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MEMOIRS OF THE COLLEGE OF SCIENCE, UNIVERSITY OF KYOTO, SERIES B,
Vol. XX, No. 4, Article 8, 1953.

Nepheline Basalt of the Chihsia District, Shantung, North China

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(Received Aug. 14, 1953)

Abstract

A new nepheline basalt, and perhaps the fourth to have been found, in East Asia is here described. Its mesa-shaped lava flows, resting on gravel beds, are attractive. The rock is typical in mineral and chemical composition, and sometimes has pegmatoid segregations and olivine nodules. Olivines and chrome diopsides in olivine nodules from nepheline basalt, and from ordinary olivine basalt seem, respectively, to show very similar mineralogical characteristics.

The significance of olivine nodules as an origin of nepheline basalt is considered.

Introduction

Forty years ago, B. Koto reported from Yingé-mên. Manchuria, "the first genuine occurrence....of nepheline-basalt in the Koreo-Japanese and Chinese regions." (1912, p. 1.) At nearly the same time, Nagahama[1] became known as a unique locality of the rock in Japan; and for a long time these two have been well-known localities of rock of this kind in these regions[2]. In 1940, I had occasion to visit the Chihsia[3] district in Shantung, North China; and during my hasty geological observations I collected fifteen or more specimens of basalt-looking lava from various portions of Tangshan[4], Hsiao-Tangshan[5], Laochaishan[6], and Fangshan[7]. On microscopic examination I found all of the specimens to be typical nepheline basalt, containing no feldspar. This occurrence of nepheline basalt has been recognized[8], perhaps for the first time, and may be only the fourth known in East Asia.

1. According to S. Yamane's recent address, the Nagahama lava which was under his investigation in 1910, was acknowledged by J. P. Iddings, then on a visit to Japan, to be a nepheline basalt (Yamane, 1953, p. 279).
2. A nepheline basalt, an amygdaloid rock in which nepheline is present not in the form of crystals but as leptomorphic mesostasis, was reported by A. Lanick (1908) from Yangshan, west of the town of Weihsien in Shantung: Cited by Koto (1912, p. 5).
3. 棲霞, 4. 唐山, 5. 小唐山, 6. 老寨山, 7. 方山.
8. A preliminary note on this rock was published some years ago (Harumoto, 1949).

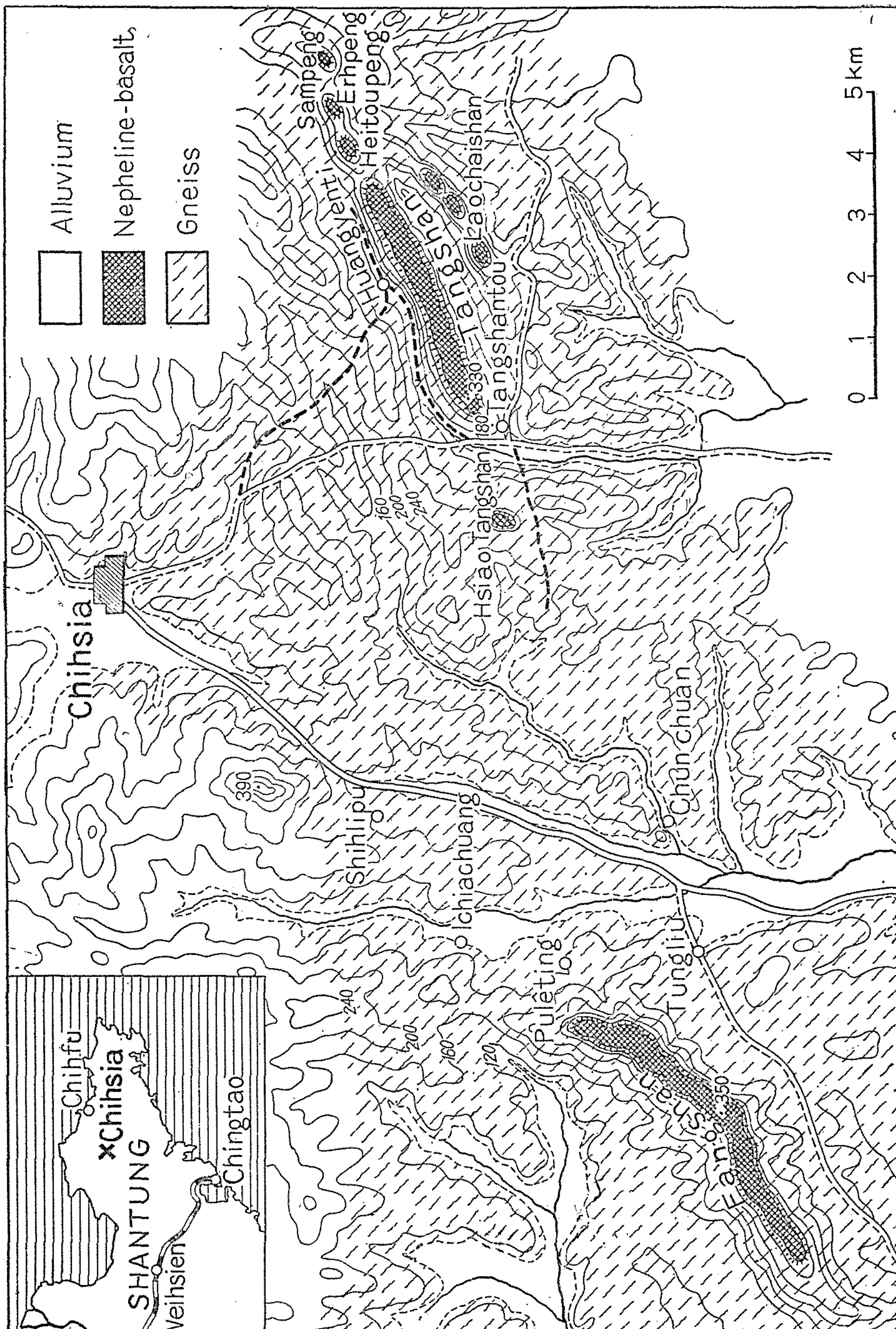

Fig. 1. Geological Map of the Chihsia District.

The lava-covered gold placers of the district were investigated by Fong, who gave a brief account of the geology, and referred to the petrography of the lavas, having regarded them as normal olivine basalt (Fong, 1937).

In this paper, description of field observations and petrography of the nepheline basalt are given. Olivine nodules from this rock and those from various basaltic rocks in Japan were compared, and their petrogenetic significance as an origin of nepheline basalt was considered. In addition, three nepheline basalts of East Asia were compared, in view of their chemical composition and geological features.

Field Relations

The Chihsia district, in the east-central part of the Shantung Peninsula, forms an undulating plateau lying about 150 to 200 m. above sea level, and is drained by a number of small broad-floored tributaries of the Lumpo River. A large part of the area consists of Taishan Complex, the most prevalent of which are gneisses, with the general trend of schistosity NNW-SSE. Lava flows of nepheline basalt occur in several rather small bodies, resting on the higher portions of the dissected plateau (Fig. 1)[1]. Tangshan, 7 km. southeast, and Fangshan, 10 to 15 km. southwest of Chihsia, the main city of the district, are two of the most striking lava-capped table mountains, both with an elevation of about 350 m. above sea level, standing conspicuously on the wavy land.

Tangshan mesa, some 4 km. long and about 300 m. wide, extends in a NEE-SWW. direction. The covering nepheline basalt flows, with a flat upper surface, have an average thickness of about 20 m., their margins being marked with vertical cliffs characteristically jointed (Pl. V, Fig. 1). A nearly horizontal bed of sand and gravel, 5 to 6 m. thick, which has been worked for placer gold, lies under the lava flows; this probably indicates that the lava-flooding took place covering a former river bed.

Near Tangshan Mountain, patches of lavas of much smaller volume also occur, making up several buttes. viz., Heitoupeng[2], Erhpeng[3], and Sampeng[4], northeast of Tangshan; Hsiao-Tangshan in the southwest; and Laochaishan (Pl. V, Fig. 2) and the neighbouring small buttes in the southeast. Some of them seemingly have been separated by erosion from the Tangshan lava-flow body; so that the lava flows appear to have been formerly of much greater bulk. The lava flows, at Laochaishan, are underlaid by an unsorted debris bed, about 3 m. thick, and at Hsiao-Tangshan, by a sand-gravel bed, about 3 m. thick. At the last named place,

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1. The accompanying geological map is only tentative, as an accurate topographical map was not available.

2. 黑頭棚, 3. 二棚, 4. 三棚.

2, 3, and 4: I had no opportunity to visit these three buttes, but to judge from the topographic features, their lava-capped nature is doubtless the lava flows are sporadically covered with a similar sediment, about one m. thick.

Likewise, Fangshan mesa, 5 km. in length, is capped with similar nepheline basalt flows (Pl. V, Fig. 3) the thickness of which is 15 to 20 m., attaining to 40 m. in some places. Here, so far as I have observed, the lava flows rest on the erosion surface of gneiss, without intervening sediments.

All the isolated bodies of the lava flows occur on a level of nearly the same height, and seem to rest on the remnant surfaces of the former peneplain.

Petrography

Nepheline Basalt

The specimen (No. 8) collected from the summit of Laochaishan, is fairly fresh, and the rock, dark bluish-gray in colour, is almost aphanitic with very few phenocrysts of olivine and augite, and with minute drusy cavities which can be detected under a hand lens.

In thin sections the rock is found to have the following mode (by volume):

Augite	53.6
Nepheline	27.3
Olivine	9.2
Magnetite	8.9
Zeolites	0.7
Glass	0.3
Apatite and Biotite	trace

Optical properties and grain sizes of constituents are as follows:

Phenocrysts

Olivine .... $\beta=1.700$, $2V\,(-)=85.4°$ (Fa_{23}), nearly colourless
(0.5 mm. in diameter)

Augite .... $\alpha=1.708$, $\beta=1.715$, $2V(+)=48.5°$, $c\wedge Z=50°$ (wedge-shaped areas of hourglass structure) and 40° (lateral areas), X, Y: light grayish green-brown
(0.2 to 0.5 mm. in diameter)

Groundmass

Augite .... $\alpha=1.700$, $c\wedge Z=54°$, olive-green, weakly pleochroic
(0.06 mm. in diameter)

Nepheline .... $\omega=1.5481$
(0.04 mm. in diameter)

Analcime.................. $N=1.4859$

Phillipsite .... $\alpha=1.465$, $c\wedge Z=18°$
(0.1 mm. in diameter)

Glass .... $N=1.5116$, colourless

Olivine occurs in subhedral grains, penetration twinning on 011 being usual. Its inclusions are rare except for a few grains of magnetite. Augite occurring as rare phenocrysts is often zoned, and in some cases the middle zone is higher in refractive indices than either the inner or outer zone. Hourglass structure is usual. Groundmass augite is prismatic in habit, often showing twinning on 100. Hourglass structure and zoning are lacking. Nepheline is usually clear and unaltered, and often shows equant outforms. The mineral encloses minute rods of augite, slender needles of apatite, and small grains of magnetite, the last named seem to be absent in the central portion of the host crystal. Extremely minute flakes of deep reddish-brown biotite are rarely interstitially present. Analcime occurs, filling minute drusy cavities, and it encloses apatite and often skeletal crystals of nepheline. Phillipsite, as felty aggregate of prismatic crystals, occurs also, filling the drusy cavities, and it commonly shows a penetration twin.

The texture of the groundmass is notable; the equant or nearly equant crystals of the nepheline are often surrounded by the prismoids of augite, thus resulting in analogical features of so-called clathrate texture (Pl. VI, Fig. 1).

The specimen described above, was chosen for chemical analysis as it seemed to be average of the lavas in character. The result is given in Table 1, along with the norm calculated (analyst: A. Harumoto).

Table 1.

SiO_2	41.13	Norm		
Al_2O_3	12.00	Or		3.06
Fe_2O_3	4.27	An		2.67
FeO	9.94	Lc		7.98
MgO	9.42	Ne		23.92
CaO	10.97	Di	Fs 5.25	34.87
Na_2O	5.22		En 11.57	
K_2O	2.24		Wo 18.05	
H_2O+	0.68	Ol	Fa 4.20	12.59
H_2O-	0.27		Fo 8.39	
TiO_2	2.62	Mt		6.19
P_2O_5	1.32	Il		4.97
MnO	0.17	Ap		3.04
	100.25			

Pegmatoid Segregations

Specimens Nos. 11 and 12, respectively, from Fangshan and Hsiao-Tangshan, differ somewhat from the foregoing in microscopic features, having larger phenocrysts of augite (1 mm. or more in diameter). Moreover, these specimens are characterized with frequent micropegmatoid segregations which occur in irregularly shaped patches, up to 1 cm. across; the coarser-textured patches are markedly in contrast with the usual fine-grained groundmass (Pl. VI, Fig. 2). Large idiomorphic crystals of nepheline ($\omega=1.540$, $\varepsilon=1.534$), 1 mm. or more across, constitute a large proportion of the pegmatoid areas, and the mineral sometimes encloses small, highly euhedral crystals of augite. Interstices among the large nepheline crystals are often occupied by felty aggregates of minute laths of thomsonite ($\gamma=1.525$; birefringence, very weak), and in turn, wedge-shaped interstices of the latter mineral are filled with deep green aegirine augite, brown aenigmatite like mineral, and colourless glass. In one instance, a partly corroded, subhedral augite crystal with longer diameter of 1 mm. is seen to be enclosed in a single large crystal of the nepheline. At the marginal portions of the pegmatoid areas the large nepheline crystals often show an outgrowth into the groundmass of the nepheline basalt. Distinct pegmatoid veinlets were not seen. Residual liquid enriched in soda and volatiles seems to have concentrated in patches at the latest stage of consolidation of the nepheline basalt.

Olivine Nodules

Coarse crystalline olivine nodules and olivine-pyroxene masses up to 2.5 cm. in diameter are found in some specimens, and isolated xenocrysts of olivine which are quite larger than the ordinary phenocrysts are sometimes met with. In one case an olivine xenocryst, 5 mm. across, is seen to be roughly rounded in shape, with a somewhat serrated margin. It is nearly colourless in sections, and has no inclusions except extremely minute drop-shaped matter. The narrow peripheral zone is slightly altered, and flecks of iddingsite occur abundantly in it. The refractive indices of this olivine are distinctly lower than those of the ordinary phenocrysts of the host nepheline basalt:

$$\alpha=1.660 \qquad \beta=1.675 \qquad \gamma=1.692$$

The olivine xenocrysts often show a characteristic lamellar structure, which is faintly perceptible between the crossed nicols.

In some cases, olivine nodules (Fangshan No. 9) consist essentially of almost colourless olivine ($\beta=1.675$, $\gamma=1.692$), associated with small amounts of deep, emerald green pyroxene, together with accessory picotite and spinel. Refractive indices[1] of this pyroxene are:

$$\alpha=1.678 \qquad \beta=1.688 \qquad \gamma=1.703$$

This is a chrome diopside. Though this mineral has a distinguishing deep emerald green colour in grains, it shows only a very faint greenish tinge in ordinary thin sections, and attracts no special attention in rock slices.

It is worthy of notice that the olivine nodules often show rounded outforms, and that the melting phemonema of nodular olivine crystals are not unusual.

Comparison of Olivine Nodules taken from Nepheline Basalt, with those from Olivine Basalt

Association of olivine and chrome diopside is seen in olivine nodules not

1. Quite similar refractive indices: $\alpha=1.674$, $\beta=1.685$, $\gamma=1.706$ of a chrome diopside (Cr_2O_3 $=0.98$ per cent) were reported by J. Harada (1943) from the dunite of Mt. Higashi-Akaishi, Ehime Prefecture, Japan.

only from nepheline basalt but also from ordinary olivine basalt. These minerals described above and those in some olivine nodules from nepheline- and olivine basalt of various localities in Japan were spectroscopically analysed[1]; the result is given in Table 2A. Refractive indices of these minerals together with those of some unanalysed are given in Table 2B.

Table 2A. Spectroscopic Analyses of Olivine and Chrome Diopside in Olivine Nodules.

		Si	Al	Fe	Mg	Ca	Na	Mn	Ti	Cu	Co	Ni	Cr	V	In
Olivine	1	+++	±	+++	+++	±	–	+	–	s.tr	–	+	s.tr	–	–
〃	3	+++	–	+++	+++	–	–	+	–	tr	–	+	–	–	–
〃	4	+++	±	+++	++++	s.tr	–	+	±?	s.tr	–	+	tr	–	–
Chrome diopside	I	+++	+	+++	++++	++	s.tr	+	+	–	–	tr	tr	tr	–
〃	II	+++	–	+++	++++	++	s.tr	+	tr	tr	–	tr	tr	s.tr	–

Note: ++++> +++> ++> +> tr> s.tr> ± ; (s.tr=small trace).
Specimen numbers correspond to those under Table 2B.

Table 2B. Refractive Indices of Olivine and Chrome Diopside in Olivine Nodules.

Olivine	1	2	3	4	5	6	7
β	1.675	1.677	1.672	1.667	1.667	1.674	1.673

		α	β	γ
Chrome diopside	I	1.678	1.688	1.703
〃	II	1.673	1.685	1.704

1. From nepheline basalt (No. 9), Fangshan, N. China.
2. From melilite-nepheline basalt (No. 32), Nagahama, Japan.
3. From olivine basalt (No. 14), Takashima Islet off the north shore of Karatsu City, Japan.
4. From olivine basalt (No. 28), Mt. Myojin-yama, Okayama Prefecture, Japan.
5. From olivine basalt (No. 27), Mt. Arato-yama, Okayama Prefecture, Japan.
6. From olivine basalt (No. 115), Mt. Oyama, 6 km. northwest of Tsuyama City, Japan.
7. From limburgite (No. 18), Sukumozuka, 6 km. southwest of Tsuyama City, Japan.

I. From the same olivine nodule as 1 (above).
II. From the same olivine nodule as 3 (above).

Both kinds of the minerals in nodules seem respectively not to show any marked difference of their mineralogical character. Generally the olivines in nodules

1. I am indebted to T. Sonoda for these spectroscopical analyses.

are of distinctly earlier crystallization than the ordinary constituent olivines of nepheline basalt and of olivine basalt. From their mineral association, mineralogical nature, and mode of occurrence, the olivine nodules found in both the kinds of rocks seem to have a common origin, and presumably are of earlier segregations from olivine basalt magma.

Comparison of Three Nepheline Basalts of East Asia

For comparison, chemical analyses of the nepheline basalts from three known localities in East Asia along with Daly's average are shown in Table 3.

Table 3.

	1	2	3	4	5
SiO_2	41.13	36.00	35.92	44.93	39.87
Al_2O_3	12.00	12.87	12.77	15.56	13.53
Fe_2O_3	4.27	5.55	5.85	5.15	6.71
FeO	9.94	9,63	9.35	7.30	6.43
MgO	9.42	8.68	8.00	3.31	10.46
CaO	10.97	16.28	13.93	9.20	12.36
Na_2O	5.22	3.64	3.84	5.34	3.85
K_2O	2.24	1.85	2.45	1.29	1.87
H_2O+	0.68	2.03	3.25	3.77	2.22
H_2O-	0.27	0.59	—	—	—
TiO_2	2.62	1.74	2.71	2.89	1.50
P_2O_5	1.32	1.55	1.62	0.43	0.94
MnO	0.17	0.31	0.31	0.23	0.21
Total	100.25	100.77	100.00	99.49	

1. Nepheline basalt, Laochaishan, the Chihsia district.
2. Melilite-nepheline basalt, Nagahama, Japan. A. Harumoto, analyst (Harumoto, 1952, p. 74).
3. "Nepheline basalts", average of 4 analyses. Nagahama, Japan. Data for calculation: Iddings, 1913, p. 307; Ichikawa, 1934, p. 80; Sugawara, et al., 1945 p. 722.
4. Nepheline basalt, Yingé-mên, Manchuria. Total includes S=0.04. S. Shimidzu and T. Ohashi, analysts (Koto. 1912, p. 12).
5. Nepheline basalts, Daly's average of 26 analyses. H_2O+ includes CO_2=0.29 (Daly, 1933, p. 25).

Three nepheline basalts show considerable variation in chemical composition. Nagahama rocks are distinctly low in silica and high in lime, and so-called "nepheline basalts" of that locality are allied to melilite-nepheline basalt in chemical composition. On the other hand the Yingé-mên rock is peculiarly high in silica and alumina, and has fairly abundant normative feldspars. Lacroix has called it Mandchourite (1928, p. 57). Only the Chihsia rock is nearly typical nepheline basalt and its chemical composition is fairly close to the average found elsewhere in the world.

Comparison of the geological features of three occurrences is shown in Table 4.

Table 4. Geological Comparison of Three Nepheline Basalts in East Asia.

Locality	Chihsia	Nagahama	Yingé-mên
Dimension of lava flows	3.5 sq. km.(1); thickness, 20 m., ca.	1.6 sq. km.(2); thickness, less than 50 m.	80 sq. km.(3); thickness, unknown
Underlying rocks	Sand and gravel, gneiss	Andesitic pyroclastics, rhyolite, phyllite	Granite
Spatially nearest lavas, possibly having genetical relation	Basalt, 60 km. north	Limburgite, 10 km. southwest	Basalt, immediately east

(1). Considerable portion seems to have been eroded away.
(2). Denudation seems to have been slight.
(3). Estimated from Koto's geological map (1912, Pl. II).

It is noticeable that the occurrences of the nepheline basalts are very sporadic, without any association of other strongly alkaline rocks. Moreover the dimensions of the lava flows are remarkably small in either case[1], as is usual with nepheline basalts in other regions of the world.

Age of the Nepheline Basalt

As to the age of the Chihsia lava flows, Fong (1937, p. 35) supposed it to be of Lower Pliocene. The topography of the lava-capped tables seems to suggest the remnants of the initial surface of the flows. The sediments, covered by the lava flows, are rather incoherent, and seem not to be of very old deposition. The lava seems to have flowed over the peneplain before erosion had deepened the present valleys, because the lava bodies, separated one from another, as stated before, now rest at nearly the same horizon. The Chihsia nepheline basalt is likely not to be older than Pleistocene age; conclusive evidence, however, is lacking.

Petrogenesis

Rare and sporadic occurrences and trifles in volume seem to be usual features of nepheline basalts. In the Pacific region alone, aside from the above-mentioned localities, occurrences of these rocks have been reported from a few places, viz., Ponape (Yoshii, 1936), Truk (Kinoshita, 1936), Oahu (Cross, 1915; Winchell, 1947), Samoa (Washington, 1917, p. 675), Tasmania (Paul, 1906), New Zealand (Turner and Verhoogen, 1951, p. 149), and New South Wales (Card, 1902); and

1. The Yingé-mên lava seems to be rather bulky; its dimension, however, is uncertain, as Koto said: "It was impossible for me to ascertain exactly the mode of occurrence of this (nepheline) basalt in my hasty journey through the snow-covered region...." (1912, p. 7).

in nearly all cases the lava seems to be always small in volume. This must be significant of one origin of nepheline basalt. Independent and extensive reservoirs of nepheline basalt magma are unlikely to exist, at least in shallow portions of the crust, so that plutonic representatives of the magma are still seldom met with. Vast flows of ordinary olivine basalt are usually uniform in petrographic character, while the small separated bodies of lava flows or of dikes are often variegated; and this may be due to local differentiation in a magma reservoir. Nepheline basalts are more likely to be products of a local and accidental differentiation in a deep-seated olivine basalt magma, the products in rather small quantity being poured out, on rare occasions, through abyssal vents. It is natural that transition types should exist between nepheline basalt and ordinary olivine basalt; in Oahu, recently, Winchell (1947) reported an association of numerous small bodies of basanite, nepheline basalt, and other allied lavas.

The inclusion of olivine nodules and allied crystalline masses in nepheline basalts is very common. Similar inclusions are not uncommon also in olivine basalts. A close affinity of the petrographic character of the olivine nodules in both the rocks seems to be significant for genetical relation between these rocks. I pointed out, elsewhere, that the olivine nodules and pyroxene-bytownite masses found in the nepheline basalt of Nagahama had their origin in earlier segregation from olivine gabbroic (basaltic) magma; and I attached importance to the evidence for formation of the augite and nepheline along a reaction zone between the hypersthene and bytownite of the nodules (Harumoto, 1952).

Not a few microscopical evidences of remelting, reaction, or resolution of nodular minerals such as olivine, pyroxene, or basic plagioclase can be observed. Markedly rounded outforms of nodular inclusions are very common. An accumulation of the earlier crystals, their subsequent reactions with inter-crystal liquid, and slowness of diffusion in the liquid may cause heterogenuity in a basaltic magma reservoir. Conversion of olivine into pyroxene may form locally undersaturated liquid; and the latter may, by accidental disturbances in the reservoir, encounter a residual liquid which was locally formed and enriched in soda. Local formation of a liquid with nepheline basaltic composition in the basaltic magma reservoir is thus to be expected. Contribution of hypersthene and bytownite for the formation of nepheline and augite rock may be another factor.

A part of this investigation was carried out with the aid of an Education Ministry grant for natural science. Thanks are due to Mr. Fumio Kizaki by whose aid the field investigation was accomplished.

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Explanation of Plates

Plate V

Fig. 1. The southwestern part of Tangshan Mesa capped with the nepheline basalt flows. Looking southeastward. The uppermost portions surrounded by cliffs are of nepheline basalt. Several pits for the gold placer deposit, now unused, are seen indicating a horizon of

the thin bed composed of sand and gravel between the lava flows above and the gneiss below.

Fig. 2. The summit of Laochaishan capped with nepheline basalt, showing a remarkable columnar joint.

Fig. 3. Fangshan Mesa. Looking southwestward. The upper limits of snow-covered portions roughly indicate the boundary between the nepheline basalt above and the gneiss below.

Plate VI

Fig. 1. Nepheline basalt from Laochaishan (No. 8). Phenocrysts with cracks are olivine. In the groundmass: nepheline (white, roughly rectangular, six-sided, or amoeboid forms); augite (gray, minute rods); iron-ore (black grains). ×48.

Fig. 2. Pegmatoid patch in nepheline basalt from Fangshan (No. 11). n: nepheline (white, large sub-idiomorphic crystals); th: thomsonite (aggregates of slender laths); ä: aegirine augite (wedge-shaped, among thomsonite laths); a: augite; o: olivine. The groundmass of nepheline basalt appears partly near the margin of the figure. ×48.

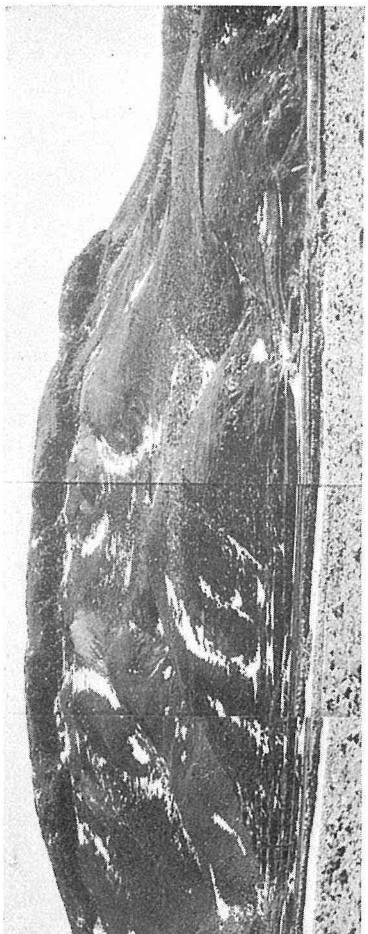

Fig. 1. Tangshan Mesa, capped with Nepheline Basalt.

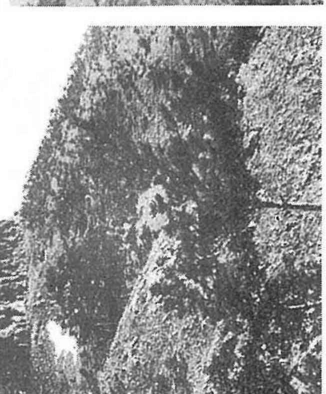

Fig. 2. The Summit of Laochaishan.

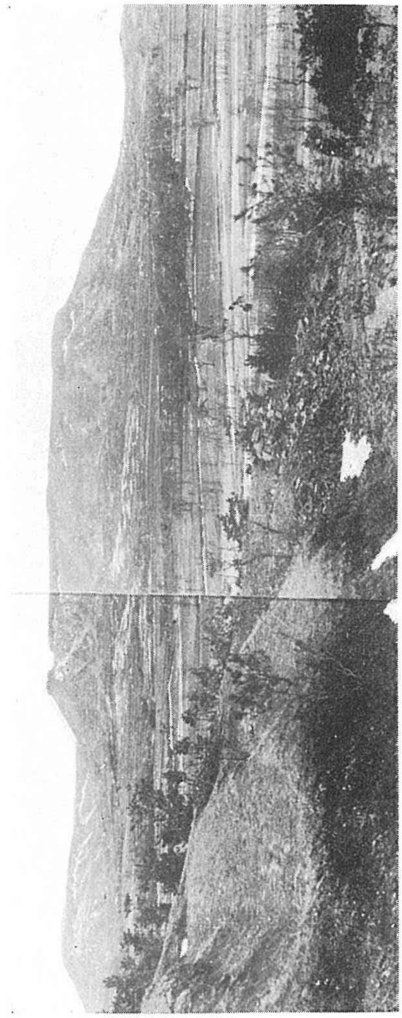

Fig. 3. Fangshan Mesa, capped with Nepheline Basalt.

Photo by the author.

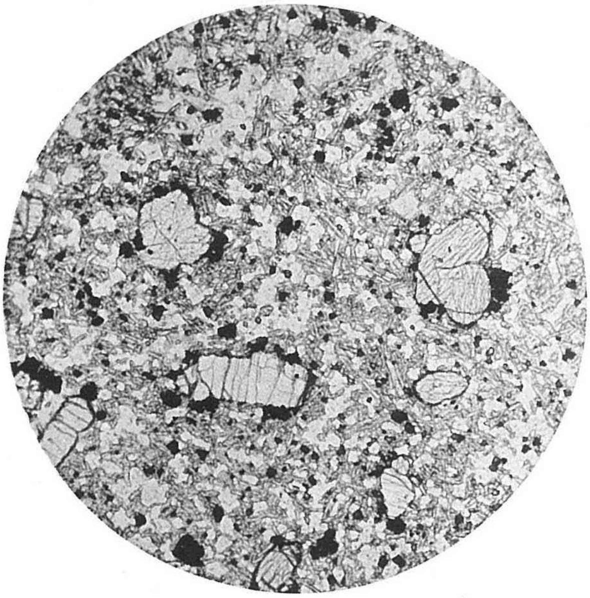

Fig. 1.

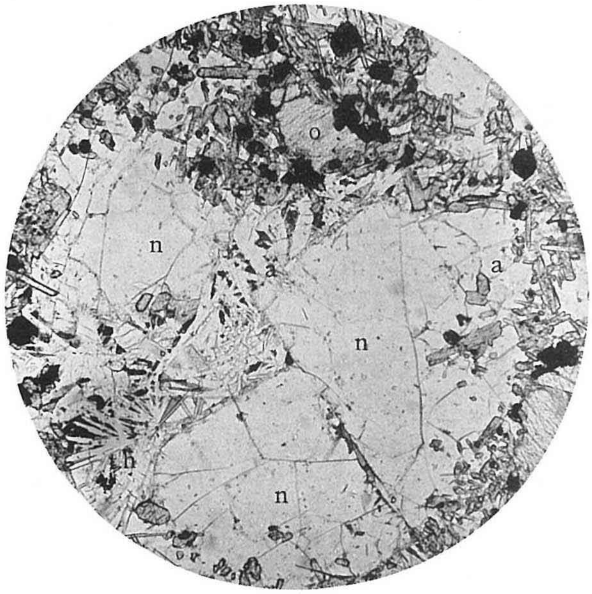

Fig. 2.