe_2O_3	4.51	3.59	2.75	3.64	2.64	0.52	3.28	3.90	1.06
FeO	7.66	8.59	7.45	10.98	6.05	8.87	6.29	3.24	7.56
MgO	9.30	4.96	6.55	7.76	8.43	7.38	10.24	4.56	2.06
CaO	10.62	8.82	10.06	9.62	12.27	8.20	8.75	11.23	7.00
Na_2O	2.82	3.31	3.28	2.25	2.33	2.78	2.49	3.37	3.72
K_2O	1.57	1.59	2.09	0.82	1.19	2.88	1.18	2.60	3.29
TiO_2	2.42	2.52	2.00	2.69	0.91	2.88	1.00	1.44	2.88
P_2O_5	0.50	0.58	0.41	0.75	0.85	0.92	0.44	0.94	0.35
MnO	0.23	0.19	0.16	0.22	0.17	0.15	0.19	0.20	0.15
H_2O+	0.76	1.71	2.00	1.37	0.44	0.07	0.30	0.69	2.78
H_2O-	0.43	1.21	0.42	0.45	0.36	0.10	0.66	2.08	0.46
CO_2	0.96	0.27	—	—	—	—	V_2O_3 0.03	—	—
Total	100.30	100.31	100.07	99.78	100.54	99.89	NiO 0.012 100.262	100.49	100.54
Anal.	RAOULT	RAOULT	RAOULT	USHIJIMA	TESHIMA	TESHIMA	KATSURA	TESHIMA	TESHIMA
Norms									*Q* 4.68
or	9.45	9.45	12.23	5.00	7.23	17.24	7.23	15.57	19.46
ab	20.83	27.77	21.22	18.86	19.39	21.48	20.96	26.46	31.44
an	18.35	21.68	19.18	28.91	32.80	24.46	30.02	19.74	11.68
ne	1.49	—	3.55	—	—	1.14	—	0.99	—
wo	10.21	6.96	11.72	5.80	9.40	4.18	4.41	12.76	8.47
en	7.20	8.50	7.30	7.90	6.90	13.67	14.40	10.50	5.20
fs	2.11	6.20	3.70	5.28	2.51	9.23	4.36	0.66	8.45
fo	11.27	2.73	6.37	8.05	9.94	11.27	7.84	0.63	—
fa	3.67	2.14	3.57	6.02	4.08	7.65	2.45	0.10	—
mt	6.50	5.34	4.18	5.34	3.71	0.70	4.87	5.57	1.62
il	4.56	4.71	3.80	5.17	1.67	5.47	1.98	2.74	5.47
ap	1.34	1.34	1.01	1.68	2.02	2.02	1.01	2.02	1.01
or	19	16	23	9	12	27	13	25	31
ab	43	47	40	36	33	34	36	43	50
an	38	37	37	55	55	39	51	32	19
Q	11	20	14	13	11	5	18	28	50
fo	67	44	55	50	63	56	62	67	18
fa	22	36	31	37	26	39	20	5	32

11. Andesine basalt; Wei-ch'ang Hsien, Je-ho Province (Lacroix, A., 1928, *Geol. Soc. China Bull.*, v. 7, p. 51).
12. Porphyritic andesine basalt; Hsiao-wan-wan-kou, Wei-ch'ang Hsien, Je-ho Province (Lacroix, A., 1928, *ibid.*, p. 48).
13. Andesine basalt, doleritic; (Lacroix, A., 1928, *ibid.*, p. 45).
14. Tephritic rock; Ichimuroyama, Takakura, Shōnaimura, Kahogun, Fukuoka Prefecture (Ueji, T., 1927, *Japan Assoc. Advancement Sci. Rept.*, no. 4, p. 351).
15. Olivine dolerite; Yamada, Goka-mura, Dōgo, Oki Islands (Tomita, T., 1951, *Fac. Sci., Kyūshū Univ., Research Rept.*, v. 3, no. 3, p. 86).
16. Hypersthene-augite-olivine-labradorite dolerite; east of Hatta, Dōgo, Oki Islands (Tomita, T., 1931, *Shanghai Sci. Inst. Jour.*, sect. 2, v. 1, p. 244).
17. Olivine dolerite; Kōnoura, Shōdoshima, Seto Inland Sea (Tomita, T., refer to 15).
18. Nonporphyritic trachyandesitic basalt; west of Kurada, Dōgo, Oki Islands (Tomita, T., 1935, p. 246).
19. Nonporphyritic vitreous trachyandesite; coast of Kama, Tōgō-mura, Dōgo, Oki Islands (Tomita, T., 1936, refer to reference 10, p. 114).

Table 5. Chemical Composition of AT_1.

No.	20	21	22	23	24
SiO_2	61.41	64.81	65.10	65.51	67.90
Al_2O_3	15.19	16.70	15.56	15.93	15.03
Fe_2O_3	2.03	1.34	2.01	1.17	2.03
FeO	1.33	2.57	2.79	2.12	1.67
MgO	trace	0.32	0.14	0.29	none
CaO	1.54	1.43	1.75	1.52	1.11
Na_2O	1.65	2.69	3.79	3.22	4.32
K_2O	4.33	7.07	6.53	6.99	5.85
TiO_2	0.75	0.75	0.76	0.69	0.66
P_2O_5	0.31	0.27	0.25	0.28	0.23
MnO	0.06	0.11	0.12	0.05	0.03
H_2O+	7.44	0.42	0.31	1.04	0.48
H_2O-	3.08	1.09	0.46	0.69	0.45
Total	99.12	99.57	99.57	99.50	99.76
Anal.	TESHIMA	TESHIMA	TESHIMA	TESHIMA	TESHIMA
Norms					
Q	32.64	17.76	14.16	11.76	18.60
C	5.61	2.65	—	1.02	—
or	25.58	42.26	38.36	41.14	34.47
ab	14.15	23.06	31.96	27.25	36.15
an	5.84	5.00	6.39	5.56	4.45
wo	—	—	—	—	0.12
en	—	0.80	0.40	0.70	—
fs	—	2.64	2.24	1.72	0.26
mt	2.09	1.86	3.02	1.86	3.02
hm	0.64	—	—	—	—
il	1.52	1.37	1.52	1.37	1.22
ap	0.67	0.67	0.67	0.67	0.34
or	56	60	50	56	46
ab	31	33	42	37	48
an	13	7	8	7	6
Q	100	87	88	87	99
fo	0	3	2	4	0
fa	0	10	10	9	1

20. Pumice of plagioclase-anorthoclase trachyte; foot-hill ESE of Mt. Yokoo, Dōgo, Oki Islands (Tomita, T., 1935, *Shanghai Sci. Inst.* Jour., sect. 2, v. 1, p. 252).
21. Plagioclase-anorthoclase trachyte; about 3 km south of Nawashiroda, Goka-mura, Dōgo, Oki Islands (Tomita, T., *ibid.*, p. 254).
22. Banded andesine-anorthoclase—sola-diopside-anorthoclase trachyte; Kōji, Goka-mura, Dōgo, Oki Islands (Tomita, T., *ibid.*).
23. Plagioclase-anorthoclase trachyte (rhyolitic); south shore of Omosu-wan, Dōgo, Oki Islands (Tomita, T., *ibid.*).
24. Plagioclase-anorthoclase trachyte (rhyolitic); a sea cliff opposite Suzume-jima, Nakamura, Dōgo, Oki Islands (Tomita, T., *ibid.*, p. 256).

Table 6. Chemical Composition of B_2 Dolerite.

No.	25	26	27	28	29	30
SiO_2	46.54	49.01	49.50	50.24	50.43	51.13
Al_2O_3	14.41	15.02	16.71	15.06	15.18	16.46
Fe_2O_3	7.07	5.02	3.52	6.32	2.77	3.41
FeO	4.49	6.89	8.86	7.68	8.92	8.16
MgO	4.88	6.31	4.04	4.05	4.98	2.88
CaO	8.81	7.86	7.68	8.08	8.96	5.30
Na_2O	5.07	3.38	3.24	3.52	3.13	4.14
K_2O	1.18	2.20	1.30	1.80	1.52	3.26
TiO_2	3.46	2.65	2.50	2.18	2.90	1.66
P_2O_5	1.88	0.76	0.64	0.34	0.49	1.27
MnO	0.15	0.27	0.20	0.05	0.21	0.46
H_2O+	0.96	0.08	0.93	0.30	0.01	0.35
H_2O-	1.18	0.17	0.55	0.26	0.11	0.21
CO_2	n.d.	0.35	0.27	n.d.	0.29	0.89
SO_3	n.d.	n.d.	n.d.	0.69	n.d.	n.d.
Total	100.08	99.97	99.94	100.57	99.90	99.56
Anal.	TESHIMA	MURATA	MURATA	?	MURATA	MURATA
Norms						
Q	—	—	1.92	3.24	0.72	0.24
or	7.23	12.79	7.78	10.56	8.90	19.46
ab	36.68	28.82	27.25	29.34	26.72	34.58
an	12.79	19.18	27.24	20.29	22.80	16.96
ne	3.41	—	—	—	—	—
wo	7.89	5.92	3.13	5.10	7.54	3.48
en	6.80	10.40	10.10	10.10	12.50	7.20
fs	—	3.04	9.64	5.55	9.64	2.38
fo	3.78	3.78	—	—	—	—
fa	—	1.22	—	—	—	—
mt	4.87	7.19	5.10	9.05	4.18	4.87
hm	3.68	—	—	—	—	—
il	6.69	5.17	4.71	4.10	5.47	3.19
ap	4.37	2.02	1.34	0.67	1.34	3.02
or	13	21	12	17	15	27
ab	65	47	44	49	46	49
an	22	32	44	34	39	24
Q	19	21	33	36	29	30
fo	81	60	33	40	38	51
fa	0	19	34	24	33	19

25. Olivine trachyandesitic basalt; Ksueh-hwa Shan, Ching-hsing Hsien, Ho-pei Province (Tomita, T., 1933, *Shanghai Sci. Jour.*, sect., 2, v. 1, p. 5).
26. Labradorite-augite-olivine dolerite; Paektu-san (Ogura, T., 1951, Chemical composition of the Manchurian igneous rocks, no. 118, *in* Geology and Mineral Resources of the Far East).
27. Augite-olivine-labradorite basalt; north of Shih-erh-tao-kou, Chang-pai Hsien, in the foothills of Paektu-san (Ogura, T., *ibid.*, no. 115).
28. Sŏkp'ŏ basalt; Kuryongso, Yongch'ŏl-li, Puktuil-myŏn, Tanch'ŏn-gun, Hamgyŏng-namdo, Korea (Kinosaki, Y., 1937, *Geological Atlas of Chōsen*, no. 14, p. 17).
29. Olivine augite-labradorite basalt; same as 27 (Ogura, T., *ibid.*, no. 109).
30. Trachyandesite; pass south of Ma-an Shan, P'aektu-san (Ogura, T., *ibid.*, no. 79).

Table 7. Chemical Composition of B_2 (Limburgites).

No.	31	32	33	34	35	36
SiO_2	42.64	42.93	43.26	42.52	42.80	42.98
Al_2O_3	12.32	10.71	13.40	12.72	14.01	13.67
Fe_2O_3	5.56	6.03	3.06	4.06	4.79	4.13
FeO	7.85	6.14	8.36	7.98	7.84	9.45
MgO	9.14	11.48	11.98	9.69	5.79	7.89
CaO	11.38	11.21	11.76	9.92	8.94	10.06
Na_2O	3.58	2.42	3.44	3.37	3.80	4.27
K_2O	1.39	1.98	1.03	2.09	3.57	2.11
TiO_2	3.44	2.48	1.75	3.46	2.22	3.18
P_2O_5	0.57	1.38	0.55	0.27	1.43	0.87
MnO	0.06	1.23	0.21	0.20	0.22	0.21
H_2O+	2.07	2.78	1.11	2.58	4.20	0.52
H_2O-	0.46		0.71	0.67	0.52	0.16
CO_2	n.d.	n.d.	n.d.	0.52	n.d.	0.64
Cl	n.d.	n.d.	n.d.	n.d.	n.d.	0.07
Total	100.46	100.77	100.62	100.05	100.13	100.34
Anal.	Raoult	Yokoyama	Harumoto	Raoult	Raoult	Raoult
Norms						
or	8.34	11.68	6.12	12.23	21.13	12.23
ab	8.38	10.48	3.67	7.86	7.07	10.35
an	13.34	12.51	18.07	13.34	10.56	12.79
ne	11.93	5.40	13.63	11.08	13.49	13.13
hl	—	—	—	—	—	0.35
wo	16.59	14.15	15.20	12.99	10.32	11.48
en	12.50	10.90	10.40	9.50	6.50	7.30
fs	2.38	1.72	3.56	2.24	3.17	3.43
fo	7.28	12.46	13.72	10.29	5.60	8.68
fa	1.53	2.04	5.20	2.75	3.06	4.38
mt	8.12	8.82	4.41	6.03	6.96	6.03
il	6.54	4.71	3.34	6.69	4.26	6.08
ap	1.34	3.36	1.34	0.67	3.36	2.02
or	28	34	22	37	54	35
ab	28	30	12	23	18	29
an	44	36	65	40	28	36
Q	18	14	12	14	12	12
fo	68	74	64	68	65	58
fa	14	12	24	18	23	30

31. Limburgite; Ch'i-hsing Shan, T'ai-an Hsien, Shan-tung Province (Lacroix, A., 1928, *Geol. Soc. China Bull.*, v. 7, p. 48).
32. Limburgite; Taifun-san, Iwami Province (H. S. Washington, 1917, U.S.G.S. Prof. paper, no. 99, p. 625).
33. Limburgite; Kasegizuka near Tsuyama, Okayama Prefecture (Harumoto, A., 1951, A lecture delivered at the 58th general meeting, *Geol. Soc. Japan*).
34. Limburgite; Kauo-tch'eng-chan, southwest of Lin-hsi Hsien, Je-ho Province (Lacroix, A., 1928) [in #31 above].
35. Limburgite; Mu-ling Ho, Chi-lin Province (Lacroix, A., 1929, *Geol. Soc. China Bull.*, v. 8, p. 55).
36. Limburgite; Ta-li-po, Ching-p'eng Hsien, Je-ho Province (Lacroix, A., 1928, [in #31 above], p. 48).

Table 8. Chemical Composition of B_2 (Nepheline Basalts).

No.	37	38	39	40	41	42	43	44	45	46
SiO_2	41.13	44.98	34.26	34.98	35.47	35.50	35.66	35.93	35.96	36.00
Al_2O_3	12.00	15.56	11.89	11.18	11.04	11.12	11.97	13.26	14.18	12.87
Fe_2O_3	4.27	5.15	7.55	5.99	7.30	5.23	5.19	5.59	6.43	5.55
FeO	9.94	7.30	8.20	8.83	9.01	6.75	9.69	10.06	8.55	9.68
MgO	9.42	3.31	8.01	8.36	9.22	8.55	8.35	7.90	7.14	8.68
CaO	10.97	9.20	14.75	13.52	14.16	15.00	14.39	13.37	14.00	16.28
Na_2O	5.22	5.34	4.16	4.22	3.62	5.41	3.65	4.92	2.44	3.64
K_2O	2.24	1.29	1.72	3.99	1.97	0.86	1.89	2.92	0.92	1.85
TiO_2	2.62	2.89	2.30	2.39	2.38	1.95	3.74	2.28	2.35	1.74
P_2O_5	1.32	0.43	2.36	2.53	1.75	2.43	1.37	2.39	2.17	1.55
MnO	0.17	0.23	0.34	0.26	0.40	0.27	0.30	0.34	0.33	0.31
H_2O+	0.68	3.77	3.49	2.49	2.98	4.88	4.04	0.57	4.43	2.03
H_2O-	0.27		0.54	1.14	0.32	1.19		0.26	1.13	0.59
CO_2	n.d.	n.d.	0.29	n.d.	0.13	0.45	n.d.	0.15	0.20	n.d.
Cl	n.d.	n.d.	0.18	n.d.	0.12	0.17	n.d.	n.d.	n.d.	n.d.
S	n.d.	0.04	0.07	0.10	0.14	0.08	n.d.	n.d.	n.d.	n.d.
Total	100.25	99.49		100.00			100.24	99.94	100.23	100.77
Anal.	Harumoto	Shimizu & Ohashi	Saito	Sugawara, Oana, & Kayama	Saito	Saito	Yokoyama	Tanaka	Tanaka	Harumoto
Norms										
or	12.79	7.78	—	—	—	—	—	—	5.56	—
ab	2.10	23.06	—	—	—	—	—	—	—	—
an	3.06	14.73	8.90	—	8.06	3.34	10.84	5.56	25.02	13.07
lc	—	—	7.85	18.75	9.16	4.36	8.72	13.52	—	8.72
ne	22.72	11.93	19.03	19.03	16.47	24.71	16.76	22.44	11.08	16.79
ac	—	—	—	0.46	—	—	—	—	—	—
wo	17.98	11.72	10.67	3.48	11.37	15.08	10.56	6.61	12.64	7.54
en	11.60	7.00	7.60	2.10	7.90	10.90	7.10	4.00	8.30	4.70
fs	5.15	4.09	2.11	1.19	2.51	2.77	2.64	2.24	3.43	2.38
fo	1.40	0.91	8.68	13.16	10.64	7.00	9.66	11.06	6.72	11.90
fa	4.18	0.51	2.65	8.87	3.67	1.94	4.08	6.63	2.96	6.53
cs	—	—	7.22	12.99	7.40	5.93	8.08	8.77	—	12.38
mt	6.26	7.42	11.14	—	10.67	7.66	7.66	7.89	9.28	8.12
il	5.02	5.47	4.41	4.56	4.56	3.80	6.99	4.41	4.41	3.34
ap	3.02	1.01	5.71	6.05	4.03	5.71	3.36	5.71	5.04	3.70
cc	—	—	—	—	—	—	—	0.30	0.10	—
Q	17	33	8	14	10	4	9	10	14	9
ne	64	57	71	50	64	85	66	63	67	66
kp	19	10	21	36	26	11	25	27	19	25
Q	6	24	13	3	9	17	12	7	16	8
fo	63	47	67	58	75	65	62	58	58	59
fa	31	29	20	39	16	18	26	35	26	33

37. Nepheline basalt; Lao-chai Shan, near T'ang-shan, Ch'i-hsia Hsien, Shan-tung Province (Harumoto, A., 1949, *Chigaku,* Kyōto Univ., v. 1, no. 1, p. 42).
38. Nepheline basalt (manchurite); Ts'ao-tzu-erh (Tsao-shi-err), Ying-e-men (Yingemen), Ch'ing-yuan Hsien, Feng-tien Province (Kotō, B., 1912, *Tōkyō Univ., Coll. Sci. Jour.,* v. 32, p. 11), (Lacroix, B., 1929, *Geol. Soc. China Bull.,* v. 8, p. 51).
39. Nepheline basalt; in the vicinity of Nagahama, Iwami Province (newly analyzed by Nobufusa Saito).
40. Nepheline basalt; same locality as above (Sugawara, S., Oana, S., and Toyama, T., 1945, *Tōkyō Imp. Acad. Proc.,* v. 20, p. 722).
41. Nepheline basalt; same locality (newly analyzed by N. Saitō).
42. Nepheline basalt, same locality (newly analyzed by N. Saitō).
43. Nepheline basalt; same locality (H. S. Washington, 1917, U.S.G.S. Prof. paper, no. 99, p. 699).
44. Nepheline basalt, same locality (Ichikawa, W., 1928, unpublished graduation thesis (MS), Tōkyō Imp. Univ., p. 55).
45. Nepheline basalt; same locality (Ichikawa, W., *ibid.,* p 56).
46. Melilite-nepheline basalt; vicinity of Takano village (Harumoto, A., 1949, *Geol. Soc. Japan Jour.,* v. 55, p. 148).

Table 10. Chemical Composition of the Rocks From Kilchu and Myŏngch'ŏn Districts.

No.	73	74	75	76	77	78	79	80	81	82	83	84
SiO_2	63.52	67.88	68.04	68.17	72.54	73.13	73.21	73.38	74.28	74.30	74.65	75.18
Al_2O_3	15.80	13.47	12.83	12.47	11.79	12.78	14.55	11.88	12.48	10.40	10.43	11.40
Fe_2O_3	3.47	2.46	2.50	0.05	2.82	2.87	0.40	2.32	0.74	2.75	3.38	1.25
FeO	2.89	3.27	3.72	0.98	1.91	1.29	2.39	1.91	2.03	2.15	1.30	2.45
MgO	0.45	tr.	0.80	0.50	tr.	0.22	1.22	tr.	0.17	0.37	0.08	tr.
CaO	1.23	1.14	2.23	0.66	0.52	0.05	1.10	0.54	0.70	0.32	0.46	0.48
Na_2O	5.65	5.72	3.99	7.89	4.44	3.71	2.69	4.08	2.75	4.19	4.13	3.92
K_2O	5.50	4.35	5.48	6.10	4.87	5.14	3.80	5.05	5.81	5.03	4.97	4.68
TiO_2	tr.	0.36	none	tr.	0.40	0.23	0.06	0.28	0.43	0.37	0.23	0.24
P_2O_5	tr.	0.07	none	tr.	0.06	none	0.01	0.08	none	0.04	0.01	0.06
MnO	0.05	0.18	tr.	none	0.13	0.05	0.23	0.10	tr.	0.09	n.d.	0.14
H_2O+	0.43	0.57	0.58	2.82	0.53	0.25	0.38	0.30	0.91	0.50	0.21	0.30
H_2O-		0.67	0.32	1.10	0.27	0.16	0.18	0.14	0.17	0.40	0.25	0.35
SO_3	1.12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Total	100.11	100.14	100.49	100.74	100.28	99.88	100.22	100.06	100.47	100.91	100.10	100.45
Anal.	Chōsen U.G.	Raoult	Seto	Seto	Raoult	Ushijima	Seto	Raoult	Seto	Yagi	Seto	Raoult
Norms												
Q	6.18	16.44	17.64	19.08	27.54	31.62	36.78	29.04	36.96	30.72	31.68	32.52
C	—	—	—	—	—	1.02	3.98	—	0.41	—	—	—
or	32.80	26.13	32.80	36.14	28.91	30.02	22.24	30.02	34.47	29.47	29.47	27.80
ab	47.68	44.54	34.06	30.39	33.54	31.44	23.06	33.01	23.06	25.68	25.68	32.49
an	1.39	—	0.28	—	—	0.28	5.56	—	3.61	—	—	—
ac	—	3.23	—	—	3.70	—	—	1.39	—	8.32	8.32	0.46
ns	—	—	—	4.76	—	—	—	—	—	0.12	—	—
wo	1.86	0.35	4.52	1.51	1.04	—	—	0.35	—	0.70	0.93	1.04
en	1.10	—	2.00	1.30	—	0.60	3.10	—	0.40	0.90	0.20	—
fs	2.51	4.49	4.62	1.85	1.72	—	4.22	1.58	2.38	3.43	1.58	3.43
mt	5.10	2.09	3.71	—	2.32	3.71	0.70	2.55	1.16	—	0.70	1.62
il	—	0.76	—	—	0.76	0.46	0.15	0.61	0.76	0.76	0.46	0.46
ap	—	0.34	—	—	—	hm 0.32	—	0.34	—	—	—	—
or	40	37	49	54	46	49	44	48	56	53	53	46
ab	58	63	51	56	54	51	45	52	38	47	47	53
an	2	0	0	0	0	0	11	0	6	0	0	1
Q	72	83	79	90	95	99	88	96	95	91	96	93
fo	8	0	6	4	0	1	5	0	1	2	0	0
fa	20	17	15	6	5	0	7	4	4	7	4	7

73. Tōryū-san alkali-trachyte; Kusŏktŏk, Yongch'ŏl-li, Puktuil-myŏn, Tanch'ŏn-gun, Hamgyŏng-namdo, Korea (Kinosaki, Y., 1932, *Geologic Atlas of Chōsen*, no. 14, p. 17).
74. Trachytes à silice libre (2^e facies); Tongho-dong, Hago-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto, Korea (Lacroix, A., 1927, *Comptes Rendus*, Tome 185, p. 1414).
75. Aegirin-augite-anorthoclase trachyte (Chongam-san hakutoite); Tongho-dong, Hago-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto (Kōzu, S., and Seto, K., 1926, Proc. 3rd Pan-Pacific Sci. Cong. Tōkyō, v. 1, p. 781).
76. Spherulitic trachyte-pitchstone (at the base of the Mokchin purplish alkali-trachyte); Wŏnsŏk-tong, Sanggo-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto (Kōzu, S., and Seto, K., 1929, Abstract from the paper of the 4th Pacific Sci. Cong. Java, v. 2, B, p. 1067).
77. Comendite (facies à lithophyses); Chaedŏk-san, Myŏngch'ŏn-gun, Hamgyŏng-pukto (Lacroix, A., 1927 [item 74], p. 1413).
78. Comendite (Puhyang alkali rhyolite); Ch'ondŏng-ni, Myŏngch'ŏn-gun, Hamgyŏng-pukto (Yamanari, F., 1925, *Geologic Atlas of Chōsen*, no. 3, p. 10).
79. Comendite; Kapsan, Unhŭng-myŏn, Kapsan-gun, Hamgyŏng-namdo (Kōzu, S., and Seto, K., 1929, p. 1067).
80. Comendite (facies à lithophyses); Kaesim-dong, Myŏngch'ŏn-gun, Hamgyŏng-pukto (Lacroix, A., 1929, p. 1413).
81. Sohō (Silbong) moonstone rhyolite; Kwangsŏk-ch'on, Sanggo-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto (Yamanari, F., 1925, p. 10).
82. Comendite (aphanitic); Sintoyong near Ch'ilbo-san, Myŏngch'ŏn-gun, Hamgyŏng-pukto (Yagi, K., 1950, *Kagaku*, [Science], v. 20, no. 2, p. 84).
83. Comendite; Kapsan, Unhŭng-myŏn, Kapsan-gun, Hamgyŏng-namdo (Kōzu, S., and Seto, K., 1922, *Geol. Soc. Japan Jour.*, v. 29, p. 216).
84. Comendite (facies micro-granulitique); K'ach'i-bong (Chak-pong), Myŏngch'ŏn-gun, Hamgyŏng-pukto (Lacroix, A., 1927 [item 74], p. 1413).

Table 11. Chemical Composition of the Rocks From Kilchu and Myŏngch'ŏn Districts.

No.	A	B	C	D	E	F
SiO_2	67.74	68.17	69.88	70.19	73.26	74.27
Al_2O_3	19.03	16.77	15.50	15.17	15.03	16.92
Fe_2O_3	2.28	2.44	3.66	2.01	0.96	0.98
FeO	1.54	2.00	2.12	2.46	1.46	2.28
MgO	0.08	0.12	0.36	0.28	tr.	0.51
CaO	0.61	0.42	0.27	0.24	tr.	1.30
Na_2O	3.16	2.99	1.96	1.76	3.34	3.26
K_2O	4.66	4.55	3.74	5.74	5.06	0.51
TiO_2	0.45	0.25	0.16	none	none	none
P_2O_5	tr.	tr.	tr.	tr.	tr.	tr.
MnO	0.15	0.09	0.23	0.22	tr.	tr.
H_2O+	0.57	0.87	0.91	0.38	0.46	0.41
H_2O-	0.23	0.55	0.55	0.26		0.19
SO_3	tr.	0.39	0.59	tr.	n.d.	n.d.
Total	100.50	99.61	99.90	99.66	99.66	100.63
Anal.	Chōsen U.G.	C.U.G.	C.U.G.	C.U.G.	C.U.G.	Seto
Norms						
Q	29.76	23.22	37.02	29.70	31.18	49.14
C	7.55	—	3.37	3.98	3.88	8.67
or	27.80	27.24	21.68	33.92	30.02	2.78
ab	26.72	25.15	16.77	23.58	28.82	27.77
an	3.06	18.90	13.34	1.11	—	6.39
wo	—	0.81	—	—	—	—
en	0.20	0.30	0.90	0.70	—	1.30
fs	0.40	1.45	0.92	3.17	1.85	1.58
mt	3.25	3.48	5.34	3.02	1.39	1.39
il	0.91	0.46	0.30	—	—	—

A. Alkaline granite porphyry; Maegong-ni, Sanggo-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto (*Mineral Survey Chōsen, Bull.*, v. 3, no. 3, p 52, 1927).

B. Kom-san hakutoite; Kwangji-bong, Ungp'yŏng-myŏn, Kilchu-gun, Hamgyŏng-pukto (*Ibid.*, p. 52).

C. Chŭng-bong moonstone rhyolite; Kwangsŏk-ch'on, Hago-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto (*Ibid.*, p. 52). (See Table 10, no. 80).

D. Chak-pong comendite; Samp'o-bong, Sanggo-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto (*Ibid.*, p. 52). (See Table 10, no. 83).

E. Quartz trachyte; Saengyang-ni, Chasŏ-myŏn, Samsu-gun, Hamgyŏng-namdo (*Ibid.*, p. 52).

F. Obsidian; Sŏngmak-tong, Hago-myŏn, Myŏngch'ŏn-gun Hamgyŏng-pukto (Kōzu, S., and Seto, K., 1929, Abstract of paper from the 4th Pacific Sci. Cong. Java, v. 2, B, p. 1067).

Table 12. Chemical Composition of Neutral, Acid and Alkaline Rocks of Oki Islands.

No.	85	86	87	88	89	90	91	92	93	94	95	96	97
SiO_2	64.51	65.37	66.55	67.51	69.11	70.57	71.32	71.37	71.77	71.94	72.21	72.73	73.14
Al_2O_3	14.18	15.63	17.27	13.69	15.53	15.15	13.16	14.72	13.28	14.27	11.20	9.57	12.28
Fe_2O_3	3.42	3.03	1.16	1.68	0.70	1.87	0.83	1.08	1.23	1.78	2.25	3.86	1.91
FeO	2.81	1.48	0.13	2.83	2.48	0.16	2.79	1.38	1.57	0.94	2.66	3.24	2.20
MgO	0.21	0.03	none	0.18	0.07	0.16	0.04	0.36	tr.	0.05	0.08	0.26	0.04
CaO	1.49	1.59	0.69	0.61	1.20	0.50	0.23	1.36	0.45	0.12	0.27	0.07	0.19
Na_2O	4.37	3.98	6.62	4.65	4.08	4.48	4.23	3.74	4.60	4.69	4.29	4.71	4.67
K_2O	5.75	6.47	5.74	5.45	5.43	6.04	4.94	5.69	5.17	5.37	4.81	4.37	4.34
TiO_2	0.59	0.35	0.89	0.53	0.46	0.40	0.24	0.04	0.22	0.29	0.44	0.24	0.40
P_2O_5	0.05	tr.	0.35	0.05	tr.	0.09	0.05	0.12	0.75	0.08	0.10	none	tr.
MnO	0.03	0.11	tr.	0.01	0.05	tr.	0.09	0.06	0.03	tr.	0.10	0.13	0.08
H_2O+	2.48	0.94	0.31	2.77	1.10	0.97	1.31	0.33	0.25	0.29	1.45	0.16	0.19
H_2O-		0.62	0.61		0.22		0.43	0.10	0.24	0.40		0.12	0.17
Total	99.89	99.60	100.32	99.96	100.43	100.39	99.76	100.35	99.56	100.22	99.86	99.46	99.61
Anal.	Yokoyama	Teshima	Teshima	Yokoyama	Teshima	Yokoyama	Teshima	Endō	Teshima	Teshima	Yokoyama	Teshima	Teshima
Norms													
Q	14.28	14.22	6.42	17.52	20.70	20.64	22.02	24.00	24.12	24.00	28.62	31.62	28.38
C	—	—	0.20	—	0.82	0.71	0.82	0.20	—	0.71	—	—	—
or	33.92	38.36	33.92	32.25	31.69	35.58	28.91	33.92	30.58	31.69	28.36	26.13	25.58
ab	36.68	34.06	55.54	39.30	34.58	37.73	35.63	31.44	38.77	39.82	30.92	26.72	39.30
an	2.22	5.28	—	0.28	5.84	1.67	0.28	5.84	0.28	—	—	—	—
ac	—	—	—	—	—	—	—	—	—	—	4.16	11.09	—
ns	—	—	—	—	—	—	—	—	—	—	—	0.12	—
wo	2.21	1.16	—	0.81	—	—	—	—	0.81	—	0.23	—	0.46
en	0.50	0.10	—	0.50	0.20	0.40	0.10	0.90	—	0.10	0.20	0.70	0.10
fs	1.45	—	tn 0.59	2.77	3.30	—	4.22	1.72	0.92	—	4.09	5.68	0.40
mt	4.87	3.94	ru 0.48	2.55	0.93	—	1.16	1.62	1.86	2.09	1.16	—	2.78
hm	—	0.32	1.12	—	—	1.76	—	—	—	0.16	—	—	—
il	1.06	0.76	0.30	1.06	0.91	0.30	0.46	—	0.46	0.61	0.91	0.46	0.76
ap	—	—	1.01	0.34	—	ru 0.24 ap 0.34	0.34	0.34	0.81	2.02	0.34	—	—
or	47	49	37	45	44	48	45	48	44	44	48	50	39
ab	50	44	62	55	48	50	55	44	56	56	52	50	61
an	3	7	1	0	8	2	0	8	0	0	0	0	0
Q	91	100	100	88	89	99	87	93	96	100	93	88	95
fo	2	0	0	2	1	1	0	2	0	0	0	1	0
fa	7	0	0	10	10	0	13	5	4	0	7	11	5

No.	98	99	100	101	102	103	104	105	106	107	108	109	110
SiO_2	73.39	73.39	73.71	73.90	74.53	67.82	69.90	70.43	70.90	73.80	61.15	57.14	62.88
Al_2O_3	11.37	14.57	10.17	13.88	12.84	11.94	15.14	11.90	10.42	9.91	19.24	18.05	17.47
Fe_2O_3	2.10	0.27	1.30	0.50	0.45	2.26	2.35	3.89	2.56	2.35	1.96	2.80	1.17
FeO	2.97	0.31	1.08	0.27	1.76	2.38	1.08	1.76	3.77	3.60	2.38	2.59	2.94
MgO	none	none	tr.	tr.	0.05	0.04	tr.	0.17	0.09	0.09	tr.	1.42	0.73
CaO	0.23	0.55	0.23	0.47	0.39	0.21	1.20	0.19	0.17	0.07	1.08	4.03	2.17
Na_2O	4.26	5.66	4.27	4.04	3.71	5.03	2.75	3.51	3.93	4.43	7.21	5.27	4.55
K_2O	4.19	4.38	4.56	5.63	5.44	4.85	4.81	4.81	4.72	4.38	4.93	4.71	5.80
TiO_2	0.45	0.25	0.10	0.58	0.15	0.19	0.22	0.36	0.23	0.28	0.28	1.82	0.91
P_2O_5	0.27	0.09	none	tr.	tr.	tr.	tr.	0.03	0.02	0.18	tr.	0.59	0.31
MnO	0.11	none	0.03	none	0.06	0.11	0.03	0.21	0.11	0.12	0.17	tr.	tr.
H_2O+	0.75	0.22	3.62	0.32	0.16	4.17	0.77	1.22	1.18	0.33	1.01	2.06	1.55
H_2O-	0.11	0.16	0.46	0.29	0.02	0.81	1.61	1.66	1.74	0.15	0.22		
Total	100.20	99.85	99.53	99.88	99.56	99.81	99.86	100.14	99.84	99.69	99.63	100.48	100.48
Anal.	Teshima	Teshima	Teshima	Teshima	Teshima	Teshima	Teshima	Tanaka	Tanaka	Teshima	Teshima	Yokoyama	Yokoyama
Norms													
Q	31.08	22.98	34.14	27.96	29.88	20.64	32.82	30.96	28.44	31.92	—	0.30	7.44
C	—	—	—	0.31	—	—	3.16	0.61	—	—	—	—	—
or	25.02	26.13	27.24	33.36	32.25	28.91	28.36	28.36	27.80	26.13	28.91	27.80	34.47
ab	35.11	47.68	26.72	34.06	31.44	34.06	23.58	29.87	27.25	26.20	55.81	44.54	38.25
an	—	1.39	—	2.22	1.95	—	5.84	0.83	—	—	5.56	11.68	10.29
ac	0.92	—	3.72	—	—	6.47	—	—	5.08	6.93	ne 2.70	—	—
ns	—	—	1.22	—	—	0.24	—	—	—	0.85		—	—
wo	—	0.23	0.46	—	—	0.46	—	—	0.35	—	fo —	1.86	—
en	—	—	—	—	0.10	0.10	—	0.40	0.20	0.20	fa 1.84	3.70	1.80
fs	3.30	—	1.85	—	2.77	2.78	—	—	6.21	6.20		—	2.90
mt	2.55	0.23	—	—	0.70	—	2.78	5.10	1.16	—	3.02	3.02	1.86
hm	—	0.16	—	0.48	—	—	0.48	0.32	—	—	—	0.80	—
il	0.91	0.46	0.15	0.61	0.30	0.46	0.46	0.76	0.46	0.61	1.34	3.50	1.67
ap	0.40	0.34	—	ru 0.32	—	—	—	—	—	—	—	1.34	0.67
or	42	35	50	48	49	46	49	48	51	50	32	33	42
ab	58	63	50	49	48	54	41	51	49	50	62	53	46
an	0	2	0	3	3	0	10	1	0	0	6	14	12
Q	92	100	92	100	93	91	100	99	86	87	0	35	71
fo	0	0	0	0	0	0	0	1	0	0	0	65	10
fa	8	0	8	0	7	9	0	0	14	13	100	0	19

85. Olivine-bearing soda diopside-anorthoclase trachyte; Utagitōge, Chūjōmura, Dōgo (Kōzu, S., 1913, *Sci. Rep. Tōhoku Imp. Univ.*, 2nd ser., v. 1, p. 45).
86. Soda diopside-bearing anorthoclase trachyte; west of Kaminishi, Chūjōmura, Dōgo (Tomita, T., 1935, *Jour. Shanghai Sci. Inst.*, sect. 2, v. 1, p. 254).
87. Groundmass of anorthoclase trachyte; Inushimazaki, Tōgōmura, Dōgo (Tomita, T., *ibid.*, p. 256).
88. Less quartzose comendite; Nakamura, Dōgo (Kōzu, S., *loc. cit.*, p. 39).
89. Soda diopside-bearing anorthoclase hyalotrachyte; Uzumoriyama, Isomura, Dōgo (Tomita, T., *ibid.*, p. 258).
90. Platy anorthoclase liparite; Terayama, Saigōmachi, Dōgo (Kōzu, S., *loc. cit.*, p. 42).
91. Anorthoclase felsite; Tonomejima, Ōhisa, Dōgo (Tomita, T., 1936, *Jour. Shanghai Sci. Inst.* sect. 2, v. 2, p. 120).
92. Obsidian; Dōgo.
93. Anorthoclase felsite; Nishida, Isomura, Dōgo (Tomita, T., 1936, p. 120).
94. Anorthoclase liparite; Tonomejima, Ōhisa, Tōgōmura, Dōgo (Tomita, T., 1936, p. 120).
95. Anorthoclase-quartz liparite (comenditic); Higashitani, Motoya, Nakamura, Dōgo (Kōzu, S., 1913, *Jour. Geol.*, v. 21, p. 66; Kōzu, S., p. 37).
96. Non-porphyritic-alkali liparite (comenditic); northwest of Takagamine, Dōgo (Tomita, T., 1936, p. 260).
97. Anorthoclase-quartz liparite (comenditic); Maokudani, Nakamura, Dōgo (Tomita, T., 1935, p. 260).
98. Aegirite-alkali hornblende-anorthoclase-quartz liparite; Okukitadani, Chōshi, Chūjōmura, Dōgo (Tomita, T., 1936, p. 122)
99. Anorthoclase felsite; Kamo, Isomura, Dōgo (Tomita, T., 1935, p. 260).
100. Alkaline liparite-perlite; between Yamada and Hisami, Gokamura, Dōgo (Tomita, T., 1936, p. 120).
101. Anorthoclase felsite; shore opposite Nishida, Isomura, Dōgo (Tomita, T., 1935, p. 260)
102. Anorthoclase liparite-obsidian; south of Hisami, Gokamura, Dōgo (Tomita, T., 1935, p. 260).
103. Biotite-bearing anorthoclase-quartz hyalophyre; Minamitani, Ushiki, Fusemura, Dōgo (Tomita, T., 1936, p. 123).
104. Biotite-bearing anorthoclase-quartz porphyry; Minamitani, Ushiki, Fusemura, Dōgo (Tomita, T., 1936, p. 123).
105. Soda sanidine-bearing quartz prophyry (grorudite); Maokudani, Nakamura, Dōgo (Tomita, T., 1935, p. 258).
106. Blue hornblende-bearing anorthoclase hyalo-quartz porphyry (paisanite); Maokudani, Nakamura, Dōgo (Tomita, T., 1935, p. 258).
107. Blue hornblende-anorthoclase-quartz porphyry; Maokudani, Ōhisa, Tōgōmura, Dōgo (Tomita, T., 1936, p. 123).
108. Anorthoclase-phonolitic trachyte porphyry (tinguaite-porphyry); Tokageiwa, ssw of Kazuoyama, Dōgo (Tomita, T., 1935, p. 252).
109. Hornblende-bearing andesine-anorthoclase trachyte; Mimiura, Dōzen (Kōzu, S., 1913, *Sci. Rep. Tōhoku Imp. Univ.*, 2nd ser., v. 1, p. 48).
110. Olivine-bearing oligoclase-anorthoclase glassy trachyte; Takuhisan, Dōzen (Kōzu, S., *ibid.*, p. 47).

Table 13. Chemical Composition of Neutral and alkaline Rocks of Matsushima and Cheju-do.

No.	111	112	113	114	115	116	117	118	119	120	121
SiO_2	62.36	63.74	64.61	64.62	54.28	54.87	56.19	56.34	59.51	60.65	61.36
Al_2O_3	17.95	14.28	17.53	17.90	17.82	17.91	16.12	17.43	18.52	18.20	18.12
Fe_2O_3	1.55	3.11	1.46	1.86	2.66	4.68	2.44	3.52	2.84	4.00	2.08
FeO	2.62	3.62	1.48	1.84	6.95	3.51	5.50	6.46	2.68	0.62	2.14
MgO	0.72	1.90	tr.	0.16	1.57	1.21	3.07	0.84	0.78	0.86	0.06
CaO	2.75	2.20	4.22	2.31	6.49	7.38	7.63	3.80	4.19	6.81	3.21
Na_2O	5.60	4.79	5.33	5.19	3.91	4.58	4.39	5.10	5.02	4.54	6.08
K_2O	4.16	4.50	4.95	5.25	3.40	3.20	2.30	3.32	3.16	3.08	4.95
TiO_2	0.66	1.07	0.43	0.27	1.23	1.33	2.14	0.94	1.13	0.44	0.37
P_2O_5	0.29	0.16	n.d.	0.02	0.29	1.02	0.55	1.24	0.14	0.98	0.23
MnO	0.48	0.17	0.19	0.08	0.18	n.d.	0.30	0.25	0.22	n.d.	0.12
H_2O+	0.87	0.03	0.26	0.18	0.37	0.77	0.47	1.02	1.37	0.21	1.75
H_2O-		0.25	0.12	0.14						0.12	
CO_2	n.d.	tr.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S	n.d.	0.06	n.d.	n.d.	SO_3 0.09	n.d.	n.d.	n.d.	SO_3 0.10	n.d.	n.d.
Total	100.01	99.88	100.58	99.82	99.24	100.46	101.10	100.29	99.66	100.51	100.47
Anal.	TAKAYANAGI	?	SETO	HARAGUCHI	HARAGUCHI	HARAGUCHI	HARAGUCHI	HARAGUCHI	HARAGUCHI	SETO	HARAGUCHI
Norms											
Q	6.48	11.10	7.98	8.82	1.14	3.48	3.96	4.44	8.10	10.98	1.38
C	—	—	—	—	—	—	—	1.33	—	—	—
or	24.46	26.69	29.47	31.14	20.02	18.90	13.34	19.46	18.90	18.35	29.47
ab	47.16	40.35	44.54	44.01	33.01	38.77	37.20	42.97	42.44	38.25	51.35
an	11.68	4.17	9.45	9.73	21.13	18.63	17.51	11.40	18.35	20.02	6.95
wo	—	2.44	4.76	0.70	3.83	4.87	6.96	—	0.70	3.01	3.37
en	1.80	4.80	—	0.40	3.90	3.00	7.70	2.10	2.00	2.20	0.20
fs	3.30	2.51	1.32	1.32	8.97	0.40	5.02	7.92	1.19	—	1.72
mt	2.32	4.41	2.09	2.78	3.94	6.73	3.48	5.10	4.18	0.70	3.02
hm	—	—	—	—	—	—	—	—	—	3.52	—
il	1.22	2.13	0.76	0.61	2.28	2.58	4.10	1.82	2.13	0.76	0.76
ap	0.67	0.34	—	—	0.67	2.35	1.34	2.69	0.34	2.35	0.34
or	29	37	35	37	27	25	19	26	24	24	34
ab	57	57	54	52	45	51	55	58	53	50	59
an	14	6	11	11	28	24	26	16	23	26	7
Q	67	71	89	88	31	65	45	48	80	88	80
fo	11	18	0	2	20	30	32	10	12	12	2
fa	22	11	11	10	49	5	23	42	8	0	18

111. Olivine-bearing soda diopside-anorthoclase trachyte; Matsushima, Hizen (Kōzu, S., 1911, *Jour. Geol.*, v. 19, p. 559).
112. Olivine-bearing soda diopside-anorthoclase trachyte;Matsushima, Hizen (Ōtsuki, Y., 1910, Explanatory text of the geological map of Iki, p. 28).
113. Fayalite-soda diopsidic aegirinaugite-anorthoclase trachyte;west wall of the crater, Halla-san, Cheju-do (Kōzu, S., and Seto, K., 1929, Abstract of Paper from the 4th Pacific Sci. Cong. Java, v. 2, B, p. 1067).
114. Ditto; same locality as above (Haraguchi, K., 1931, *Bull. Geol. Surv. Chōsen*, v. 10, part 1, p. 10).
115. Seikiho trachyandesite; Sŏgwip'o, U-myŏn, Cheju-do (Haraguchi, K., *ibid.*, p. 10).
116. Hornblende-bearing trachyandesite; Tondo-ak, Taejŏng-myŏn, Cheju-do (Haraguchi, K., *ibid.*, p. 10).
117. Ditto; Pyŏlto-bong, Cheju-myŏn, Cheju-do (Haraguchi, K., *ibid.*, p. 10)
118. Kaianri (Haeal-li) trachyandesite; Cheju-do (Haraguchi, K., *ibid.*, p. 10).
119. Sambōsan (Sanbang-san) trachyandesite; Pong-san, Chung-myŏn, Cheju-do (Haraguchi, K., *ibid.*, p. 10).
120. Oligoclase andesite; same locality as above (Kōzu, S., and Seto, K., 1929 p. 1067).
121. Aegirinaugite-bearing trachyte; Sam-do, Cheju-do (Haraguchi, K., 1931 p. 10)

Table 14. Chemical Composition of B_3.

No.	122	123	124	125	126	127	128	129	130	131	132	133	134
SiO_2	47.52	47.63	49.05	44.22	45.46	45.75	47.54	48.01	48.42	49.03	49.29	52.19	52.39
Al_2O_3	15.67	16.65	14.35	16.14	15.04	17.15	15.34	18.59	11.43	14.43	18.49	19.74	15.62
Fe_2O_3	7.81	4.16	3.02	7.01	3.17	3.06	3.84	6.82	3.42	1.29	2.38	4.72	1.50
FeO	4.47	8.83	10.57	5.13	6.39	7.27	6.98	6.07	8.67	9.40	6.77	6.28	8.06
MgO	3.78	4.89	4.25	5.46	8.58	3.13	5.28	5.26	8.60	11.93	6.09	2.24	6.92
CaO	8.18	7.38	8.66	9.68	10.55	7.30	11.79	8.48	11.64	7.28	8.14	6.99	8.68
Na_2O	4.17	3.59	3.23	2.84	3.81	6.04	3.16	2.59	3.31	3.14	3.93	3.48	3.43
K_2O	2.22	1.95	1.40	1.41	1.38	1.46	1.15	1.86	0.72	1.24	1.79	2.04	0.79
TiO_2	4.16	3.19	3.19	3.80	3.17	3.21	2.53	0.48	2.64	1.71	2.22	n.d.	1.47
P_2O_5	0.76	0.57	0.57	0.90	1.08	1.69	0.63	0.33	0.36	0.44	tr.	n.d.	0.33
MnO	0.21	0.21	0.27	0.30	0.16	0.18	0.17	0.12	0.21	tr.	0.22	0.06	0.13
H_2O+	0.68	0.40	0.34	0.09	0.74	1.44	1.03	1.47	0.54	0.73	0.88	1.25	0.22
H_2O-	0.30	0.26	0.20	2.58	0.16	1.69	0.71	0.60	0.44				0.24
CO_2	n.d.	0.23	0.73	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Total	99.93	99.94	99.83	99.56	99.69	99.37	100.15	100.68	100.40	100.62	100.20	98.99	99.78
Anal.	RAOULT	MURATA	MURATA	TESHIMA	TESHIMA	TESHIMA	TESHIMA	ENDŌ	TESHIMA	YOKOYAMA	SUGIURA	ŌNO	YAMAGUCHI
Norms													
Q	—	—	0.12	—	—	—	—	2.34	—	—	—	3.06	—
or	12.79	11.68	8.34	8.34	8.34	8.90	7.23	11.12	3.89	7.23	10.56	11.12	5.00
ab	33.01	30.39	27.25	24.10	17.82	32.49	19.91	22.01	25.41	26.72	27.77	29.34	28.82
an	17.79	23.63	20.57	26.97	19.74	15.57	23.91	33.36	14.46	21.41	27.52	32.25	24.74
ne	1.14	—	—	—	7.67	9.94	3.69	—	1.28	—	2.84	—	—
wo	7.19	3.94	7.89	6.50	10.56	3.94	12.99	2.90	16.93	4.99	5.34	1.04	6.84
en	6.20	2.60	10.60	10.50	8.00	2.20	8.40	8.80	11.10	5.40	3.40	5.60	16.20
fs	—	1.98	12.14	—	1.45	1.58	3.70	4.75	4.62	2.37	1.58	7.92	10.82
fo	2.31	1.26	—	2.24	9.45	3.92	3.36	—	7.28	17.08	8.26	—	0.77
fa	—	0.92	—	—	2.04	3.37	1.63	—	3.47	8.57	4.28	—	0.51
mt	3.02	6.03	4.41	6.26	4.64	4.41	5.57	9.98	4.87	1.86	3.48	6.73	2.09
hm	5.76	—	—	2.72	—	—	—	—	—	—	—	—	—
il	7.90	6.08	6.08	7.30	6.08	6.08	4.71	0.91	5.02	3.19	4.26	—	2.74
ap	2.02	1.34	1.34	2.02	2.69	4.03	1.34	0.67	1.01	1.01	—	—	0.67
or	20	18	15	14	18	16	13	17	9	13	16	15	9
ab	52	46	48	41	40	57	44	33	58	48	42	40	49
an	28	36	37	45	42	27	43	50	33	39	42	45	42
Q	22	18	26	25	13	10	20	38	14	7	8	39	26
fo	78	46	33	75	72	57	54	39	71	62	61	24	43
fa	0	36	41	0	15	33	26	23	15	31	31	37	31

122. Olivine-labradorite-bearing trachybasalt; Mutu-bong (about 16 km ESE of P'aektu-san) (Lacroix, A., 1928, *Bull. Geol. Soc. China.* v. 7, p. 58).
123. Trachybasalt; Andugal parasitic volcano, Paektu-san (Ogura, T., 1951, *Chemical composition of the igneous rocks of Manchuria, in* Geology and Mineral Resources of the Far East).
124. Olivine-oligoclase basalt; Taeyŏnji-bong, P'aektu-san (Ogura, T., *ibid.*).
125. Olivine-labradorite basalt; Noridabana, Nakamura, Dōgo, Oki Island (Tomita, T., 1935, *Jour. Shanghai Sci. Inst.*, sect 2, v. 1, p. 240).
126. Augite-bearing titanaugite-olivine basalt; Suzumejima, Nakamura, Dōgo, (Tomita, T., *ibid.*, p. 242).
127. Groundmass of olivine-labradonite-augite-bearing kaersutite basalt; Chikaishi, Chūjōmura, Dōgo (Tomita, T., *ibid.*, p 242).
128. Olivine-titanaugite-labradorite trachybasalt; SE foothill of Taihōsan, Dōgo (Tomita, T., *ibid.*, p. 242).
129. Labradorite-bearing olivine-biotite trachybasalt; Mutsurejima, Nagato (Kōzu, S., Yoshimoto, B., 1929, *Japanese Assoc. Mineralogists, Petrologists, and Economic Geologists, Jour.*, v. 1, p. 159).
130. Augite-labradorite-olivine trachybasalt; top of Taihōsan, Dōgo (Tomita, T., *loc. cit.*, p. 244).
131. Hypersthene-bearing olivine trachybasalt; Shimomotoya, Nakamura, Dōgo (Kōzu, S., 1913, *Sci. Rep. Tōhoku Imp. Univ.*, 2nd ser., v. 1, p. 51).
132. Olivine trachybasalt; Tajima Gembudō (H. S. Washington, 1917, U.S.G.S. Prof. Paper, no. 99, p. 513).
133. Trachybasalt; Mawatarijima, Hizen (Kōzu, S., 1911, *Jour. Geol.*, v. 19, p. 574).
134. Quartz-basalt excluding quartz xenocrysts; Daidonjima, Izumo (Sakai, S., 1929, Geol. Soc. Japan Jour., v. 46, p. 275).

Table 15. Chemical Composition of Volcanic Rocks of Ullŭng-do.

No.	135	136	137	138	139	140	141	142	143	144
SiO_2	47.82	52.75	56.57	57.61	57.91	59.11	60.63	61.52	61.65	62.30
Al_2O_3	17.57	16.61	19.21	18.70	18.22	19.02	18.80	18.48	18.15	17.89
Fe_2O_3	3.06	2.98	1.90	3.51	1.90	1.82	1.01	2.65	1.77	1.13
FeO	6.22	4.22	3.31	1.77	3.20	2.68	3.96	1.49	2.40	2.38
MgO	3.20	2.81	1.37	1.05	1.01	1.05	0.15	0.58	0.11	0.15
CaO	8.28	5.11	3.57	2.66	3.58	2.51	1.11	1.32	1.23	1.26
Na_2O	3.62	5.38	5.80	6.45	4.98	5.83	7.67	6.70	5.30	8.06
K_2O	3.47	4.58	6.06	5.77	6.69	5.69	5.60	6.14	5.67	5.41
TiO_2	3.35	1.83	1.42	1.18	0.65	0.83	0.66	0.56	0.59	0.49
P_2O_5	0.93	0.49	0.36	0.35	0.48	0.18	0.07	0.03	0.29	0.20
MnO	0.15	0.10	0.10	0.07	0.27	0.14	0.02	0.17	1.45	0.21
H_2O+	1.59	2.89	0.15	0.41	0.82	0.94	0.14	0.64	0.68	0.30
H_2O-	0.85	0.63	0.15	0.11	0.38	0.43	0.30	0.35	0.59	0.29
ZrO_2	n.d.	n.d.	n.d.	n.d.	0.07	n.d.	n.d.	n.d.	0.04	n.d.
Total	100.11	100.38	99.97	99.64	100.16	100.23	100.12	100.63	99.92	100.07
Anal.	HARUMOTO	HARUMOTO	HARUMOTO	HARUMOTO	ŌHASHI	USHIJIMA	HARUMOTO	USHIJIMA	ŌHASHI	OYAMA
Norms										
Q	—	—	—	—	—	—	—	—	5.10	—
C	—	—	—	—	—	—	—	—	1.84	—
or	20.57	27.24	35.58	33.92	39.48	33.92	33.36	36.14	33.92	31.69
ab	23.58	30.92	36.15	40.35	33.54	44.01	46.63	49.78	44.54	49.78
an	21.41	7.51	8.34	5.00	7 23	8.62	—	2.22	3.89	—
ne	3.69	7.95	7.10	7.67	4.83	2.84	9.94	3.69	—	6.53
ac	—	—	—	—	—	—	—	—	—	3.23
ns	—	—	—	—	—	—	—	—	—	0.61
wo	5.92	5.92	0.70	2.20	2.44	1.28	1.97	1.74	—	2.20
en	4.20	4.10	0.40	1.90	1.00	0.90	0.20	1.00	0.30	0.20
fs	1.19	1.32	0.26	—	1.45	0.26	1.98	—	4.75	2.24
fo	2.66	2.03	2.10	0.49	1.05	1.73	0.14	—	—	0.14
fa	0.82	0.71	1.63	—	1.73	0.21	2.65	—	—	1.33
mt	4.41	4.41	2.78	2.55	2.78	2.55	1.39	3.94	2.55	—
hm	—	—	—	1.76	—	—	—	0.16	—	—
il	6.38	3.50	2.74	2.28	1.12	1.52	1.22	1.06	1.06	0.91
ap	0.96	1.34	1.01	1.01	1.68	0.34	0.34	—	0.67	0.34
or	31	42	45	43	49	39	42	46	41	39
ab	36	47	45	51	42	51	58	51	54	61
an	33	11	10	6	9	10	0	3	5	0
Q	20	19	4	19	12	12	10	30	62	17
fo	70	60	56	81	33	69	6	70	2	10
fa	10	21	40	0	57	19	84	0	36	73

135. Trachybasalt; To-dong, Nam-myŏn, Ullŭng-do (Harumoto, A., 1934, *Geol. Soc. Japan Jour.*, v. 41, p. 354).
136. Trachybasalt; Sŏdal-lyŏng, Sŏ-myŏn, Ullŭng-do (Harumoto, A., *ibid.*)
137. Trachyandestic vicoite; north side of Nan-bong, Ullŭng-do (Harumoto, A., *ibid*).
138. Hornblende trachyandesite; Sŏkp'o-dong, Chugam, Pung-myŏn, Ullŭng-do (Harumoto, A., *ibid.*)
139. Vulsinitic vicoite; Nan-bong, Ullŭng-do (Tsuboi, S., 1920, *Geol, Soc. Japan Jour.*, v. 27, p. 469).
140. Aegirinaugite-biotite trachyte; river bed, southwest of Sŏngin-bong, Nam-myŏn, Ullŭng-do (Harumoto, A., 1934).
141. Aenigmatite-aegirinaugite trachyte; Chatae, Sŏ-myŏng, Ullŭng-do (Harumoto, A., 1934).
142. Aegirinaugite trachyte; Haengnam, Nam-myŏn, Ullŭng-do (Harumoto, A., 1934).
143. Aegirinaugite phonolite (nepheline-tinguaite); SW foot-hill of Kwanmo-bong, Ullŭng-do (Tsuboi, S., 1920 p. 468).
144. Phonolite; north side of Ch'o-bong, Ullŭng-do (Harumoto, A., 1934).

Table 16. Chemical Composition of B_4.

No.	145	146	147
SiO_2	49.94	50.89	52.08
Al_2O_3	16.33	17.28	17.81
Fe_2O_3	2.32	1.75	1.53
FeO	7.63	7.34	8.30
MgO	4.80	4.88	7.01
CaO	9.82	11.56	8.08
Na_2O	1.44	2.77	3.16
K_2O	3.51	0.71	0.74
TiO_2	3.95	1.95	1.09
P_2O_5	none	0.23	—
MnO	0.02	0.81	0.15
H_2O+	none	0.10	0.22
H_2O-	0.18	0.29	—
Cl	tr.	tr.	n.d.
Total	99.94	100.56	100.17
Anal.	SETO	SETO	MIZUMA
Norms			
Q	2.10	0.96	—
or	20.57	3.89	4.45
ab	12.05	23.58	26.72
an	27.80	32.80	32.25
wo	8.70	9.86	3.25
en	12.00	12.20	15.50
fs	5.55	10.17	11.09
fo	—	—	1.40
fa	—	—	1.02
mt	3.25	2.55	2.09
il	7.60	3.80	2.13
ap	—	0.34	—
or	34	7	7
ab	20	39	42
an	46	54	51
Q	28	30	25
fo	48	36	42
fa	24	34	33

145. Olivine basalt; Pangsong-ni, Ch'angdo-myŏn, Kŭmhwa-gun, Kangwŏn-do, Korea (Kōzu, S., and Seto, K., 1929, Abstract of Paper from the 4th Pacific Sci. Cong. Java, v. 2, B, p. 1067)

146. Potashandesine-olivine basalt (Yūtoku basalt); Mokchin-dong, Sanggo-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto, Korea (Kōzu, S., and Seto, K., *ibid.*).

147. Olivine basalt; Sangnong-ni, Suha-myŏn, Tanch'ŏn-gun, Hamgyŏng-namdo, Korea (Kinozaki, Y., 1938, *Geol. Atlas of Chōsen*, no. 19).

Table 17. Chemical Composition of Wu-ta-lien-chih and Erh-k'o-shan Lavas.

No.	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169
SiO_2	50.54	51.68	53.46	47.15	47.28	48.14	49.92	51.12	51.38	51.62	52.52	53.06	53.20	47.96	48.82	52.68	52.94	49.20	50.81	50.58	51.12	51.26
Al_2O_3	14.50	15.07	14.66	14.27	13.45	13.91	14.16	12.99	14.54	14.24	14.25	14.58	14.16	13.24	14.06	14.38	14.69	14.08	14.71	14.14	13.76	14.66
Fe_2O_3	2.31	2.95	1.78	9.32	7.00	9.10	7.90	4.36	8.06	2.07	2.70	7.50	3.00	2.93	0.48	1.43	0.89	1.52	2.36	4.48	1.28	7.84
FeO	6.96	5.74	5.89	1.44	3.43	2.00	1.42	5.39	0.85	6.44	5.15	3.14	6.97	7.87	8.47	7.76	8.05	6.89	6.20	4.61	6.70	1.30
MgO	7.41	5.90	6.16	7.78	8.44	8.86	7.43	6.01	6.34	6.36	6.76	4.27	6.62	7.48	7.56	6.38	6.08	8.26	7.43	6.68	6.95	4.21
CaO	7.01	5.20	5.92	8.32	7.72	7.22	6.61	5.84	6.16	5.88	6.16	4.76	5.05	8.02	7.35	5.82	6.01	7.75	6.65	5.74	6.44	6.27
Na_2O	3.57	4.26	3.33	3.25	4.56	3.31	3.23	3.24	3.72	4.89	3.35	4.19	2.60	3.79	4.22	3.36	3.35	4.18	3.56	4.08	4.22	4.54
K_2O	4.28	5.14	5.20	4.56	4.22	2.93	4.48	5.67	4.67	4.40	4.24	4.57	3.88	4.89	4.70	5.43	5.13	4.30	5.21	4.81	5.61	5.27
TiO_2	2.05	2.50	2.77	2.46	2.30	2.40	2.25	2.70	2.20	2.28	2.35	2.25	2.27	2.83	2.80	1.88	2.00	2.50	2.19	2.56	2.45	2.42
P_2O_5	1.06	1.21	0.92	1.07	0.75	1.01	1.20	0.98	1.13	0.82	0.74	0.90	1.25	1.03	1.12	1.10	1.01	1.05	1.06	1.04	1.06	1.14
MnO	0.15	0.08	0.01	0.18	0.08	0.09	0.14	0.06	0.07	0.10	0.07	0.08	0.14	0.02	0.14	0.15	0.15	0.12	0.14	0.10	0.12	0.08
H_2O+	0.69	0.40	0.27	0.79	0.77	0.83	0.98	1.02	0.64	0.73	1.54	0.69	0.50	0.37	0.13	0.11	0.32	0.11	0.29	1.16	0.39	1.03
H_2O-		0.13	0.10		0.34	0.17	0.16	0.16	0.14	0.19	0.38	0.21	0.18	0.05	0.07			0.07		0.10	0.10	0.61
Total	100.53	100.26	100.47	100.59	100.34	99.97	99.88	99.54	99.93	100.02	100.21	100.20	99.82	100.01	99.93	100.48	100.62	100.03	100.61	100.08	100.20	100.18
Anal.	Murata	Geol. Sur.	Sawatari	Murata	Geol. Sur.	Geol. Sur.	Geol. Sur.	Geol. Sur.	Geol. Sur.	Geol. Sur.	Geol. Sur.	Geol. Sur.	Geol. Sur.	Sawatari	Geol. Sur.	Murata	Murata	Geol. Sur. S. M. Ry	Murata	Geol. Sur. S. M. Ry	Geol. Sur. S. M. Ry	Geol. Sur. S. M. Ry
Norms																						
Q	—	—	—	—	—	—	—	—	—	—	—	—	3.30	—	—	—	—	—	—	—	—	—
or	25.58	30.02	30.58	26.69	25.02	17.24	26.69	33.36	27.24	26.13	25.02	27.24	22.80	28.91	27.80	31.69	30.02	25.58	30.58	28.36	33.36	31.14
ab	21.48	25.94	27.77	12.84	22.01	17.03	24.10	23.06	28.82	24.10	28.30	35.63	22.01	7.34	6.81	23.58	23.06	12.58	16.77	20.70	14.15	24.89
an	10.84	6.95	10.01	10.84	3.61	14.46	10.84	4.17	9.17	3.61	11.40	7.23	15.57	4.45	5.56	8.34	10.01	6.95	11.68	5.84	1.95	4.17
ne	4.54	5.54	—	8.09	9.09	5.82	1.70	2.27	1.42	9.37	—	—	—	13.35	15.62	2.56	2.84	12.21	7.10	7.52	11.64	7.24
wo	6.84	4.76	5.68	8.58	3.48	6.15	5.22	7.66	4.06	8.35	6.15	4.52	0.46	12.06	9.74	5.45	5.68	10.09	5.80	9.16	9.28	6.84
en	4.50	3.40	4.30	7.40	3.00	22.20	4.50	6.00	3.50	5.50	8.30	7.50	16.60	8.00	5.90	3.20	3.00	6.80	4.00	7.70	6.00	5.90
fs	1.85	0.92	1.32	—	—	—	—	0.79	—	2.24	1.72	—	6.86	3.17	3.30	1.98	2.51	2.51	1.32	0.26	2.64	—
fo	9.80	7.98	7.77	8.40	12.67	—	9.87	6.30	8.68	7.28	6.02	2.24	—	7.49	9.10	8.96	8.54	9.43	10.22	6.30	7.98	3.22
fa	4.69	2.45	2.75	—	—	—	—	0.82	—	3.16	1.43	—	—	3.26	5.81	6.32	6.53	3.98	3.57	0.31	7.34	—
mt	3.25	4.41	2.55	—	4.41	—	—	6.50	—	3.02	3.94	3.71	4.41	4.18	0.70	2.09	1.39	2.09	3.48	6.50	1.86	—
hm	—	—	—	9.28	4.00	9.12	7.84	—	8.16	—	—	4.96	—	—	—	—	—	—	—	—	—	7.84
il	3.80	4.71	5.17	3.50	4.41	4.41	3.19	5.17	1.98	4.41	4.41	4.26	4.26	5.32	5.32	3.65	3.80	4.71	4.26	4.86	4.56	2.89
tn	—	—	—	1.57	—	0.20	1.37	—	2.94	—	—	—	—	—	—	—	—	—	—	—	—	2.16
ap	2.69	2.69	2.02	2.69	1.68	2.35	2.69	2.35	2.69	2.02	1.68	2.02	3.02	2.35	2.69	2.69	2.35	2.69	2.69	0.34	2.69	2.69
or	44	48	45	53	49	35	43	55	42	48	39	39	38	71	69	50	48	57	52	52	67	52
ab	37	41	40	25	44	35	39	38	44	45	44	51	36	18	17	37	36	28	28	38	29	41
an	19	11	15	22	7	30	18	7	14	7	17	10	26	11	14	13	16	15	20	10	4	7
Q	6	9	10	14	6	30	9	15	9	12	16	23	38	14	10	7	11	11	8	16	10	19
fo	64	79	67	86	94	70	91	75	91	61	68	77	36	60	55	55	50	63	68	80	51	81
fa	30	12	23	0	0	0	0	10	0	27	16	0	26	26	35	38	39	26	24	4	39	0

148. Olivine-anorthoclase banakite (plateau lava); Shih-to-fang-tzu, Wu-ta-lien-chih, Lung-chiang Province (Ogura, T., Matsuda, K., Nakagawa, T., Matsumoto, M., and Murata, K., 1936, *Report on volcanoes in Manchuria*, no. 1, p. 51: Ryojun Coll. Eng.).
149. Anorthoclase banakite (shield plateau lava); Wei-shan-lien (Ogura, T., 1951, *Chemical composition of the Manchurian igneous rocks, in* Geology and Mineral Resources of the Far East, no. 100).
150. Anorthoclase banakite (shield plateau lava); Sh'ih-t'ang, Lung-chiang Province (Ogura, T., and others, 1936, p. 52).
151. Leucite absarokite (older volcanic cone), light brown, vesicular, massive lava; Tung-lung-men Shan, Lung-chiang Province (Ogura, T., and others, 1936, p. 55).
152. Leucite-olivine banakite (older volcanic cone), light grayish brown, vesicular, massive shield plateau lava; Mo-la-pu Shan, Lung-chiang Province (Ogura, T., 1951, no. 137).
153. Leucite absarokite (older volcanic cone), reddish brown, vesicular, massive lava; Tung-chao-te-pu Shan, Lung-chiang Province (Ogura, T., 1951, no. 127).
154. Olivine absarokite (older volcanic cone), reddish brown, vesicular, massive lava; Pi-chia Shan, Lung-chiang Province (Ogura, T., 1951, no. 113).
155. Leucite absarokite (older volcanic cone), brownish gray minutely vesicular, massive lava; Yao-chuan Shan, Lung-chiang Province (Ogura, T., 1951, no. 105)
156. Leucite-olivine banakite (older volcanic cone), brownish, finely vesicular, massive lava; Pei-ko-la-ch'iu Shan, Lung-chiang Province (Ogura, T., 1951, no. 102).
157. Glassy banakite, (older volcanic cone), black scoriaceous ejecta; Wei-shan, Lung-chiang Province (Ogura, T., 1951, no. 101).
158. Glassy banakite (older volcanic cone), black scoriaceous ejecta; Lung-men Shan, Lung-chiang Province (Ogura, T., 1951, no. 98).
159. Trachyandesite (older volcanic cone), reddish brown vesicular massive lava; Hsi-chiao-te-pu Shan, Lung-chiang Province (Ogura, T., 1951, no. 95).
160. Olivine trachybasalt (older volcanic cone), black porous scoriaceous ejecta; Wo-hu Shan, Lung-chiang Province (Ogura, T., 1951, no. 94).
161. Leucite trachyte, spinal shihlunite flow; south of Lao-hei Shan, Lung-chiang Province (Ogura, T., and others, 1936, p. 64).
162. Leucite trachyte, spinal shihlunite lava flow (the same type as no. 181?); south of Lao-hei Shan, Lung-chiang Province (Ogura, T., 1951, no. 120).
163. Shihlunite proper, shihlunite lava flow; northern foot-hill of Lao-hei Shan, Lung-chiang Province (Ogura, T., and others, 1936, p. 63).
164. Shihlunite proper, Shihlunite flow; Shih-to-fang-tzu, Lung-chiang Province (Ogura, T., 1936).
165. Shihlunite proper (younger volcanic cone), black vesicular massive lava flow; Huo-shao Shan, Lung-chiang Province (Ogura, T., 1951, no. 116).
166. Shihlunite proper (younger volcanic cone), black vesicular massive lava flow; Lao-hei Shan, Lung-chiang Province (Ogura, T., and others, 1936, p. 65).
167. Leucite shihlunite, black lava; crest of Tung Shan, Erh-k'o Shan, K'o-tung Hsien, Lung-chiang Province (Ogura, T., and Matsumoto, M., 1938).
168. Leucite basanite (shield plateau lava); Ho-chia-t'un, Lung-chiang Province (Ogura, T. and Matsumoto, M., 1938, p. 10).
169. Leucite basanite (Erh-k'o Shan lava); summit of Erh-k'o Shan, Lung-chiang Province (Ogura, T. and Matsumoto, M., 1938, p. 11).

Table 18. Chemical Composition of Ch'i-hsing Shan Lavas.

No.	170	171	172	173	174	175	176	177
SiO_2	40.86	42.23	44.96	45.71	45.96	46.20	47.49	48.31
Al_2O_3	12.97	12.46	12.28	14.03	15.69	14.87	18.24	16.95
Fe_2O_3	4.87	2.89	2.24	2.01	0.53	1.61	3.15	1.22
FeO	9.85	10.93	11.47	11.01	10.76	10.69	7.13	8.99
MgO	9.98	11.81	10.64	9.66	10.22	10.05	4.52	6.65
CaO	8.67	10.30	7.39	9.05	9.47	9.07	10.97	9.68
Na_2O	4.56	3.91	3.95	3.17	2.71	2.91	3.66	3.69
K_2O	1.60	1.73	1.33	2.12	1.70	1.62	2.03	2.10
TiO_2	2.86	2.02	2.36	2.10	1.80	1.86	1.94	1.42
P_2O_5	0.89	0.71	0.91	0.47	0.42	0.40	0.33	0.53
MnO	0.17	0.19	0.20	0.16	0.14	0.21	0.20	0.19
H_2O+	1.50	1.50	1.41	0.68	0.82	0.88	0.87	0.85
H_2O-	0.96		0.79					
Total	99.74	100.68	99.93	100.17	100.22	100.37	100.53	100.58
Anal.	GEOL. SUR. S. M. RY	SAWAYAMA	GEOL. SUR. S. M. RY	SAWAYAMA	SAWAYAMA	SAWAYAMA	SAWAYAMA	SAWAYAMA
Norms								
or	9.45	8.34	7.78	12.23	10.01	9.45	6.12	12.23
ab	6.81	—	20.96	11.53	12.31	15.72	25.15	18.86
an	10.29	11.68	11.95	17.79	25.58	22.80	30.02	23.91
lc	—	1.31	—	—	—	—	—	—
ne	17.04	17.89	6.82	8.24	5.82	4.83	3.12	6.53
wo	11.37	14.50	8.00	10.21	7.77	8.12	9.40	8.47
en	7.60	9.10	4.80	5.90	4.50	4.70	5.40	4.50
fs	2.90	4.49	2.77	3.83	2.90	3.04	3.56	3.70
fo	12.18	14.28	15.26	12.81	14.84	14.28	4.13	7.77
fa	5.10	7.96	8.98	8.87	10.61	9.79	3.16	7.55
mt	7.19	4.18	3.25	3.02	0.70	2.32	4.64	1.86
il	5.32	3.80	4.41	3.95	3.50	3.50	3.65	2.74
ap	2.02	1.68	2.02	1.01	1.01	1.01	0.67	1.34
or	35	42	19	29	21	19	10	22
ab	26	0	52	28	26	33	41	34
an	39	58	29	43	53	48	49	44
Q	11	17	6	8	6	7	15	9
fo	63	53	59	54	55	55	49	47
fa	26	30	35	38	39	38	36	44

170. Olivine trachybasalt; Po-po-t'u Shan, Ch'i-hsing Volcano (Ogura, T., Sawatari, M., and Murayama, K., 1939, *Report of volcanoes in Manchuria*. no. 30, p. 27: Ryojun Coll. Eng.).
171. Leucite basanite; Nao-po Shan, Ch'i-hsing Volcano (Ogura, T., and others, 1936 p. 29).
172. Olivine trachybasalt; Po-li Shan, Ch'i-hsing Volcano (Ogura, T., and others *ibid.*, p. 25).
173. Olivine trachybasalt; Shih-t'ou Shan, Ch'i-hsing Volcano (Ogura, T., and others, *ibid.*, p. 32).
174. Olivine trachydolerite; Hsiao-t'u-k'o-erh-t'sai Shan, Ch'i-hsing Volcano (Ogura, T., *ibid.*, p. 30).
175. Olivine trachybasalt; Hsi-ha-la-pa Shan, Ch'i-hsing Volcano (Ogura, T., *ibid.*, p. 25).
176. Olivine trachydolerite; Ta-t'u-k'o-erh-t'sai Shan, Ch'i-hsing Volcano (Ogura, T., *ibid.*, p. 31).
177. Olivine trachybasalt; Tuhg-ha-la-pa Shan, Ch'i-hsing Volcano (Ogura, T., *ibid.*, p. 24).

Table 20. Chemical Composition of Holocene Lavas of Cheju-do.

No.	198	199	200	201	202	203	204
SiO_2	43.41	46.86	47.60	48.33	49.61	50.02	51.50
Al_2O_3	15.52	16.37	14.77	16.13	15.20	15.08	15.45
Fe_2O_3	3.99	6.01	2.78	4.60	6.81	6.42	1.82
FeO	8.15	6.04	8.58	7.39	6.66	7.11	8.17
MgO	6.78	4.25	4.64	4.13	5.04	5.08	4.93
CaO	10.77	6.81	12.76	10.67	6.37	6.40	9.19
Na_2O	4.28	5.28	3.76	3.74	4.42	4.33	4.09
K_2O	1.30	2.41	1.03	1.07	2.85	2.97	3.52
TiO_2	2.58	2.96	1.78	2.31	2.12	2.25	1.89
P_2O_5	1.29	1.71	1.40	1.46	n.d.	n.d.	n.d.
MnO	1.38	1.23	0.61	0.12	0.24	0.20	none
H_2O+	0.46	1.01	0.45	0.56	0.40	0.64	0.04
H_2O-					0.06	n.d.	0.04
SO_2	0.03	n.d.	n.d.	n.d.	n.d.		n.d.
Total	99.98	100.67	100.16	100.51	99.78	100.50	100.64
Anal.	Haraguchi	Haraguchi	Haraguchi	Haraguchi	Seto	Haraguchi	Seto
Norms							
or	7.78	14.46	6.12	6.12	16.68	17.79	20.57
ab	12.58	23.58	22.79	27.77	30.39	29.87	17.29
an	19.18	13.90	20.29	24.19	13.34	13.07	13.62
ne	12.78	11.36	4.97	1.99	3.69	3.41	9.37
wo	10.79	3.60	14.15	11.60	7.66	7.77	13.34
en	6.10	2.50	7.00	6.90	5.40	5.20	7.00
fs	4.22	0.79	6.86	4.09	1.58	1.98	5.94
fo	7.56	5.67	3.22	2.38	4.18	5.25	3.71
fa	5.71	2.24	3.57	3.57	1.53	2.14	3.37
mt	5.80	8.82	4.18	6.73	9.98	9.28	2.55
il	3.04	5.17	3.34	4.41	3.95	3.95	3.65
ap	3.02	4.03	3.36	0.34	—	—	—
or	20	28	13	11	28	29	40
ab	32	45	46	48	50	49	34
an	48	27	41	41	22	22	26
Q	12	8	18	20	15	14	17
fo	50	66	39	48	65	61	43
fa	38	26	43	32	20	25	40

198. Basanitoid (Kŭmnyŏng basalt); Kŭmnyŏng, Kucha-myŏn, Cheju-do, (Haraguchi, K., 1931, *Bull. Geol. Surv. Chōsen*, v. 10, part 1, p. 10).
199. Plagioclase-augite-olivine basalt; Cheju, Cheju-myŏn, Cheju-do (Haraguchi, K., *ibid*).
200. Microporphyritic plagioclase basalt; east wall of the crater of Halla-san, Cheju-do (Haraguchi, K., *ibid.*).
201. Augite basalt (Yongdam lava); Yongdam, Cheju-do (Haraguchi, K., *ibid.*).
202. Trachybasalt; Sŏ-myŏn, Cheju-do (Kōzu, S., and Seto, K., 1929, Abstract of paper from the 4th Pacific Sci. Cong. Java, v. 2, B, p. 1067).
203. Olivine-trachybasalt (Saektal lava); Saektal, Cheju-do (Haraguchi, K., 1931).
204. Olivine-basalt (Hallasan basalt); same locality as 200 (Kōzu, S., and Seto, K., 1929).

Table 19. Chemical Composition of the Lung-wan Volcanic Rocks.

No.	178	179	180	181	182	183	184	185	186	187
SiO_2	45.54	45.54	46.16	46.67	46.70	46.93	47.03	47.36	47.36	47.54
Al_2O_3	13.13	17.87	15.41	16.86	16.81	17.95	16.01	12.98	17.45	17.59
Fe_2O_3	1.25	3.02	5.84	3.22	2.39	1.20	3.52	2.66	1.71	7.50
FeO	9.13	9.08	5.15	9.14	9.48	10.83	7.88	10.90	8.51	4.07
MgO	12.11	7.07	13.51	8.04	8.15	6.76	11.03	8.21	8.73	6.58
CaO	8.73	8.48	5.73	7.58	8.01	7.83	6.85	7.91	7.21	6.45
Na_2O	4.31	3.66	2.33	3.53	3.69	2.88	2.84	4.48	4.09	2.50
K_2O	1.91	2.17	1.88	2.17	2.31	2.33	2.26	2.38	2.44	2.22
TiO_2	0.83	2.74	2.10	2.36	1.92	2.53	2.13	1.04	2.31	2.10
P_2O_5	0.43	0.44	0.57	0.29	0.50	0.58	0.27	0.57	0.24	0.68
MnO	0.29	0.20	0.23	0.25	0.22	0.24	0.33	0.33	0.25	0.26
H_2O+	0.45	0.06	0.41	0.55	0.49	n.d.	0.29	0.31	0.24	2.23
H_2O-	1.27	0.16	0.11	0.04		0.11	0.03	0.74	0.03	0.12
Total	99.38	100.49	99.39	100.50	100.67	100.46	100.47	99.87	100.57	99.84
Anal.	Geol. Sur. of S. M. Ry.	Murata	Murata	Murata	Sawayama	Murata	Murata	Geol. Sur. of S. M. Ry.	Murata	Murata
Norms										
Q	—	—	—	—	—	—	—	—	—	3.18
C	—	—	0.31	—	—	—	—	—	—	1.22
or	11.12	12.79	11.12	12.79	13.34	13.90	13.34	14.46	14.46	12.79
ab	7.34	14.67	19.91	19.39	10.48	20.44	20.96	15.72	16.77	20.96
an	10.84	25.85	25.02	23.91	22.52	28.91	24.19	7.78	22.24	27.24
ne	15.62	8.80	—	5.68	11.36	2.27	1.70	12.21	9.66	—
wo	12.41	5.68	—	4.99	5.68	2.67	3.25	11.60	4.87	—
en	7.80	3.30	12.60	3.10	2.50	1.40	2.30	6.30	3.10	16.50
fs	3.83	2.11	0.66	1.58	3.17	1.19	0.66	4.88	1.45	—
fo	15.75	10.08	14.84	11.90	12.60	15.81	17.71	9.94	13.09	—
fa	8.57	7.14	0.82	7.04	17.54	10.61	6.22	8.57	7.24	—
mt	1.86	4.41	8.35	4.64	3.48	1.86	5.10	3.94	2.55	8.12
hm	—	—	—	—	—	—	—	—	—	1.92
il	1.52	5.17	3.95	4.56	3.65	4.86	4.10	1.98	4.41	3.95
ap	1.01	1.01	1.34	0.67	1.34	1.34	0.67	1.34	0.67	1.68
or	38	24	20	23	29	22	23	38	27	21
ab	37	28	35	35	23	32	36	41	31	34
an	25	48	45	42	48	46	41	21	42	45
Q	9	6	12	5	4	2	3	10	5	42
fo	61	55	83	60	38	45	72	48	61	58
fa	30	39	5	35	58	53	25	42	34	0

No.	188	189	190	191	192	193	194	195	196	197
SiO_2	48.10	48.20	48.28	48.56	48.68	48.86	49.66	49.96	50.16	50.16
Al_2O_3	14.54	18.16	18.61	17.54	16.96	13.63	17.29	19.33	16.46	18.49
Fe_2O_3	2.77	1.57	7.29	3.84	6.23	7.74	2.23	9.35	0.74	7.34
FeO	9.26	9.60	3.74	7.80	5.29	3.47	8.32	1.35	9.42	3.43
MgO	5.74	6.88	5.44	7.96	6.60	9.00	6.85	4.16	8.15	5.86
CaO	8.54	7.44	6.97	7.16	7.74	8.22	6.87	6.38	8.58	6.28
Na_2O	5.11	3.18	3.84	3.07	3.24	4.41	3.74	3.53	3.08	3.17
K_2O	2.59	1.81	2.93	1.49	2.58	1.82	2.66	2.70	1.15	2.47
TiO_2	1.01	2.22	1.54	2.09	2.13	1.00	1.80	1.78	1.75	2.10
P_2O_5	0.63	0.61	0.32	0.57	0.39	0.35	0.47	0.71	0.29	0.15
MnO	0.31	0.23	0.10	0.25	0.23	0.31	0.20	0.20	0.19	0.25
H_2O+	0.05	0.34	1.51	n.d.	0.33	0.07	0.27	0.64	0.36	0.46
H_2O-	1.36	0.28		0.12	0.12	0.18	0.18	0.41	0.19	0.05
Total	100.01	100.53	100.57	100.45	100.57	99.06	100.54	100.50	100.52	100.21
Anal.	Geol. Sur. of S. M. Ry.	Murata	Sawayama	Murata	Murata	Geol. Sur. of S. M. Ry.	Murata	Murata	Murata	Murata
Norms										
Q	—	—	—	—	—	—	—	1.50	—	0.84
C	—	—	—	—	—	—	—	0.71	—	—
or	15.57	10.56	17.24	8.90	15.57	10.56	16.12	16.12	6.67	14.46
ab	15.72	26.72	27.25	25.68	27.25	28.82	26.20	29.34	26.20	26.72
an	8.90	30.02	24.74	29.75	24.19	11.95	22.52	26.97	27.80	28.91
ne	14.77	—	2.84	—	—	4.54	2.84	—	—	—
wo	12.53	1.39	3.25	0.93	4.76	10.79	3.60	—	5.45	0.58
en	6.30	2.60	2.80	8.80	3.80	9.30	2.10	10.40	8.00	14.70
fs	5.94	1.85	—	4.36	0.66	—	1.32	—	5.54	—
fo	5.67	10.22	9.52	7.77	8.89	9.24	10.57	—	8.68	—
fa	5.81	8.57	—	4.18	1.94	—	8.24	—	6.73	—
mt	4.18	2.32	7.89	5.57	9.05	9.05	3.25	—	0.93	5.80
hm	—	—	1.92	—	—	1.44	—	9.34	—	3.36
il	1.98	4.26	2.98	2.13	2.13	1.98	3.50	3.34	3.34	3.95
ap	1.34	1.34	0.67	1.34	1.01	1.01	1.01	1.68	0.67	0.34
or	39	16	25	14	23	21	25	22	12	21
ab	39	40	39	40	41	56	40	41	43	38
an	22	44	36	46	36	23	35	37	45	41
Q	14	5	8	14	7	15	4	39	13	34
fo	42	52	92	56	58	85	54	61	49	66
fa	44	43	0	30	35	0	42	0	38	0

178. Olivine-trachyandesitic basalt, crust of volcanic bomb; Ta-i Shan, Lung-wan Volcano (Ogura, T., 1951, *Chemical composition of igneous rocks of Manchuria, in* Geology and Mineral Resources of the Far East, no. 150).
179. Olivine trachybasalt, lava flow; south of Ta-lung-wan (Ogura, T., *ibid.*, no. 149).
180. Olivine trachybasalt, reddish scoria; Ta-i Shan, Lung-wan Volcano (Ogura, T., *ibid.*, no. 145).
181. Olivine trachybasalt, lava flow; Shuang-yang-tung Ho, Lung-wan Volcano (Ogura, T., *ibid.*, no. 143).
182. Olivine trachybasalt, lava flow; west of Ta-i Shan, Lung-wan Volcano (Ogura, T., *ibid.*, no. 141).
183. Olivine trachybasalt, lava flow; Ha-ma-t'ang, Lung-wan Volcano (Ogura, T., *ibid.*, no. 140).
184. Olivine trachybasalt, scoria; Ta-i Shan, Lung-wan Volcano (Ogura, T., *ibid.*, no. 139).
185. Olivine-trachyandesitic basalt, scoria; Hsi Shan, Hsien-shui-ting-tzu, Lung-wan Volcano (Ogura, T., *ibid.*, 134).
186. Olivine trachybasalt, lava flow; Chen-chia-p'u, Lung-wan Volcano (Ogura, T., *ibid.*, no. 135).
187. Olivine trachybasalt, black scoria; Ta-ku Shan, Lung-wan Volcano (Ogura, T., *ibid.*, no. 131).
188. Olivine-trachyandesitic basalt, lava flow; west of Huang-ni-kang-hsi, Lung-wan Volcano (Ogura, T., *ibid.*, no. 128).
189. Olivine trachybasalt, black scoria; Hu-lu-lung-wan, Lung-wan Volcano (Ogura, T., *ibid.*, no. 125).
190. Olivine trachybasalt, lava flow; east shore of Hu-lu-lung-wan, Lung-wan Volcano (Ogura, T., *ibid.*, no. 124).
191. Glassy basalt, lava flow; Ta-lung-wan, Lung-wan Volcano (Ogura, T., *ibid.*, no. 122).
192. Olivine trachybasalt, scoria; Hsiao-i Shan, Lung-wan Volcano (Ogura, T., *ibid.*, no. 121).
193. Olivine-trachyandesitic basalt, scoria; Ta-lung-wan Volcano (Ogura, T., *ibid.*, no. 119).
194. Olivine trachybasalt, compact lava; Hsiao-weng-ch'uan crater, Lung-wan Volcano (Ogura, T., *ibid.*, no. 114).
195. Olivine trachybasalt, brown scoria; Kuan-ts'o Ling, Lung-wan Volcano (Ogura, T., *ibid.*, no. 112).
196. Olivine trachybasalt, lava flow; north of Hsi-heng-tao Shan, Lung-wan Volcano (Ogura, T., *ibid.*, no. 111).
197. Olivine trachybasalt, brown scoria; north of Hsi-heng-tao Shan, Lung-wan Volcano (Ogura, T., *ibid.*, no. 110).

Table 21. Chemical Composition of Basalts From Western Japan.

No.	205	206	207
SiO_2	47.56	48.33	55.90
Al_2O_3	14.13	16.29	16.00
Fe_2O_3	1.89	3.24	0.92
FeO	10.00	8.73	6.10
MgO	8.37	5.70	4.89
CaO	8.43	8.50	7.32
Na_2O	2.95	3.59	3.56
K_2O	1.38	1.49	1.52
TiO_2	2.77	2.40	1.56
P_2O_5	0.66	0.79	0.37
MnO	0.13	0.11	0.12
H_2O+	1.92	0.82	0.98
H_2O-			0.14
Total	100.19	99.99	99.33
Anal.	Yokoyama	Yokoyama	Taguchi
Norms			
Q	—	—	6.48
or	8.34	8.90	8.90
ab	25.15	30.39	29.87
an	21.13	22.80	23.35
wo	6.73	4.64	4.18
en	7.90	9.20	12.10
fs	3.96	9.10	8.05
fo	9.10	0.21	—
fa	6.53	0.31	—
mt	2.78	4.64	1.39
il	5.32	4.56	3.04
ap	1.68	2.02	1.01
or	15	14	14
ab	46	49	48
an	39	37	38
Q	12	26	45
fo	53	35	32
fa	35	39	23

205. Olivine-titanaugite-labradolite trachydolerite; top of Daimanjiyama, Dōgo, Oki Islands (Kōzu, S., 1913, *Sci. Rep. Tōhoku Imp. Univ.*, 2nd ser., v. 1, p. 50).

206. Trachydolerite; On-dake, Fukue-jima, Gotō Islands (Kōzu, S., 1911, *Jour. Geol*, v. 19, p. 574).

207. Quartz basalt, in the upper part of lava; Kasa-yama, Nagato Province (Sugi, K., 1942, Mem. Fac. Sci., *Kyūshū Imp. Univ.*, ser., D, v. 1, no. 3, p. 82).

Table 22. Chemical Composition of Rocks at Otsurumizu and Hyŏnam.

No.	a	b	c	d	e	f	g
SiO_2	45.58	53.91	54.64	55.31	55.54	60.27	61.52
Al_2O_3	11.60	15.65	17.11	16.96	17.31	17.38	17.53
Fe_2O_3	3.12	3.75	3.07	2.16	2.09	4.45	1.72
FeO	7.31	2.82	5.38	5.18	4.73	1.83	0.91
MgO	8.71	4.81	4.04	4.17	3.70	1.03	0.24
CaO	7.98	7.09	5.35	5.70	5.46	3.01	2.46
Na_2O	4.02	4.12	5.85	5.88	3.96	6.27	6.54
K_2O	2.67	2.47	2.84	2.73	3.53	4.77	6.40
TiO_2	2.97	2.00	0.27	0.15	1.10	0.26	0.17
P_2O_5	1.98	1.28	0.08	0.12	0.38	tr.	0.12
MnO	0.04	tr.	0.41	0.68	0.12	0.15	0.15
H_2O+	4.39	2.05	1.26	1.02	0.99	0.72	1.32
H_2O-			0.45	0.41	1.14	0.67	0.51
CO_2	n.d.	n.d.	n.d.	n.d.	0.12	n.d.	n.d.
Total	100.37	99.95	100.75	100.47	100.17	100.81	99.59
Anal.	Yokoyama	Yokoyama	Koike	Koike	Raoult	Koike	Koike
Norms							
Q	—	3.06	—	—	5.22	—	—
or	15.57	15.01	16.68	16.12	20.57	28.36	37.81
ab	32.49	34.58	39.30	39.82	34.06	52.40	46.63
an	5.84	16.96	11.95	11.95	18.90	5.00	—
ne	0.85	—	5.68	5.40	—	0.28	4.26
ac	—	—	—	—	—	—	0.46
wo	3.02	4.18	5.80	6.50	2.20	4.18	4.76
en	2.20	12.00	3.10	3.40	9.30	2.60	0.60
fs	0.53	1.59	2.51	2.90	5.15	—	0.40
fo	11.37	—	4.90	4.90	—	—	—
fa	4.18	—	4.08	4.49	—	—	—
mt	4.41	5.57	4.41	3.25	3.02	5.57	2.32
hm	—	—	—	—	—	0.64	—
il	5.78	0.46	0.46	0.30	2.13	0.46	0.30
ap	4.70	3.02	0.34	0.34	1.01	—	0.34
or	29	23	24	24	28	33	45
ab	60	52	58	59	46	61	55
an	11	25	18	17	26	6	0
Q	4	42	10	11	47	30	27
fo	71	50	52	46	33	70	42
fa	25	8	38	43	20	0	31

a. Glassy monchiquitic rock; Otsurumizu, Kanzaki, Bungo Province (Kōzu, S., 1914, *Sci. Rep. Tōhoku Imp. Univ.*, 2nd ser., 1, p. 80).
b. Soretite trachyandesite; same locality as above (Kōzu, S., *ibid.*, p. 79).
c,d. Syenodolerite; Hyŏnam, Kuk-tong, Tong-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto, Korea (Itō, T., 1937, *Beiträge zur Mineralogie von Japan*, Neue Folge, 2 (Tōkyō), p. 152).
e. Dolerite; same locality as above (Lacroix, A., 1928, *Bull Geol. Soc. China*, v. 7, p. 58).
f. Syenite; same locality as above (Itō, T., 1937, p. 151).
g. Syenite-aplite; same locality as above (Itō, T., 1937, p. 153).

Table 9. Chemical Composition of Paektu-san Lavas.

No.	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
SiO_2	61.30	61.68	61.83	62.98	64.42	64.76	64.78	64.89	65.04	65.68	65.84	66.24	66.27	67.42	67.68	67.84	68.98	70.81	70.95	71.76	72.76	72.86	54.64	66.28	71.67	73.20
Al_2O_3	16.47	17.36	18.27	16.53	16.26	15.08	15.00	15.42	16.66	15.93	15.39	14.64	14.57	15.07	12.55	15.27	13.18	10.63	12.23	11.65	11.06	10.64	16.95	14.86	13.05	9.31
Fe_2O_3	2.76	1.79	1.48	1.94	2.26	4.63	3.73	2.94	2.36	3.02	1.45	1.45	1.87	0.44	3.00	2.22	0.44	2.60	1.22	2.51	2.94	3.42	2.11	2.26	1.00	3.25
FeO	3.75	4.03	3.47	4.00	3.77	1.85	2.55	3.68	2.93	3.44	3.55	3.52	3.08	2.79	2.85	2.38	3.49	4.01	4.13	3.23	2.46	2.77	6.63	2.92	2.80	3.10
MgO	0.25	0.37	0.37	0.55	0.17	0.35	0.13	0.12	0.02	0.03	0.03	0.79	0.59	0.25	0.24	0.04	0.69	0.23	0.05	—	0.10	tr.	3.17	0.34	none	0.04
CaO	1.69	1.53	1.63	2.17	1.24	1.34	1.21	1.23	0.99	0.72	1.50	0.49	0.94	1.42	1.25	0.82	1.60	0.75	0.47	0.62	0.59	0.64	6.14	1.66	3.32	0.38
Na_2O	5.38	4.68	4.92	4.73	5.44	4.85	6.28	5.46	6.08	4.76	5.96	7.46	7.70	6.11	6.31	5.32	6.02	5.97	5.46	4.68	4.55	4.73	3.77	6.34	4.83	5.25
K_2O	5.10	5.10	5.98	5.66	4.74	5.23	4.90	4.74	4.88	5.06	5.27	4.44	4.41	5.01	4.71	5.02	5.08	3.47	4.60	4.51	4.33	4.30	3.17	4.73	4.02	4.43
TiO_2	0.55	0.65	0.60	0.69	0.55	0.53	0.50	0.40	0.40	0.42	0.66	0.15	0.28	0.72	0.31	0.35	0.40	0.11	0.30	0.38	0.29	0.32	1.81	0.40	0.21	0.60
P_2O_5	0.02	0.03	0.03	0.23	0.02	0.12	tr.	tr.	tr.	tr.	0.12	n.d.	n.d.	0.07	0.19	none	—	0.05	tr.	0.05	0.08	tr.	0.42	0.10	—	0.10
MnO	0.14	0.13	0.06	0.13	0.12	0.20	0.07	0.12	0.09	0.07	0.17	0.39	0.37	0.14	0.06	0.05	0.62	0.10	0.09	0.10	0.05	0.12	0.16	0.10	none	0.19
H_2O+	0.73	0.27	0.28	none	0.10	0.47	none	none	none	0.05	0.21	} 0.27	} 0.13	0.36	0.51	none	0.14	0.93	none	0.59	0.71	0.36	none	0.13	0.11	0.28
H_2O-	0.57	0.39	0.52	0.10	0.22	0.37	0.20	0.12	0.14	0.02	0.08			0.05	0.08	0.14	0.12	0.40	0.04	0.22	0.33	0.21	0.25	0.09	0.02	0.12
CO_2	1.23	1.80	0.45	0.20	0.28	0.12	0.40	0.58	0.16	0.31	n.d.	n.d.	n.d.	n.d.	n.d.	0.22	n.d.	n.d.	0.36	n.d.	n.d.	n.d.	0.57	n.d.	n.d.	n.d.
Total	99.94	99.81	99.89	99.91	99.59	99.90	99.75	99.70	99.75	99.71	100.23	99.84	100.21	99.85	99.74	99.67	100.76	100.06	99.90	100.30	100.25	100.37	99.79	100.21	100.94	100.25
Anal.	Murata	Murata	Murata	Murata	Murata	Murata	Murata	Murata	Murata	Murata	Raoult	Kin'nari	Kin'nari	Raoult	Nemoto	Murata	Seto	Seto	Murata	Raoult	Nemoto	Raoult	Murata	Nemoto	Seto	Raoult
Norms																										
Q	5.40	7.50	4.44	4.20	9.90	14.16	7.80	11.22	7.80	15.42	7.56	6.84	6.42	9.84	14.22	15.60	14.94	24.24	21.54	25.56	30.42	28.50	2.04	7.86	21.78	31.62
C	—	1.43	0.71	—	—	—	—	—	—	1.22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
or	30.02	30.02	35.58	33.92	27.80	30.58	28.91	27.80	28.91	30.02	31.14	26.13	26.13	29.47	27.80	29.47	30.02	20.57	27.24	26.69	25.58	25.58	18.90	27.80	23.91	26.13
ab	45.59	39.82	41.39	39.82	46.11	40.87	50.30	46.11	51.35	40.35	50.30	50.30	50.30	49.78	38.77	44.54	39.30	35.11	37.20	35.11	27.77	30.39	31.96	50.30	40.35	23.06
an	5.84	7.51	8.06	6.95	6.12	4.17	—	3.61	3.89	3.61	—	—	—	—	—	3.34	—	—	—	—	—	—	20.02	—	2.22	—
ac	—	—	—	—	—	—	2.77	—	—	—	—	4.16	5.54	1.39	8.78	—	1.39	7.39	3.70	4.16	8.32	8.32	—	2.77	—	9.70
ns	—	—	—	—	—	—	—	—	—	—	—	1.83	1.95	—	1.10	—	2.32	1.59	1.10	—	0.37	—	—	—	—	2.44
wo	1.04	—	—	0.81	—	0.70	2.44	0.93	0.46	—	2.78	1.04	1.97	2.55	2.20	0.23	3.36	1.51	0.93	1.28	0.35	1.28	3.25	3.13	5.68	0.81
en	0.60	0.90	0.90	1.40	0.40	0.90	0.30	0.30	0.10	0.10	0.10	2.00	1.50	0.60	0.60	0.10	1.50	0.60	0.10	—	0.30	—	7.90	0.90	—	0.10
fs	3.83	5.02	4.22	4.88	4.36	—	1.85	3.96	2.77	3.30	4.49	6.86	5.81	4.22	4.88	2.11	6.86	7.39	7.13	4.36	4.09	4.36	7.39	3.70	3.96	4.62
mt	4.18	2.55	2.09	2.78	3.26	5.34	3.94	4.18	3.48	4.41	2.09	—	—	—	—	3.25	0.76	—	—	1.62	—	0.70	3.02	1.86	1.39	—
mh	—	—	—	—	—	0.96	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
il	1.06	1.22	1.22	1.37	1.06	0.91	0.91	0.76	0.76	0.76	1.22	0.30	0.61	1.37	0.61	0.61	—	0.15	0.61	0.76	0.61	0.61	3.50	0.76	0.46	1.22
ap	—	—	—	0.67	—	0.34	—	—	—	—	0.34	—	—	0.34	0.34	—	—	—	—	—	0.34	—	1.01	0.34	—	0.34
or	37	39	42	42	35	40	36	36	34	41	38	34	34	37	42	38	43	37	42	43	48	46	27	36	36	53
ab	56	51	49	49	57	54	64	59	61	54	62	66	66	63	58	58	57	63	58	57	52	54	45	64	61	47
an	7	10	9	9	8	6	0	5	5	5	0	0	0	0	0	4	0	0	0	0	0	0	28	0	3	0
Q	66	66	59	55	75	96	84	79	79	86	71	58	59	75	79	91	73	81	81	89	90	90	35	72	79	90
fo	4	5	7	9	2	4	2	1	1	0	1	9	8	3	2	0	4	1	0	0	1	0	32	5	11	0
fa	30	29	34	36	23	0	14	20	20	14	28	33	33	22	19	9	23	18	19	11	9	10	33	23	10	10

47. Soda-diopside-anorthoclase trachyte; P'aektu-san (Ogura, T., 1951, Chemical composition of igneous rocks of Manchuria no. 63, *in* Geology and Mineral Res. Far East).
48. Yellow augite-anorthoclase trachyte; Maan-san, P'aektu-san (same as above, no. 62).
49. Fayalite-augite-anorthoclase-trachyte; (same as above, no. 61).
50. Yellow augite-olivine-anorthoclase-potash oligoclase trachyte; Mach'ŏnmol, P'aektu-san (same as above, no. 60).
51. Fayalite-soda diopside-anorthoclase trachyte; Mach'ŏnmol, P'aektu-san (same as above, no. 59).
52. Fayalite-augite-anorthoclase trachyte; (same as above, no. 58).
53. Fayalite-soda diopside-anorthoclase trachyte; in the vicinity of Changbaek hot spring, P'aektu-san (same as above, no. 57).
54. Alkali hornblende-fayalite-soda diopside anorthoclase pantellerite; P'aektu-san formation (same as above, no. 40).
55. Anorthoclase-soda diopside trachyte; south of P'aektu-san formation (same as above, no. 56).
56. Anorthoclase trachyte; in the valley of Mach'ŏnmol, P'aektu-san (same as above, no. 55).
57. Alkali-trachyte obsidian; Pyŏngsiam, P'aektu-san (Lacroix, A., 1927, Les rhyolites et les trachyte hyperalcalines quartzifères, à propos de la Corée: *Comptes Rendus*, Tome 185, p.1414).
58. Fayalite-bearing soda diopsidic-aegirine-augite-anorthoclase trachyte; at the foot of the east wall of Talmun, P'aektu-san (Watanabe, T., 1934, *Volcanol. Soc. Japan, Bull.*, v. 2, p. 65).
59. Fayalite-soda diopside-anorthoclase trachyte; at the foot of Taejong-bong, P'aektu-san (Watanabe, T., *ibid.*).
60. Trachyte à silice libre (2^e facies) (hakutoite); (Lacroix, A., 1927).
61. Hyalo-pantelleritic trachyte; top of P'aeg-am, P'aektu-san (Nemoto, T., 1935, *Japan. Assoc. Mineralogists, Petrologists and Econ. Geologists Jour.*, v. 14, p. 157).
62. Aegirine-soda diopside-anorthoclase pantellerite; Mach'ŏnmol, P'aektu-san (Ogura, T., 1951, no. 37).
63. Aegirine-riebeckite trachyte (pantelleritic); at the top of P'aektu-san (Kōzu, S., and Seto, K., 1929, Abstract of paper from the 4th Pacific Sci. Congress Java, v. 2, B, p. 1067).
64. Hyalopantellerite; P'aektu-san (Kōzu, S., and Seto, K., 1922, *Geol. Soc. Japan Jour.*, v. 29, p. 215).
65. Quartz-glassy pantellerite; on the side of P'aektu-san, P'aeg-am (Ogura, T., same as 62, no. 34).
66. Comendite (facies à lithophyses); P'aektu-san (Lacroix, A., 1927 [item 57], p. 1413).
67. Comenditic pantellerite; entrance of Taejong-bong trail, P'aektu-san (Nemoto, S., 1935, cited under sample 61).
68. Pantellerite (facies à lithophyses); P'aektu-san (Lacroix, A., 1927 [item 57], p. 1413).
69. Olivine labradorite-soda anorthoclase-trachybasalt; gravels scattered at the top of Taejong-bong, P'aektu-san (Ogura, T., 1951, no. 92).
70. Nordmarkitic ejecta; at the top of P'aektu-san (Suzuki, J., 1938, *Hokkaidō Imp. Univ., Fac. Sci. Jour.*, ser. IV, v. 4, p. 180).
71. Pumice (comendite type); at the top of P'aektu-san (Kōzu, S., and Seto, K., 1929. [item 63], p. 1067).
72. Pantellerite (facies vitreux); P'aektu-san (Lacroix, A., loc. cit. [item 57], p. 1413).

Note: 69–72, eruptive material of the Pleistocene age.

Table 23. Chemical Composition of Rocks From Hoeryŏng and Chongsŏng.

No.	h	i	j	k	l	m	n	o
SiO_2	46.22	47.08	49.27	50.26	58.43	47.82	50.75	59.74
Al_2O_3	16.33	13.41	20.30	19.23	21.73	17.98	18.07	20.59
Fe_2O_3	1.24	2.85	0.41	1.00	1.56	2.88	2.91	2.21
FeO	7.40	7.19	7.82	3.89	1.75	6.74	6.39	1.35
MgO	7.88	3.97	6.43	3.21	0.88	3.86	0.07	0.17
CaO	8.46	12.38	10.84	7.70	2.53	8.96	8.85	2.44
Na_2O	4.33	4.83	1.78	7.69	6.03	2.66	3.00	7.88
K_2O	2.25	4.91	0.51	4.39	5.24	5.88	6.33	4.09
TiO_2	2.78	0.57	1.62	1.93	none	0.62	0.72	0.23
P_2O_5	0.54	0.10	0.14	—	none	0.37	0.91	none
MnO	0.17	0.14	0.33	0.08	0.03	—	0.04	none
$H_2O\pm$	1.74	0.39	0.60	0.93	1.23	1.72	1.67	1.38
H_2O-	0.13	1.81	0.13	0.29	0.34	0.67	0.54	0.02
CO_2	0.41	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Cl	n.d.	n.d.	tr.	n.d.	0.49	0.31	0.27	0.58
Total	99.88	99.59	100.18	100.60	100.24	100.47	100.52	100.68
Anal.	Raoult	Seto	Seto	Seto	Seto	Seto	Seto	Seto
Norms								
Q	—	—	0.60	—	—	—	—	—
C	—	—	—	—	1.53	—	—	—
or	13.34	28.91	2.78	26.13	31.14	32.53	37.25	24.46
ab	15.46	6.81	15.20	6.29	44.01	—	11.00	51.87
an	18.63	0.56	45.87	4.73	12.51	19.46	17.24	8.62
lc	—	—	—	—	—	1.96	—	—
ne	10.93	18.18	—	31.81	3.69	12.21	7.67	7.95
wo	8.24	13.46	3.02	14.04	—	9.28	8.82	1.51
en	5.40	6.50	16.10	8.00	—	4.70	0.20	0.40
fs	2.24	6.73	11.88	3.30	—	4.36	8.32	0.26
fo	10.01	2.38	—	—	1.54	3.50	—	—
fa	4.59	2.65	—	—	1.53	3.47	—	—
mt	1.86	4.18	0.70	1.39	2.32	4.18	4.18	3.25
il	5.32	1.06	3.04	3.65	—	1.22	1.37	0.46
ap	1.34	0.34	0.34	—	—	1.01	2.02	—

h. Basanitoid; Undusŏng, P'arŭl-myŏn, Hoeryŏng-gun, Hamgyŏng-pukto, Korea (Lacroix, A., 1928, *Bull. Geol. Soc. China*, v. 7, p. 28).

i. Trachydolerite; same locality as above (Kōzu, S., and Seto, K., 1922, *Jour. Geol. Soc. of Japan*, v. 29, p. 217).

j. Olivine trachybasalt; top of Sansŏng-san, Hoeryŏng-ŭp, Hoeryŏng-gun (Kōzu, S., and Seto, K., 1929, Proc, 4th Pacific Sci, Cong., Java, v. 2, B, p. 1067).

k. Trachydolerite with sodalite and analcite; north side of Sansŏng-san, Hoeryŏng-ŭp, Hoeryŏng-gun (Kōzu, S., and Seto, K., *ibid.*, p. 1067).

l. Sodalite microsyenite; Yŏndae-bong, Pyŏksŏng-myŏn, Hoeryŏng-gun (Kōzu, S., and Seto, K., *ibid.*, p. 1067).

m. Alkali-gabbroid rock (fine-grained); Nanchuri, Shokwamen, Chongsŏng-gun, Hamgyŏng-pukto, Korea (Kōzu, S., and Seto, K., 1926, *Proc. 3rd Pan-Pacific Sci. Cong.* Tōkyō, v. 1, p. 781)

n. Alkali-gabbroid rock (coarse-grained); same locality as above (Kōzu, S., and Seto, K., 1926. ibid.).

o. Sodalite microsyenite; same locality as above (Kōzu, S., and Seto, K., 1926, *ibid.*).

Table 24. Chemical Composition of Rocks From Manchuria, Taiwan and China.

No.	p	q	r	s	t
SiO_2	43.03	47.56	48.10	48.74	48.98
Al_2O_3	14.25	13.21	15.64	15.84	14.12
Fe_2O_3	6.91	6.65	6.80	6.90	2.25
FeO	4.26	2.98	2.78	2.82	7.40
MgO	8.01	3.59	3.80	3.85	7.98
CaO	11.55	5.04	7.77	7.88	10.30
Na_2O	3.73	4.20	2.61	2.65	2.61
K_2O	2.61	4.64	3.49	3.54	1.61
TiO_2	1.76	4.23	2.26	2.29	2.88
P_2O_5	0.28	2.21	1.66	1.68	0.30
MnO	0.41	—	tr.	—	0.15
H_2O+	2.34	5.11	4.40	4.46	1.03
H_2O-			1.32		0.32
CO_2	1.55	n.d.	n.d.	n.d.	n.d.
Total	100.72	99.42	100.63	100.68	99.93
Anal.	Murata	Kōno	Kōno	Kōno	Yagi
Norms					
Q	—	—	3.60	3.36	—
or	15.57	27.74	20.57	21.13	9.45
ab	7.34	35.11	22.01	22.53	22.01
an	14.46	3.34	20.57	20.85	21.96
ne	13.06	0.28	—	—	—
wo	12.99	1.97	2.90	3.02	11.37
en	11.20	1.70	9.50	9.60	12.30
fs	—	—	—	—	4.49
fo	6.16	5.11	—	—	5.39
fa	—	—	—	—	2.14
mt	9.98	—	2.55	2.32	3.25
hm	—	6.72	5.12	5.28	—
il	3.34	6.38	4.26	4.41	5.47
pf	—	1.50	—	—	—
ap	0.67	5.04	4.03	4.03	0.67
cc	3.50	—	—	—	—
or	42	42	32.5	33	17
ab	19	53	35	35	42
an	39	5	32.5	32	41
Q	23	7	49	48	19
fo	77	93	51	52	58
fa	0	0	0	0	23

p. Barkevikite monchiquite; P'i-tzu-wo, Kuan-tung Province (Ogura, T., 1933, *Mem. Ryojun Coll. Eng.*, v. 6, no. 9).

q,r,s. Teschenite; near Lu-k'u, T'ai-pei Province, Taiwan (Ichimura, T., 1932, *Geol. Mag.*, v. 69, p. 72).

t. Olivine trachybasalt; Wei-chou Tao, Kuang-tung Province, China (Yagi, K., 1949, *Kagaku* [Science], v. 19, p. 331).

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