Volcanoes in Manchuria

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I. GENERAL REMARKS

1. Introduction

The earliest description of a Manchurian volcano was made by a Chinese governor in the year following the eruption of Uyunhordongi in north Manchuria (1720). Since the middle of the 19th century, survey reports on the same volcano have been issued by many Russians. Hakutosan (Chang-pai-shan) in southeastern Manchuria was famous for many centuries as a holy place in Manchuria-Korea. Scientific research on the volcano began in 1920; the geological works by YAMANARI of the Geological Survey of Korea and WATANABE of Hokkaido University are notable. In 1919 and 1922, SOWERBY, an English naturalist, published a note on the crater lakes of Lung-wan volcano in eastern Manchuria. TANAKA (1924) and NIINOMI (1930) described the volcanoes of Manchuria, but their observations seem rather incorrect. Since the establishment of Manchoukuo (1932), the Harhintun volcano in western Manchuria was studied by KIYONO and the Dalinor volcano in western Manchuria by SASAKURA. In 1935, a geological and volcanological survey of Manchurian volcanoes was undertaken by members of the College of Engineering in Port Arthur under the leadership of OGURA. Five volcanic districts were studied: the Wu-ta-lien-chi volcano of northern Manchuria in 1935, the Erh-ko-shan volcano of northern Manchuria in 1936, the Chi-hsing-shan volcano of central Manchuria in 1938, the Lung-wan volcano of eastern Manchuria in 1940 and 1942, and the Chang-pai-shan volcano of southeastern Manchuria in 1942 and 1943.

For the former three volcanoes, survey reports were published in 1936, 1937 and 1939 as Nos. 1, 2 and 3 of "Survey Reports of Volcanoes in Manchuria." For the latter two, however, maps, notes, rock specimens and other research materials were all unfortunately lost at the end of the war.

2. Regional Distribution of Volcanoes

Some 16 volcanic groups are found in Manchuria, as described in many reports and unpublished papers. They are distributed in the central, southeastern, southwestern and northern provinces (see Fig. 1).

In the central provinces, including the Chi-lin, Ssu-ping and Mukden districts, the (1) Ta-tun, (2) I-tung and (3) Chi-hsing-shan groups are found in the hilly country of Kung-chu-ling. In the southeastern provinces, including An-tung, Tung-hua and Chien-tao districts, three groups of volcanoes occur, (4) Kuan-tien, (5) Lung-wan and (6) Chang-pai-shan. The latter, situated on the Manchuria-Korea border, rise 2,751 m above sea level. Another volcanic group, (7) Da-li-no-erh, is situated on the Manchuria-Mongolia border.

In the northern provinces, six volcanic groups are distributed in Pei-an, Lung-chiang and Hsing-an-ling districts. They are found within a 150 km radius. They are the (8) Erh-ko-shan, (9) Wu-ta-lien-chi, (10) Ko-lo, (11) Ka-tsung, (12) Kan-kuei and (13) Sha-tu volcanoes. The cones of these volcanic groups stand like islets in the hilly country in the east and on mountainous land of moderate relief in the west. In addition, there are two volcanic groups, (14) Ha-r-hin-tun and (15) O-ne-nor, in the Great Hsing-an-ling Mountains, and four cones are found along the Sungari (Sung-hua-chiang) River, east of Harbin.

Each volcanic group consists of more than two cones. In some cases, the boundary between two groups is not clear because of their close proximity, in other cases a single cone represents one volcanic group. The numbers and names of cones in each volcanic group are listed below (Fig. 1).

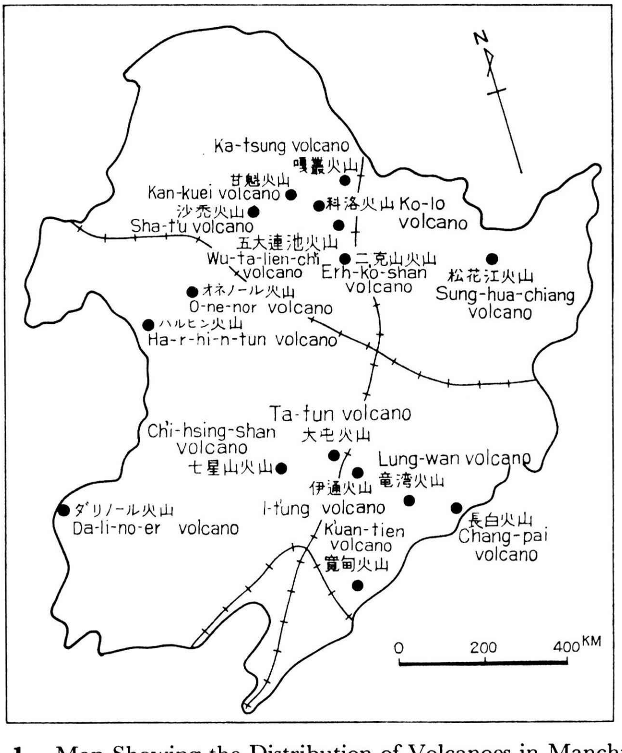

Fig. 1. Map Showing the Distribution of Volcanoes in Manchuria.

Volcanic group (number of cones)	*Main cones*
1. Ta-tun (4)	Ping-lin-shan
	Tung-shan
	Ping-ting-shan
	Chien-shan
2. I-tung (6)	Tung-chien-shan
	Hsi-chien-shan
	Ma-an-shan
	Mo-li-ching-shan
	Ta-ku-shan
	Hsiao-ku-shan
3. Chi-hsing-shan (7)	Tung-ha-la-pa-shan
	Hsi-ha-la-pa-shan
	Po-li-shan
	Po-po-tu-shan
	Nao-pao-shan
	Hsiao-tu-ko-erh-chi-shan
	Ta-tu-ko-erh-chi-shan
4. Kuan-tien (4)	Huang-i-shan
	Ching-i-shan
5. Lung-wan (35)	Hsing-an-nan-shan
	Ta-ting-tzu
	Hsi-heng-tao-shan
	Tung-heng-tao-shan
	Ta-i-shan
	Teng-chia-wang
	Chien-shui-ting-tzu
	Ta-ku-shan
	Hsiao-ku-shan
	Weng-chuan
	Hsiao-weng-chuan
	Ya-pa-kang
	Kuan-tzo-ling
	Shih-men-tzu-shan
	Hsiao-lung-wan
	Erh-lung-wan
	Ta-lung-wan
	Hu-lu-lung-wan
	Tung-lung-wan
	Nan-lung-wan
	Pan-pan-lung-wan
Another group near Lung-wan (20)	Hsi-pai-tzu-lung-wan
Another group near Chang-pai-shan (40)	

	(With parasitic cones)
6. Chang-pai-shan (1)	
7. Da-li-no-erh (10)	
8. Erh-ko-shan (3)	Tung-shan
	Hsi-shan
	Hsiao-ko-shan
9. Wu-ta-lien-chi (14)	Wei-shan
	Mo-la-pu-shan
	Tung-lung-men-shan
	Hsi-lung-men-shan
	Yen-pei-shan
	Tung-chiao-te-pu-shan
	Hsi-chiao-te-pu-shan
	Nan-ko-la-chiu-shan
	Pei-ko-la-chiu-shan
	Huo-shao-shan
	Lao-hei-shan
	Pi-chia-shan
	Wo-hu-shan
	Yao-chuan-shan
West of Wu-ta-lien-chi (1)	Chien-shan
East of Wu-ta-lien-chi (2)	
10. Ko-lo (7)	Tuan-tzu-shan
	Ko-lo-nan-shan
	Ta-i-shan
	Hsiao-i-shan
	Ta-hei-shan
	Hsi-shan
11. Ka-tsung (4)	
12. Kan-kuei (4)	
13. Sha-tu (8)	Sha-ti-erh-shan
	Tu-hu-lu-shan
14. Ha-r-hin-tun (1)	
15. O-ne-nor (1)	
16. Sung-hua-chang (4)	Ma-ku-li

The total number of cones is 176, 17 in the center, over 106 in the southeast, 10 in the southwest, 43 in the north and the remaining 6 in other regions; consequently most of the volcanoes are found in southeastern and northern Manchuria.

3. Arrangement of Volcanoes

Volcanoes are widely distributed over all Manchuria as stated above, but they do not seem to be arranged in any systematical or regular state. They rather have the appearance of being irregularly distributed, each volcano being independent.

The volcanic groups do not run parallel to the direction of the mountain ranges or stratigraphical foldings, but some parts seem to have some relation to the geological structure of the regions.

There is a tendency for the cones to be aligned NE–SW or NW–SE in some groups. For instance, in the Wu-ta-lien-chi volcano in northern Manchuria, 14 cones are separately situated on lines or their intersections which are indicated by NE or NW fissures. In the Lung-wan volcano in eastern Manchuria, over 37 cones are arranged on fissure lines running E–W.

In a region 150 km long connecting the Lung-wan and Chang-pai-shan volcanoes, there are over 90 cones in the midst of dense forests.

There are several groups within a 150 km radius, with Mo-erh-ken at the center. This region lies between the Great Hsing-an-ling Mts. and Little Hsing-an-ling Mts.; here the volcanoes are arranged NNE–SSW along the southeastern foot of the Great Hsing-an-ling Mts. This fact is seen to be closely related to the geological structure of the Mo-erh-ken district near the intersection of two mountain ranges. Next, three volcanic groups, the Chi-hsing-shan, I-tung and Ta-tun volcanoes, are found at the periphery of the Hei-liao Divide which extends from Kung-chu-ling northwest. It is believed to be related to the geological structure based on upheaval of the divide. Thus, the volcanoes in Manchuria scatter irregularly without showing any zonal arrangement as in Japan; in some cases, the arrangement of volcanoes seems to be related to geological structure.

4. Morphology of Volcanoes

According to the state of volcanic activity in Manchuria, volcanoes are classified into three types, those of lava flow, mamelon, and ejecta (such as ash and lapilli). In detail, the volcanoes are classified as follows:

(1) Volcanoes consisting of massive lava.
- (a) Shield volcanoes, such as the Wu-ta-lien-chi and Erh-ko-shan volcanoes, and others in northern Manchuria.
- (b) Lava flows, such as the Wu-ta-lien-chi and Lung-wan volcanoes.
- (c) Mamelon, such as the Chi-hsing-shan, Ta-tun and I-tung volcanoes.

(2) Volcanoes consisting of scoria.
- (d) Cinder cones, such as the Kuan-tien, Da-li-nor, Lung-wan, Wu-ta-lien-chi and Erh-ko-shan volcanoes, and others in northern Manchuria.
- (e) Volcanoes having crater lakes, such as the Lung-wan, Wu-ta-lien-chi and Chang-pai-shan volcanoes.

(3) Volcanoes consisting of massive lava and scoria.
- (f) Stratovolcanoes, such as the Chang-pai-shan volcano.

In the classification, shield volcanoes (a) are characterized by gentle hills on basalt plateaus which lie as the foundation of cinder cones in northern Manchuria. Thus, beautiful landscapes have been formed on the skirts of volcanoes. In the

Wu-ta-lien-chi volcano, the area of such shield volcano is 10–20 km^2 and the lava flows, called "shih-tang," "stone barrier," are often observed on the gentle slope. Shih-tang consists of an aggregate of block lavas 1 m in diameter and the length of lava flow exceeds 4 km in the larger ones. The shield volcano forming the foundation of the Chang-pai-shan volcano is over 100 km in diameter and its uppermost limit is 2,000 m above sea level.

(b) Lava flow is especially prominent in the *shih-lung* lava field of the Wu-ta-lien-chi volcano and in the *ha-la-tzu* lava flows of the Lung-wan volcano. The *shih-lung* lava forms a lava field of jet-black obsidianic basalt which occupies an area of 68 km^2 like a kind of racket in the central part of the district. This lava poured from the central part of the field in all directions along the slope and ran over an area 8 km long and 1 km wide to the south along a valley corresponding to the racket handle. This lava field has a very gentle slope and is nearly horizontal away from the center. The microtopography of the surface is very conspicous: pahoehoe, ropy and spiny lavas are found; trunk-like, ripple-like, wavy, tabular and reptile-like features are also sculptured on the lava surface. In addition, strange features such as hornito, lava tunnels and depressions are found here and there in the lava field.

There are four basalt lava flows in the Lung-wan volcanic district. These flows ran down through the lower levels or along the valley courses and consist of large and small volcanic blocks; such flows are called *ha-la-tzu,* "waste land of black blocks." In the southern part, the flows, 8 km long and 500 m wide, ran down along the Liang-shui-ho east to west. The second flow issued from the Ta-i-shan crater to the west, and has a length of 6 km and a width of 2.2 km. The third lava flow poured from the Ta-ku-shan crater, ran down the northern mountain slope and turned west along a valley over an area 9 km long and 2 km wide. The fourth flow, the largest in the district, originated in the Chin-lung-ting-tzu cone of the eastern part and ran down along the Hsiang-shui-ho toward the west, 35 km long and 5 km in maximum width. It is also known that several lava flows ran down from the craters of Hu-lu-lung-wan and Nan-lung-wan along the valleys toward the northwest.

(c) Mamelon volcanoes are found around the Hei-liao upwarping zone, as in Ta-tun and I-tung districts in the eastern edge and in Chi-hsing-shan district in the south. They are composed of black, massive basalt. They are mostly mammillary or dome-shaped with a steep slope except for some low humps in the Ta-tun volcano; the basal section is circular or elliptical. The average relative height of the 7 domes in the Chi-hsing-shan volcano is 67 m, the 4 domes in the Ta-tun 28 m, the 6 domes in the I-tung 87 m and the diameter of the basal section is 600–850 m.

(d) Cinder cones are widely and abundantly distributed throughout Manchuria, especially in the northern and southern parts. The structure of cinder cones is simple; they are formed from a mixture of ejecta such as block, lapilli, bomb and ash, sometimes intercalated by lava flow. Such mixed strata measure over 20 m thick and incline toward the outside of the crater at an angle of about 25°. Scoria is porous basaltic rock, irregular in form and size, black or brown in color. Volcanic bombs are abundant and many specimens were collected easily, especially in Lao-shan in Wu-ta-lien-chi, Ta-i-shan, and Shih-men-tzu-shan in Lung-wan and Da-li-nor districts. Small volcanic bombs are 3 cm in size and large ones over 30 cm, mostly fusiform or amygdaloid in form. Basement rocks ejected from the crater consist of granite, sandstone or olivine nodules. Olivine nodules in the Weng-chuan crater of Lung-wan district are over 30 cm in size and abundantly scattered within the crater.

Cinder cones have a similar aspect, the general form being a truncated cone, like an overturned boat seen from the side. The basal section is roughly circular and the angle of the slope does not exceed 30°. In most cases there is one crater on the summit, but there are 4 craters in Wo-hu-shan in Wu-ta-lien-chi district. The crater is circular to elliptical with a diameter of 300–400 m, but the craters of Weng-chuan and Ya-pa-kang in Lung-wan district are over 1,300 m in diameter. The inner wall of the crater inclines steeply, and its bottom has become shallow due to the accumulation of detritus from the wall. The bottom of the crater is sometimes flat, resembling an amphitheater. On the flat bottom of the crater of Yao-chuan-shan in Wu-ta-lien-chi and Tung-shan in the Erh-ko-shan volcanoes, several wooden temples have been built. The depth of the craters varies, being about 50 m on the average. The crater of Lao-hei-shan in Wu-ta-lien-chi district is funnel shaped and 136 m deep, being the deepest in this district. Thus, the truncated cone has a rather large basement compared to its height. The summit is surrounded by a crater ring of similar height, and a part of the crater ring is almost broken. Since this feature of a cinder cone with a broken crater wall resembles an arm chair, there are many cones, such as Ta-i-shan or Huang-i-shan, where the name includes "i" meaning arm chair. The average relative height of the cones, the diameter of the basement, the diameter and depth of the crater in 3 volcanic groups are given in the following table (Table 1).

Table 1

Name of volcano	Number of cones	Relative height (m)	Diameter of base (m)	Diameter of crater (m)	Depth of crater (m)
Wu-ta-lien-chi	14	101.9	828	333	54
Erh-ko-shan	3	68	487	173	30
Lung-wan	27	113	1039	599	90

These cones were not built over a long period of times, but by temporary igneous activity.

(e) Crater lakes exist in Wu-ta-lien-chi, O-ne-nor, Lung-wan, and Chang-pai-shan volcanic districts. In Wu-ta-lien-chi district two cones of Mo-la-pu-shan and Nan-ko-la-chu-shan have crater lakes, but these appear in the crater only in the rainy season and usually swampy. There are no records for the O-ne-nor crater lake, but it was very probably formed by an eruption of the crater.

Eight crater lakes are known in Lung-wan district and its environs, all called lung-wan, "dragon's pit." These lakes have not been known for a long time, because of dense forests in the environs of Hui-nan and Meng-chiang Prefectures.

Table 2

Measurement / Name of crater lake	Lake surface above sea level (m)	Longer dia. (m)	Shorter dia. (m)	Circumference (m)	Area (km^2)	Deepest point (m)	Transparency (m)	Water temp. Surface (°C)	Water temp. Lowest (°C)	Water temp. Bottom (°C)
Hsiao-lung-wan	645	310	250	900	0.064	27	4.0	23.5	—	4.6
Erh-lung-wan	725	750	500	2000	0.28	41.1	10.5	22.5	—	—
Ta-lung-wan	629	1150	800	4175	0.81	88.5	11.45	23	5.0	7.5
Hu-lu-lung-wan	722	1050	300	2900	0.465	76	5.65	24	—	—
Nan-lung-wan	567	750	470	2100	0.20	71.8	4.5	25.5	4.5	5.3
Tung-lung-wan	563	750	730	2300	0.41	123	5.5	23.5	4.4	5.8
Pan-pan-lung-wan	605	1050	750	3200	0.60	117.5	5.5	25	4.25	4.6
Hsi-pai-tzu-lung-wan	745	800	750	2550	0.47	—	—	—	—	—

Their features were obtained by surveys in 1940 and 1942. These crater lakes were formed by water precipitation into the crater or pit on the granite foundation, and they are unusual in depth and temperature distribution compared with other lake waters in Manchuria. Measurement on eight lakes are given in the following table (measured in August, 1940 and 1942): (Table 2).

The crater lakes are circular, elliptical, gourd-like, purse-like or rhombic in shape. The deepest lake is Tung-lung-wan, 123 m deep, followed by Pan-pan-lung-wan, Ta-lung-wan, Hu-lu-lung-wan and Nan-lung-wan, all deeper than 50 m. In depth, these lakes are surpassed only by Tien-chih, a crater lake on the Chang-pai-shan mountain.

The temperature of the lake water, according to measurements in Ta-lung-wan, Tung-lung-wan, Nan-lung-wan and Pan-pan-lung-wan, quickly decreases to a minimum of 4–5°C, 30–35 m below the surface. Below this depth, the tempera-

Table 3. Water Temperature Change of the Lung-wan Lakes.

Name / Depth (m)	Hsiao-lung-wan	Ta-lung-wan	Tung-lung-wan	Nan-lung-wan	Pan-pan-lung-wan
0	23.5° C	23.5° C	23.5° C	25.5° C	25.8° C
5		22.5			
10		13.1	8.2	8.7	11.8
20		6.0	4.7	5.2	5.7
25			4.4		
27	4.6				
30		5.0	4.7	4.7	
35			4.8	4.5	
40		5.7	4.9	5.0	4.7
50		6.5		4.5	
60			5.3		4.3
68		7.0		5.3	
80			5.5		4.25
88		7.5			
100			5.7		4.25
116					4.6
121			5.8		

ture gradually increases at a rate of 0.3°–0.5°C per 20 m (see Table 3). In Ta-lung-wan, for example, the temperature reaches a minimum of 5°C 30 m below the surface, and gradually increases toward the bottom (7.5°C at the bottom, 88 m down). Water temperatures of this sort have never been observed in crater lakes in Japan, except in the Okama crater lake of Zao volcano in Miyagi Prefecture, where such a phenomenon had been observed temporarily.

Inside the crater of Hu-lu-lung-wan, granite cliffs stand high on the southern side, the lava flows appear on the other side, and a granite islet rises above the lake. These features are characteristic of craters of the maar type; that is, a violent explosion occurred in the granite region, resulting in a great pit and new lava flowed out from the pit southwest along a valley. In Erh-lung-wan, granite is exposed in the cliff wall of the crater, and also at the bottom of the Weng-chuan crater.

The lake water of Erh-lung-wan flows out from the southwest corner through a barranco; there is no exit in other lakes. The water level of Ta-lung-wan is the same as the groundwater table in Hsiao-chin-chuan, a small village near Ta-lung-wan. It is believed that the water in both places is connected through volcanic lapilli beds. These eight crater lakes exist in dense forests and provide a combination of mountains, waters and trees, presenting one of the finest landscapes in Manchuria.

Tien-chih, or Lung-wang-tan, on the summit of the Chang-pai-shan volcano, is a caldera lake. The surface of the lake is 2,257 m above seal level, the highest peak of the crater wall is 2,751 m above sea level, and the maximum depth of water was measured at 375 m; therefore, the depth of the crater is 869 m, the deepest in Manchuria-Korea. The crater has a swollen pear shape in the north-western section, is 3 km in length east–west, 4 km north–south, 9.2 km^2 in area and 13.7 km in circumference. Water flows out from Ta-men in the northern part of the lake and runs north through a barranco, forming 60 m high waterfall called the Chang-pai. The lower course is called the Erh-tao-pai-ho, which is the origin of the Sung-hua-chiang River.

(f) Volcanoes composed of volcanic scoria and lava flow consist of cinder cones occasionally intercalated with lava flow as mentioned above, but these do not occur on a large scale. Representative of this type is Chang-pai-shan, composed of an alternation of volcanic ejecta and lava flows. Chang-pai-shan is situated on the border between Manchuria and Korea; and had been known as the highest point Ta-cheng-fen (2,745 m), but in 1943 the highest point was observed to be 2,751.48 m, 95 m west of a triangular survey mark at Ta-cheng-fen. The crater at the summit is nearly circular, 5 km in diameter, and the crater wall is surrounded by peaks over 2,600 m above sea level; the northern section is broken, running through a barranco.

The inner crater wall is steep and a cliff formed by lava flow rises several hundred meters. At the bottom of the crater lies the caldera lake of Tien-chih. Lake water runs out to the north, forming the Chang-pai waterfall.

In the river bed 2 km below the fall (1,800 m above sea level), there are several hot springs called the Chang-pai hot springs. These springs are mostly simple, weakly alkaline springs 80°C in maximum temperature; others are carburetted and weak sulphur springs. Here, the width of the valley is 2 km; both sides, east and west, have steep cliffs rising over 400 m, and the south is bounded by the crater wall of Chang-pai-shan, giving the crater the appearance of like a kettle bottom. The remnants of a lacustrine deposit were found midway up the eastern cliff. The above observations support the existence of an old eruption-type crater lake. At one time, the Tien-chih crater and this eruption-type crater stood side by side in a north-south direction. The outer crater wall is mostly covered with pumice ejecta, and has a gentle slope. Under the pumice cover, pantellerite and alkaline trachyte lava flows intercalated with layers of tuff and agglomerate make up the main body of Chang-pai-shan, and measure several hundred meters in thickness.

The upper limit of tree growth on Chang-pai-shan is 1,800 m above sea level in the east and 2,200 m in the west; a thick forest region exists below these limits.

In this great volcanic mass, the part above 2,200–2,300 m is steeply inclined at 20°–30°; the section below this level down to 1,000 m consists of shield basalt. On the gentle slope at about 2,000 m, there were several parasitic cones 100 m high; the mud lava of the last eruption covers a great area in the lower section.

On the whole, Chang-pai-shan volcano consists of a gentle basalt plateau between 1,000 and 2,000 m above sea level, the major part of alkaline trachyte occupies an area 30–40 km in diameter and the uppermost part of alkaline ryolite has a steeper inclination (10 km in diameter); thus a stratovolcano was formed.

5. Modes of Eruption

In Manchuria, there is no volcano active at present, and except for the two dormant Chang-pai-shan and Wu-ta-lien-chi volcanoes, most are extinct; thus, the mode of eruption can be seen from the structural features of the volcanoes.

In the two volcano types (a) and (b), massive basalt lavas ran slowly and smoothly from the crater. From the great amounts of issuing lava, plateaus or shield volcanoes were formed on the hilly land, and lava flowed (several to 30 km) along the valleys. Type (c) also consists of basalt, but dome-shaped mountains were formed around the crater, with no flow. Such differences seem due to the chemical composition of the lava and the quantity of issuing lava. Type (d), the cinder cone type, has two forms: one has a shield volcano at its base (often seen in north Manchuria), and the other stands directly on the old formation (seen in southeast Manchuria) without any shield basalt. In both cases, these cones are composed essentially of volcanic scoria mixed with some basement blocks. The truncated shape of the cones is not destroyed and the original form has been fairly well preserved.

Lao-hei-shan and Huo-shao-shan, which stand on the Shih-lung lava field in

Wu-ta-lien-chi district, are the product of an eruption in the 59th year of Kanhsi (1720) (ascertained from a reliable document); thus the Wu-ta-lien-chi volcano is only a dormant volcano. In the Ning-ku-ta journal edited in 1721 by Chenchan Wu, it is written that: "There is a lake measuring 30 ri around, northeast of Chichihar City. Great fires and smoke suddenly began to rise high in the sky in the vicinity of the lake in June and July of 1720 and the clap of thunder did not cease day and night for several days, and could be heard 50 ri away. At last the ejected stones, blocks and sulphur formed a mountain, but because of the severe heat spread for at least 30 ri around, it could only be observed from remote highlands. Then the heat became less and less, but still we could approach no closer than several ri." This is a description of the eruption of Lao-hei-shan and Huo-shao-shan. Due to the explosive type of eruption, the lava was ejected as scoria or bombs, and these materials accumulated around the crater to form hills. Stratifcation is more or less observable and even lava flow is intercalated with volcanic scoriaceous layers.

The structure of the cone is rather simple, the feature and structure resemble the island newly formed in the South Sulphur Islands in 1904. The volume of erupted material is greater in Lao-hei-shan, (0.1 km/) than in 13 other cones. Thus the formation of two cones took place in a relatively short time, but the continuation of eruption after birth was deduced to form the accumulation of lapilli measuring over 1 m thick on the lava field near the Lao-hei-shan and Huo-shao-shan craters, and fusiform bombs spread far out.

In other scoria cones, ejecta accumulated and formed cones immediately around the craters, but in the case of Ta-i-shan in Lung-wan district, small bombs were thrown 2 km away from the crater.

There are many examples of scoriaceous truncated cones from the last eruption of lava from the craters. In Huo-shao-shan in Wu-ta-lien-chi, Ta-i-shan, Chin-lung-ting-tzu, Ta-ku-shan, Hu-lu-lung-wan, Nan-lung-wan in Lung-wan district, lava issued from the craters and ran from several to 30 km down the valleys. From the craters of parasitic cinder cones in the northwestern section of Chang-pai-shan, lava flowed out at the last eruption.

On the top of scoriaceous cones (e), there are one or more craters, but because of the loose material and breaking of part of the crater walls, the accumulation of rain water and hence the formation of crater lakes was difficult, this is the reason for the lack of crater lakes in this type of cone. In the eight Lung-wan crater lakes, the compactness of building material the great depths and intactness of the crater walls were favorable for holding precipitation for the formation of lakes. On the whole, the formation of such craters took place during short-term eruptions just as for other cones. The Hu-lu-lung-wan crater is a maar type formed in the granite region.

The above cones were formed one by one in a relatively short time and on a small scale, and the form and structure are simple and similar. The Chang-pai-shan volcano is, however, a much larger volcanic body, unmatched in Manchuria and Korea; its duration, formation and complex structure are characteristic. Volcanic activity occurred in the central part of wide basalt basement, and alkaline trachyte issued forth; lava, tuff and agglomerate accumulated to a thickness of over 300 m, forming the foundation of the volcano. Next, a great quantity of pantellerite lava issued forth attaining over 400 m in thickness. Thus, the main body of Chang-pai-shan was formed.

After formation of the volcanic body, parasitic cones of scoria erupted on the slope and a great quantity of pumice, blown out from the summit, covered wide areas of the slope above 2,000 m; at the same time, a great caldera was formed on the summit. In the last stage, mud-lava flowed from the caldera in all directions, going some 20 km along valleys. Then activity came to an end. To the north of the great caldera an explosion-type crater was produced and a crater lake also formed, but afterwards the lake was destroyed, and the present location of the Chang-pai-shan hot spring is thought to be the bottom of the old explosion crater.

6. Time of Eruption

There is no reliable evidence concerning the time of eruption of Manchurian volcanoes, except for a record of the eruption of Lao-hei-shan and Huo-shao-shan in the Wu-ta-lien-chi volcano in 1720. But judging from the features and geological relations of the volcanoes, the eruption of other cones must have occurred not too long ago, mostly in the Quaternary or a later age. Scoria cones of the Wu-ta-lien-chi volcano lie on a gravel bed, massive cones of the Chi-hsing-shan volcano intruded Diluvial sediments, the ha-la-tzu lava flows of the Lung-wan volcano flowed out along the recent river bed and some scoria cones stand on those lava flows.

At the present time, post volcanic activity is seen only in the Chang-pai-shan volcano. The Chang-pai hot springs of 80°C spout from a spot 2,000 m above sea level north of the Tien-chih caldera. The Tang-chui-ping hot spring of 50°C gushes out at 1,700 m on the western slope, and a hot spring of 30°C has been found at the lake side of Tien-chih within the crater.

Some standing woods preserved under pumice layers as natural charcoal were found at a point 2,000 m above sea level, 3 km southeast of the summit, and the species of buried wood are identified to be the same as modern types. Such a phenomenon seems to indicate an eruption in the not too distant past. The upper limit of tree growth on Chang-pai-shan is 2,200 m above sea level on the west and 1,800 m on the east slope. This may be explained as follows: in the eruption which occurred in the recent past, the falling of pumice was more severe on the east than on the west slope, and trees were burned out on the east side. A recent eruption is also supported by the existence of natural charcoal under the pumice bed. According to tradition, Chang-pai-shan erupted twice, in 1597 and 1702, but it is not clear whether there is any relation between these eruptions and the facts mentioned above.

The Wu-tai-lien-chi volcano, which consists of 14 cones, was called Uyun-hordongi which means 9 mounts in former times. It is thought that the remaining 5 cones were formed in the eruption which occurred after the old mountains were named, but this is not necessarily so. The eruption of 1720 refers to the formation of Lao-hei-shan and Huo-shao-shan and the shih-lung lava field of that district is believed to have already existed at that time; that is, in the Wu-tai-lien-chi volcano 12 cones erupted first, next the shih-lung lava issued forth forming 5 dammed lakes, and then in 1720, Lao-hei-shan and Huo-shao-shan appeared. At the present time no post-volcanic activity is observed in this district. In Lung-wan district, long wide basalt lavas issured from craters of cinder cones and flowed along recently formed river courses.

Basalt flows are dated from two periods in southeast Manchuria; in the former case, the basalt is situated on a high level and covers the high, often dissected, land surface forming a table land. This is seen in the basal lava of Chang-pai-shan and on the top of the high land along the Mu-tan-chiang River. The basalt of the later period lies on a lower level and usually occupies river courses; Ha-la-tzu basalt flows of the Lung-wan volcano and the wide basalt field between the Tiao-shui-lou waterfall hanging on the edge of Ching-po-hu Lake and the old town of Tung-ching-cheng in the course of the Mu-tan-chiang River are outstanding examples.

Hot spring directly related to these volcanoes are rare in Manchuria except for the Chang-pai-shan volcano; other famous hot springs are not concerned with these volcanoes.

7. Characteristics of Volcanic Rocks

Volcanic rocks constituting the volcanoes of Manchuria are wholly basaltic in character except for the alkaline trachyte and pantellerite of Chang-pai-shan and quartz-trachyte of O-ne-nor and Ha-r-hin-tun volcanoes.

Massive rocks of shields in the Wu-ta-lien-chi and Erh-ko-shan volcanoes are black to blackish-gray compact trachybasalt. The constituent minerals are plagioclase, anorthoclase, augite, olivine, magnetite, ilmenite, glass, etc. The shih-lung lava is jet-black obsideanic glassy rock with microphenocrysts of olivine and augite in a glassy groundmass, and sometimes with leucite microphenocrysts, less than 0.1 mm, in size as well as xenoliths of granite pieces and quartz grains. Volcanic cones of the Wu-ta-lien-chi volcano consist of porous black or brown scoria containing microphenocrysts of augite, olivine and leucite, and resembling the above shih-lung lava. Thus these rocks were named "shihlunite" by the author and assigned to alkaline basalt. Other cones in the vicinity of Mo-erh-ken are thought to have the same composition as the above.

Cones of the Chi-hsing-shan volcano consist of black massive microcrystalline to phanerocrystalline rock, both being trachybasaltic varieties. Components are plagioclase, augite, titanaugite, aegirine-augite, olivine, picotite and glass. In

Nao-pao-shan, leucite basalt crops out. The same rocks are found in cones of the Ta-tun and I-tung volcanoes.

In the Lung-wan volcano, the lava flow is massive. In some cases it is black to grayish-black basalt, consisting of oligoclase, augite, olivine, magnetite, biotite and glass, with xenocrysts of olivine. The scoria is black or brown porous rock, resembling the former in mineral composition. It sometimes contains a large quantity of big olivine nodules.

In the Chang-pai-shan volcano, many kinds of rocks are found. The order of eruption is as follows: first came basic basalt, next intermediate alkaline trachyte and last a great quantity of pantellerite issued forth contributing on a large scale to the formation of the volcano. This is the normal order of differential eruption for basaltic magma. In the next stage a small scale eruption of basalt occurred, forming several scoriaceous parasitic cones, succeeded by a pumice explosion from the summit. The nature of the pumice is not clear, but it seems to correspond to alkaline liparite; its chemical composition was described by Dr. Rault as pantellerite. The mud flow, the last period of activity, was of alkaline trachyte.

The mineral components of the volcanic rocks of Chang-pai-shan are as follows: labradorite-olivine-basalt basement has large phenocrysts of plagioclase, and the groundmass consists of plagioclase, augite, iron ore, olivine and glass. Next, the alkaline trachyte is classified into three kinds according to its components: yellow augite-alkaline trachyte, fayalite-yellow augite-anorthoclase-trachyte and fayalite-yellow augite-anorthoclase glassy trachyte. Pantellerite trachyte grades into proper pantellerite and finally into glassy pantellerite. Components of pantelleritic rocks are abundant phenocrysts of anorthoclase and augite, and the groundmass is generally of aegirine-augite or aegirine, cossyrite, riebeckite and glass, sometimes with magnetite, barkevikite and arfvedosonite. The pumice is white, fibrous, silky lustrous and alkaline rhyolitic in character, having abundant phenocrysts of anorthoclase in a colorless groundmass. Xenoliths exploded with pumice forms blocks of basalt, alkaline trachyte, alkaline syenite, kali-granite, etc. Mud lava is brown to black, loose alkaline trachytic rock, containing phenocrysts of anorthoclase with soda pyroxene in a grayish-brown glassy groundmass. In this mud lava several kinds of xenoliths are found of pre-existing rocks. Thus, the volcanic rocks of Chang-pai-shan are alkalic and different from those of other volcanoes in Manchuria.

The chemical compositions of volcanic rocks of Manchuria are shown in the following table (values are the average for each volcano): (Table 4).

In general chemical composition, the percent alkali is comparatively high in every case; in comparison with percent alumina, the trachyte and quartz-trachyte of Chang-pai-shan properly belong to alkaline rock, the leucite-basanite of the Wu-ta-lien-chi and Erh-ko-shan volcanoes is sub-alkaline and the basalt of the Chi-hsing-shan and Lung-wan volcanoes belongs to calc-alkaline rock. But from the mineral composition, these rocks are said to be alkaline in nature. A characteristic difference between rocks of volcanic districts is that the percent K_2O is always

Table 4. Average Chemical Composition (%) of Volcanic Rocks.

	Wu-ta-lien-chi	Erh-ko-shan	Lung-wan	Chi-hsing-shan	Chang-pai-shan		
					Basalt	Trachyte	Pantellerite
SiO_2	50.76	50.99	48.15	45.10	49.96	63.61	67.89
TiO_2	2.38	2.48	2.15	2.04	2.70	0.54	0.35
Al_2O_3	14.37	14.19	17.49	14.65	15.95	16.35	14.91
Fe_2O_3	2.96	4.53	4.14	2.30	3.15	2.66	2.13
FeO	6.10	4.20	7.08	10.07	8.89	3.31	3.40
MnO	0.11	0.10	0.23	0.18	0.21	0.11	0.09
MgO	7.02	5.95	7.47	9.16	4.51	0.25	0.07
CaO	6.60	6.15	7.21	9.30	8.32	1.40	0.84
Na_2O	3.72	4.28	3.23	3.55	3.18	5.28	5.41
K_2O	4.76	5.23	2.16	1.77	1.41	5.18	4.79
P_2O_5	1.04	1.08	0.46	0.58	0.56	0.07	—
$-H_2O$	0.51	0.98	0.15	1.30	0.33	0.33	0.10
$+H_2O$			0.45		0.47	0.31	—
Total	100.33	100.16	100.37	100.00	99.64	99.40	100.98
Number of samples	19	3	13	8	2	9	3

greater than the percent Na_2O in northern Manchuria, but the reverse in the central and southeastern districts. There are many possible explanation of why $K_2O > Na_2O$. Some say it is the result of the assimilation of foundation granite in the northern district, but the foundation is also granite in the Lung-wan district and the volcanic rock often captures granite blocks; the volcanic rock in this district is not rich in K_2O, but is sodic. Therefore it is not likely that the source of the large amount of K_2O in volcanic rocks is the K_2O of granite. Alkaline rocks in the Chang-pai-shan district are also rich in Na_2O. From this point of view, it is assumed that the underground magma was differentiated into kalic and sodic parts which then erupted locally. Where then is the boundary of the kalic and sodic districts? The chemical composition of the ignerous or volcanic rocks in the districts between Erh-ko-shan and Chi-hsing-shan (300 km apart) has not been known, and their boundary probably lies in the intermediate districts.

II. Description of Volcanoes

1. Ta-tun Volcano

There are four domes in the Ta-tun and Han-chia-tun district between Kung-chu-ling and Chang-chun along the Ta-lien-Harbin Railway line. On the east side of the railway, there are Chien-shan (266 m above sea level), Ping-ting-shan (266 m) and Ta-tun-tung-shan (225 m), and on the west, Ta-tun-ping-ling-shan (283 m). The relative height of the domes is under 40 m. They are small aspite types with gentle slopes, and are arranged in two parallel lines NE-SW. The rock is black compact basalt and has columnar joints. It is quarried for railway construction.

2. I-tung Volcano

Six domes of basalt are distributed over an area of 5–15 km, stretching E-W near I-tung, Chilin Province. These are Tung-chien-shan (371 m above sea level) south of I-tung, Hsi-chien-shan (353 m), Ma-an-shan (272 m) and Mo-li-ching-shan (321 m) to the northwest, and Ta-ku-shan (389 m) and Hsiao-ku-shan (270 m) to the south.

They are of mamelon type 50 m high, and stand out above the hilly land. Tung-chien-shan, Hsi-chien-shan, Ta-ku-shan and Hsiao-ku-shan are arranged in a NE-SW line, and Ma-an-shan and Mo-li-ching-shan are on another line parallel. These cones are thought to be composed of black, compact basalt.

3. Chi-hsing-shan Volcano

The Chi-hsing-shan volcano consists of seven domes scattered around the hilly land of Cheng-chia-tun district, Feng-tien Province. The name probably comes from the arrangement which is similar to that of the seven stars of the *Ursa Major* constellation. Po-li-shan, one of the seven domes, is famous for a grand view from the window of trains passing through the environs of Cheng-chia-tun station (Fig. 2).

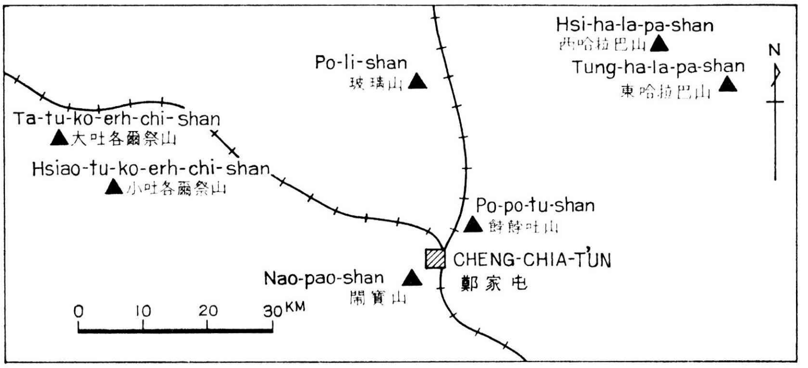

Fig. 2. Map Showing the Distribution of Cones in the Chi-hsing-shan Volcanic District.

Topography

The centre of the district lies at Long. 123°30′E and Lat. 43°30′N, and the seven domes are scattered over an area of 100 km E-W and 30 km N-S. Three of them stand on the east side of the Hsin-kai-ho River running parallel to the railway line, and four on the west. The district spreads over the central part of the Manchurian Plain, 150–200 m above sea level. The eastern part of the district is a wide, hilly plain, the central part (the environs of Cheng-chia-tun), often forms a flood plain, because of the intersection of the Hsi-liao-ho and Hsin-hai-ho. The western part is distinguished by irregularly arranged groups of sand dunes, 240 m above sea level in the southwest.

The Chi-shing-shan volcanic group consists of seven domes. Their height, base diameters and height above sea level are shown in the following table, going east to west (Table 5.)

Tung-ha-la-pa-shan: The dome is situated 12 km ENE from the town of Shuang-shan. The base is elliptical, being elongated to WNW; the summit forms a ridge in the same direction. While the slope near the summit is nearly 30°, it gradually decreases below 20° towards the foot. On the eastern edge of the summit, columnar joints of basalt stand precipitously.

Hsi-ha-la-pa-shan: Located 12 km N-W of Tung-ha-la-pa-shan, it is a mamelon type with a gentle slope. A great rift runs straight through the summit in a N-W direction, which corresponds to the direction of a line connecting Tung-ha-la-pa-shan and Hsi-ha-la-pa-shan.

Po-li-shan: Located 8 km west of the railway and can be seen from the train. The dome is typically mamelon-shaped, very much resembling Hsi-ha-la-pa-shan. The relative height is 110 m, the highest of the seven domes; the lower part is

Table 5

Name of cone	Height above sea level (m)	Relative height (m)	Diameter of base (m)
Tung-ha-la-pa-shan	293	90	550
Hsi-ha-la-pa-shan	318	70	650
Po-li-shan	278	110	770
Po-po-tu-shan	220	70	900
Nao-pao-shan	170	30	320
Hsiao-tu-ko-erh-chi-shan	267	50	490
Ta-tu-ko-erh-chi-shan	238	44	700
Average	255	67	626

covered with aeolian sand. There are several stone piles called obo on the summit, which are folk symbols of worship.

Po-po-tu-shan: Northeast of Cheng-chia-tun, just opposite the town on the Hsin-kai-ho River. In the western part, there is a basalt quarry. It resembles a sea cucumber in shape and the greater part is covered with aeolian sand except for the summit, on which basalt is exposed east to west.

Nao-pao-shan: A small dome, 30 m high on the plain, situated 3.5 km SW of Cheng-chia-tun. Although the dome is completely covered with thick aeolian sand, it seems to be formed of somma and a central cone.

Hiao-tu-ko-erh-chi-shan: A butte dome in the sand dune region, 45 km WNW of Cheng-chia-tun. The basement is elliptical, going NW-SE; the relative height is 50 m and the summit forms a 50 m long ridge in the same direction.

Ta-tu-ko-erh-chi-shan: Located 11 km NW of Hsiao-tu-ko-erh-chi-shan and situated in the western extremity of the district. The mount stands on a rhombic basement; the foot is covered with sand and the slope becomes gradually steeper toward the summit 44 m high. The summit is elongated E-W, bending slightly towards the south. There is a big obo on the summit.

These seven domes are arranged like the seven stars of *Ursa Major*; the three domes of Ta-tu-ko-erh-chi-shan, Hsiao-tu-ko-erh-chi-shan and Nao-pao-shan correspond to the handle, and the other four to the ladle. With respect to the fissure system, there seems to be no regular arrangement of domes, but a line S 47° W connecting Hsi-ha-la-pa-shan, Po-po-tu-shan and Nao-pao-shan, a line S 82° W connecting Hsi-ha-la-pa-shan, Po-li-shan, Ta-tu-ko-erh-shan, a line S 63° E connecting Hsi-ha-la-pa-shan and Tung-ha-la-pa-shan and a line S 12° W connecting Hsi-ha-la-pa-shan and Shih-tou-shan, a very low hill, are considered these four directions radiate from Hsi-ha-la-pa-shan as a center, but it cannot be concluded that a radial fissure system is present. From the petrological character of these domes, Po-po-tu-shan and Nao-pao-shan form a center, and the others are arranged concentrically. But, it still is not certain whether a concentric fissure system exists.

Geology

The foundation of this volcanic group consists of a Quaternary system; hilly land east of the Hsi-liao-ho is essentially composed of sand and clay and west of the river the sand dunes consist of aeolian sand; the low plain is chiefly of clay-like sand. The sand dunes are 20–25 m in height and the aeolian sand over 25 m in thickness. The fluvial plain is 3–4 km in width and consists of fine grayish-black sand and clay.

Volcanic rocks forming the seven domes and Shih-tou-shan belong to black compact and massive basalt or trachy-basalt which is fine-grained in Nao-pao-shan and Po-po-tu-shan in the inner zone, medium-grained and phanerocrystalline in Hsi-ha-la-pa-shan, Shih-tou-shan, Po-li-shan and Hsiao-tu-ko-erh-chi-shan in the middle zone and coarse-grained in Tung-ha-la-pa-shan and Ta-tu-ko-erh-chi-shan in the outer zone. Mineral constituents are generally similar in each rock type, and essential components are oligoclase, olivine, titanaugite and augite with additional alkali feldspar, aegirine-augite, biotite, apatite, picotite and leucite, which is an essential component of Nao-pao-shan lava. This occurrence of leucite was the first record in central and eastern Manchuria. The average chemical composition of the seven domes and one hill is shown on Table 6.

Table 6

SiO_2	45. 10 %	CaO	9. 30 %
TiO_2	2. 04	Na_2O	3. 55
Al_2O_3	14. 65	K_2O	1. 77
Fe_2O_3	2. 30	P_2O_5	0. 58
FeO	10. 07	H_2O	1. 30
MnO	0. 18		
MgO	9. 16	Total	100. 00 %

This volcano situated in the center of the Manchurian Plain, lies on the southern edge of the upheaved Hei-liao divide (a hilly highland 250 m above sea level stretching SE to NW between Kung-chu-ling and Tao-nan). In the northeastern edge of this divide lies the Ta-tun volcano and in the east the I-tung volcanic group; the domes of these volcanoes consist of black basaltic rocks and are mamelon shaped. Eruption of these domes is thought to be connected with the upheaval of the Hei-liao divide.

4. Kuan-tien Volcano

The Kuan-tien volcano consists of several cones west of Kuan-tien Town, Tung-hua Province. Huang-i-shan in the western suburbs of Kuan-tien is a truncated cone 513 m above sea level and the crater wall is broken on the south side. The rock is mostly reddish-brown porous scoria of a basaltic character. Ching-i-shan is also a truncated cone, several km west of Huang-i-shan, but no details are available. There is also a cone north of Ching-i-shan.

5. Lung-wan Volcano

The Lung-wan volcano belongs to Hui-nan Prefecture, Tung-hua Province, and is situated 130 km WNW of Chang-pai-shan, standing on the west side of the Lung-kang Mts. The central part of the district is located at Long. 126°15′ E and Lat. 42°30′ N, and the volcanic district is limited to 25 km E-W and 20 km N-S (see Fig. 3). There are many volcanic cones in the eastern neighboring thickly forested zone but little is known about them. The district is a dissected mountainous land 400 m high in the west and 800 m in the east. The foundation of the district consists essentially of granite and granite-gneiss, the former distributed in the north and the latter in the south. In the west, Cambro-Ordovician shale and limestone occasionally crop out.

Topography

The volcano consists of basalt, divided into cone-basalt and flow-basalt according to the mode of occurrence.

There are over 35 cones in the district, the most important of which are listed here, going from west to east:
Hsing-an-nan-shan, Hsi-heng-tao-shan, Tung-heng-tao-shan, Hsiao-i-shan (455 m), Ta-i-shan (524 m), Teng-chia-wang, Chien-shui-ting-tzu, Ta-ku-shan-tzu, Hsiao-ku-shan, Shih-men-tzu-shan, Weng-chuan, Hsiao-weng-chuan, Ya-pa-kang, and Kuan-tso-ling. These are homatic truncated cones.

In the eastern part there are eight cones with crater lakes on their summits: Hsiao-lung-wan, Erh-lung-wan, Ta-lung-wan, Hu-lu-lung-wan, Nan-lung-wan, Tung-lung-wan, Pan-pan-lung-wan and Hsi-pai-tzu-lung-wan.

A topographical survey had been carried out on these cones and the size, depth and other crater measurements were obtained in detail. Part of these data, however, was lost at the end of the war. The general features of the volcanoes will be described in the following pages, although there may be gaps due to the lost of information (Fig. 3).

First, the cones are generally isolated and low truncated in form. The basement is mostly round with a diameter of 1,000 m on the average, 1,500 m being maximum (Weng-chuan and Ya-pa-kang). They are low, usually less than 100 m, the highest being 179 m above its base in Ta-i-shan.

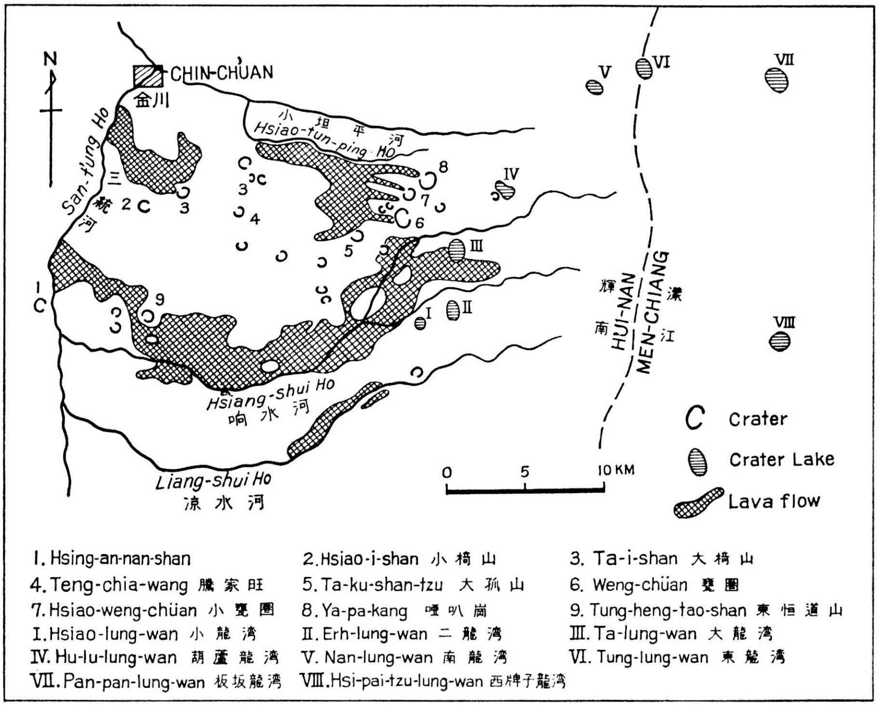

Fig. 3. Map Showing the Distribution of Principal Cones in the Lung-wan Volcanic District.

There are craters on the summits, mostly less than 500 m in diameter, but greater than 1,000 m in Weng-chuan, Ya-pa-kang, Ta-lung-wan and Hu-lu-lung-wan. In Weng-chuan crater, a prefectural road has been built along the inner wall. On the top of Hsiao-ku-shan, there is a small conical crater. The crater of Ya-pa-kang is round and 1,500 m in diameter, the largest in the volcanic district, and the western part is broken. The cone consists of alternate layers of volcanic scoria and ash, occasionally with lava flow; the layers incline about 25° toward the outside of the crater. Volcanic bombs are characteristic of this district; many fusiform or round bombs have been collected, especially near Ta-i-shan, Shih-men-tzu-shan and Chien-shui-ting-tzu. The basal rock of the district is chiefly granitic, and crops out at the bottom of the crater of Weng-chuan. Granite blocks are found among the efecta of Ta-i-shan, Hsiao-i-shan, Heng-tao-shan.

Eight crater lakes are found in the eastern part of a pseudo-trapezoidal area 20 km E-W and 15 km N-S. These lakes lie in a dense forest area, only 3 or 4 being known previously. All eight lakes were investigated for the first time in 1940. About eight crater lakes in Lung-wan district, there has been described on pages 378–380 of this Volume 2.

There are 4 principal lava flows in the district, and several other flows are said to be found in the northern craters from where lava flowed out to the northwest along valley floors. These lava flow zones consist of an accumulation of various sized block-lavas forming a stony river bed; they are thickly covered with forests or consist of damp ground. Such waste land is called *"ha-la-tzu"* by the natives, meaning a black stony place. The greatest lava flow is situated in the central southern region, running east to west. The lava erupted from near the Chin-lung-ting-tzu cone, east of Ta-lung-wan crater, flowed along the crater rim of Ta-lung-wan, ran west along the Ha-ma-tang-ho, then the Hsiang-shui-ho and down to the San-tung-ho rivers, the total length of flow being over 35 km. The course of flow generally followed the valley floor, but not always; there are several areas without lava near low hills within the flow zone. The flow is variable in width, being 3 km on the average. In the west central region, the flow became over 5 km wide; then it flowed northwest, deflecting from the Hsiang-shui-ho, narrowed to 200 m at the foot of Tung-heng-tao-shan and then reached the San-tung-ho 5 km from there. Along the San-tung-ho River, the lava is distributed over a distance of 3 km with a thickness of over 20 m at the cliffs. The surface of the flow has an accumulation of block-lava and is covered with thick forests which are not utilized, but places free of lava flow are sometimes cultivated, as seen in Ha-ma-tang and Li-tai-fang Villages.

The second lava flow erupted from the Ta-i-shan crater in the northwest, and ran down about 6 km WNW to the San-tung-ho. It is 2.5 km wide and has two step terraces consisting of upper and lower lava flows, 7 and 13 m thick, respectively. Several "hornito-like" puff cones are found on the flow. There are also many volcanic bombs ejected in a later eruption scattered on the flow surface at the western foot of Ta-i-shan. On the cliff of the Shuang-yang-tung-ho, east of Ta-i-shan, there is a thick lava flow beneath the volcanic lapilli layer.

The third flow erupted from the top of Ta-ku-shan-tzu, 9 km ESE of Ta-i-shan, and ran down the slope north to the Hsiao-tan-ping-ho leaving several small islets of granite, turned west and stopped east of Jen-ho-pu Village. The length of flow was 9 km with a 1 km width. Small flows from Weng-chuan, Hsiao-weng-chuan and Ya-pa-kang craters, northeast of Ta-ku-shan-tzu, formed part of the third flow.

The fourth flow developed along the upper course of the Liang-shui-ho in the south and ran southwest for 8 km. The lava remains only on one side of the eroded valley cliff and is 17 m thick.

As mentioned above, the lava flowed westward from the craters, due to the topography of the district—higher in the east and lower in the west—and the flows made their way according to the topography of the valleys. The areas encompassed by these lava flows are 66 km^2 in the Hsiang-shui-ho and 11.5 km^2 in both Ta-i-shan and Ta-ku-shan-tzu; the whole area is estimated at over 90 km^2. This area is more than 3 times larger than that of the 35 volcanic cones which occupy about 30 km^2 of this volcanic district.

Petrology

Volcanic cones consist of alternate layers of volcanic scoria, lapilli and ash. Scoria is fist- to head-sized, round porous block, reddish-brown in color. The component minerals are not visible to the naked eye, but plagioclase, olivine and glass can be detected under the microscope. The rock is basaltic. Volcanic bombs are plentiful, being mostly fusiform and less than 20 cm in length. Many olivine nodules over 30 cm long are scattered among the ejecta, being especially abundant in the crater of Weng-chuan. The nodules are formed essentially of olivine aggregate with some pyroxene and picotite. The flow lava is grayish-black and porous, with a microporphyritic structure, and consists of olivine, plagioclase, pyroxene and magnetite, showing a basaltic texture. Occasionally olivine nodules are found. Scoria and flow lava are different in appearance, but not in chemical composition, as seen in the following table (Table 7).

Table 7

	Scoria (%)	Lava (%)
SiO_2	48.75	47.52
TiO_2	2.04	2.01
Al_2O_3	17.69	17.11
Fe_2O_3	5.40	1.81
FeO	5.71	9.48
MnO	0.24	0.22
MgO	6.85	7.97
CaO	6.86	7.84
Na_2O	3.18	3.45
K_2O	2.40	2.08
P_2O_5	0.44	0.38
H_2O	0.81	0.48
Total	100.37	100.35

Scenery

Little has been known of the Lung-wan volcano except for 2 or 3 crater lakes reported 30 years ago. The study in 1940 and 1942, just 10 years after the founding of Manchoukuo, revealed the main features of the volcanic district: (i) the existence of over 35 well-preserved cones with craters in a narrow region (ii) the existence of 4 long lava flows and 8 deep crater lakes of Lung-wan, and (iii) the limnological characteristics of the crater lakes.

Thus, the district furnishes not only valuable material for volcanology, but also one of the most scenic landscapes in Manchuria.

6. Chang-pai-shan Volcano

Chang-pai-shan, called Pai-tou-shan in Korea, is the biggest mountain on the boundary of Manchuria and Korea. The highest peak, Ta-cheng-feng is situated at Long. 128°05′ E and Lat. 41°59′ N.

The volcano has been surveyed by many scientists, but the study carried out in 1942 and 1943 by the Chang-pai-shan Scientific Expedition under the auspices of the Science and Technical League of Manchoukuo was one of the most complete and successful. The members of the expedition were specialists in zoology, botany, forestry, physics, meteorology, geology, land survey, wireless telegraphy and photography.

Drs. Riuji ENDO, Goro ASANO, and Tsutomu OGURA took part in the geological research. The results were not previously published, however, because the manuscripts of the reports were lost at the end of the war. This report is therefore based on memory and on the description provided by Dr. ASANO.

Topography

A triangulation point on Ta-cheng-feng at 2,745 m above sea level was previously considered the highest peak, but it became clear in this expedition that the highest point is at 2,751.48 m, 95 m west of the 2,745 m point.

The base of Chang-pai-shan is a basalt plateau 120–150 km in diameter. The plateau has a gentle slope at the foot, but becomes gradually steeper as it rises presenting an aspite-shield aspect. Plateau basalt is found in the upper region roughly 2,000 m above sea level. The upper part of this aspite is the main body of Chang-pai-shan, and is formed by alkaline trachyte from the first eruption. The lava is nearly 300 m thick and its surface has an inclination of less than 10°. The lava area is 30–40 km in diameter but the greater part is covered by an accumulation of pumice or mud lava. Pantallerite from the last eruption forms the uppermost dome of Chang-pai-shan; it has an inclination of 20°–30° and is over 400 m thick. The base of the pantellerite dome is 10 km in diameter.

On the summit, a crater wall 2,600 m high surrounds the crater lake Tien-chih. The main peaks on the crater wall are Pai-yen to the north, Wang-tieh-hou to the east, Ta-cheng-feng (Ping-shih-yen) to the south, and Mo-tien-yu and Tseng-yen to the south and northwest. The outer wall of the crater slopes gently, especially on the Korean side, but the inner wall is quite steep and lava flows crop out strongly on the inner cliff. The crater wall has a pseudo-octahedral form, 5 km long east-west and north-south. The crater lake at the bottom is shaped like a pear with the large end to the north. It has a diameter of 3 km in east-west and 4 km north-south, with an area of 9.2 km^2 and a circumference of 13.75 km. The depth of the lake was not measured by this particular expedition, but according to an expedition by Kyoto University some ten years ago it is 375 m at the deepest point. The surface of the lake is 2,257 m above sea level and the distance from the highest point of the crater wall to the surface of the lake is 494 m; therefore the depth of the crater is estimated at 869 m, making it the deepest crater in Manchuria. The lake water breaks through the crater wall between Pai-yen and Tseng-yen and flows out to the north from Tamen through a barranco, forming a waterfall 66 m high. This fall is called Chang-pai Fall, and is the highest in Manchuria. The valley widens suddenly in the lower course of the fall and it flows north as the source of the Erh-tao-pai-ho River. The flow of water was measured in August 1943 and estimated at 200,000 t per day at this point.

In the lower course 2 km from Chang-pai Fall, at 1,800–1,850 m above sea level, there are several hot springs in a 100 m square area with maximum temperatures of 70°–80°C, and weak alkaline simple springs with a slight odor of hydrogen sulfide. Some carburetted springs of lower temperature are found in the neighborhood. The total amount of water provided by the hot springs in this vicinity has been estimated at 10,000 t per day.

With respect to the topography near Chang-pai hot springs, the valley is 2 km wide, is flanked by steep cliffs over 400 m high to the east and west, and looks like the bottom of a kettle. In the middle wall of the eastern cliff there is a deposit of alternate layers of sand and gravel, 50 m thick, which is assumed to be the remnant of a lake. On the basis of the points mentioned earlier, this spring area is thought to be the bottom of an old explosion crater; in other words, this explosion crater and Tien-chih were originally connected north-south at the time of their formation.

In addition to these hot springs of Chang-pai-shan, there is a hot spring of 30°C near the shore of Tien-chi lake at the foot of Pai-yen; the rocks in its vicinity have turned brown. In summer the water temperature of Tien-chi at the foot of Ta-cheng-feng was 2–3°C, while the water temperature of the river in the lower course of Chang-pai Fall was 7–8°C, probably due to another hot spring in the lake, as in the case of Pai-yen. There are carburetted springs in the western outer wall of Mo-tien-yu and there is the Tang-shui-chang hot spring (58°C) in the upper course of the Man-chiang in the southwestern part.

There are several cinder cones of basalt on the slope of Chang-pai-shan. Ta-yen-chih-feng to the southeast of Ta-cheng-feng and Hsiao-yen-chih-feng 4 km southeast of Ta-yen-chih-feng are cinder cones with brown peaks standing out from the white pumice layers. There are also three parasitic cones on the northwest slope of the Tseng-yen crater wall, 30–40 meters high and 1 km in basal diameter. Farther west there are several other parasitic cones, two of which are found near Tang-shui-chang hot spring. Although they are relatively low, they break the monotony of the landscape at 2,000 m above sea level.

One characteristic of Chang-pai-shan is the pumice which covers a large circular area of 40 km radius with the caldera of the summit as its center. It forms a surface on the slope, and has an attractive white color. It is 10–20 m thick on the average and 40 m at maximum. A wide distribution of mud lava is also characteristic west and north of the caldera. Highly fluid mud lava poured out from the caldera to a distrance of 40 km, resulting in a gentle topography. Vertical erosion by river water is strong in this rock, and there is a long narrow gorge over several km along the Erh-tao-pai-ho, forming deep grooves or natural bridges. As mentioned earlier, Chang-pai-shan holds first place in Manchuria on the following points: it has the deepest caldera and Tien-chih on the summit, the highest Chang-pai waterfall and hottest Chang-pai spring, remarkable change in distribution of characteristic trees and animals according to the altitude, and a rare occurrence of alkaline rocks that built the main body.

Little is known about the history of the eruptions of Chang-pai-shan. Traditional accounts of eruptions in 1597 and 1702 are not altogether reliable. This mountain has the highest hot spring, Chang-pai spring, and several other springs are known, but no other post-volcanic action such as solfatara has been observed. At a point 2,000 m above sea level and 3 km southeast of the summit, natural charcoal was found buried in the volcanic ash, and the types of trees are similar to recent flora such as *Picea koraiensis* NAKAI and *Larix dahurica* TURCZ. The fact that the upper tree limit on Chang-pai-shan is 2,200 m on west side and 1,800 m on the east side can be explained by the great forest fire caused by the greater fall of ash on the east side than on the west in the past. If the ejection and accumulation of pumice is older in time than the issue of mud lava, the eruption which produced the pumice cannot have occurred 400 years ago as tradition holds.

Geology and structure

As revealed by the foregoing descriptions, the topography of the Chang-pai-shan Volcano coincides well with the geology, and can be divided into four stages. The oldest formation, constituting the foundation of the volcano, occupies the lowest horizon, but is now exposed at a level of 600–1,000 m. Above this, the plateau basalt accumulated in an area 120–150 km across and 2,000 m above sea level at the highest point, forming the gentle slopes of the volcano, and resulting in an aspite-type of mountain. The third stage is represented by alkaline trachyte, consisting of alternating lava flows and agglomerates, which formed the base of the main body of the volcano. The surface of the trachyte is inclined about 10° and joins the plateau basalt below. The fourth stage is the formation of the main body of the volcano, which has a 20–30° inclination. The main body consists of pantelleritic lava flows, 30–40 m to 300–400 m thick. A dome, 1.1 km in diameter, was formed on the top by the accumulation of these lava flows, and rises over 2,750 m above sea level.

The older formation which makes up the foundation is mostly pre-Mesozoic. Near Nai-tou-shan, 30 km north of the summit, a hill of pre-Cambrian quartzite and dolomite stands like an island on a basalt plateau. In Man-chiang village in the west, the Mesozoic sedimentary and igneous rocks are distributed under the plateau basalt in the capital city of Chang-pai Prefecture. Cambro-Ordovician rocks are present in the south. On the gentle, eroded surface of these older rocks the plateau basalt accumulated in large quantity after the central eruption, and made the entire surface flat. This basalt is not homogeneous in character but is generally of the type called augite-olivine basalt. The next eruption is represented by alkaline trachyte which forms the lower part of Chang-pai-shan Volcano proper. The center of eruption gradually moved from south of the present caldera to the north and southwest side repeating the explosion and eruption of the lava. In the first phase alkaline trachyte erupted, and then the more acid sodic pantelleritic alkaline trachyte. The trachyte is not exposed on the summit, but in Ma-an-shan to the south where rock covers the basalt and is covered by agglomerate, tuff and lava flow. The rock comprises three varieties: (i) yellow augite-anorthoclase trachyte, (ii) fayalite-yellow augite-anorthoclase trachyte, and (iii) fayalite-yellow augite-anorthoclase glassy trachyte.

Another type, called pantelleritic trachyte, which differs from the above types and from pantellerite, is exposed in the lower part of the inner wall of the caldera along a deep valley below Mo-tien-yu and under the pantellerite flow near the eastern forest boundary of Pai-yen. In the valley bottom east of Mo-tieh-yu alternating layers of tuff and agglomerate, several to 30–40 meters thick, and thinner lava flows amount to 200–300 m in total thickness. This lava is dark grayish cryptocrystalline with a few phenocrysts.

The pantellerite is distributed around the caldera. It piled up after several eruptions without any mixing of agglomeratic substance, each lava flow being 30–40 m to 300 m thick and running down the slope to the lower limit of the tree line at 2,000 m. The inclination of the slope is 20–30° above the 2,000 m line and less than 10° below. The pantellerite lava erupted in great quantity. Marked with tabular and columnar joints, it forms prominent cliffs. The rock is grayish blue and contains abundant phenocrysts of anorthoclase and augite in compact groundmass. It is called fayalite-soda pyroxene-aegirine augite-anorthoclase pantellerite from its mineral composition. It corresponds to "hakutoite" reported from the northeastern part of Korea, and is not known in other parts of Manchuria. A glassy variety of pantellerite flowed out of the top of Pai-yen and Ta-cheng-feng, presenting a unique topographical feature. It has numerous white phenocrysts of anorthoclase in black glassy groundmass. The rock belongs to a later eruption than pantellerite proper, and is distributed as long narrow flows around the summit.

The main body of the mountain was formed, for the most part, by accumulation of alkaline trachyte and pantellerite, and the initial height is assumed to have been 3,500 m above sea level. Later, a number of parasitic cones were formed on the sides of Chang-pai-shan: Ta-yen-chih-feng and Hsiao-yen-chih-feng on the southeast side, three cones on the northwest side, and several on the west side. These are cinder cones of basaltic rock containing phenocrysts of olivine, monoclinic pyroxene and labradorite. Many crystal bombs of labradorite are found on the cones northwest of Tseng-yen. In the final stage, lava flowed out of these cones.

After the eruption of lava, the volcano remained quiescent for some time; finally, it erupted again, ejecting a pumice and fragments of older lava, basalt, nordmarkite and similar plutonic or hypabyssal rocks which were especially abundant in the upper part of the accumulation. The size of the pumice stones ranges from that of a fist to that of a head, and it has a white silky luster. It is an alkaline rhyolitic rock and consists of colorless glass dotted with phenocrystic anorthoclase and less aegirie augite. It is excellent for polishing lithographic plates.

Formation of the caldera, which has a diameter of 5 km is assumed to have occurred at the same time as the eruption of pumice. Later mud lava issued from the caldera in all directions, especially from north to west. The Sung-te-ssu temple above the Ta-men barranco was built on this mud lava within the caldera. Half way to Tseng-yen the rest of the mud lava is seen stuck on the caldera wall. Rolling debris is also observed between Pai-yen and Ta-cheng-feng. Along the lower course of the Erh-tao-pai-ho the mud lava flow is prominent. The mud lava is dark brown to black and rather loose; and consists of glassy groundmass with phenocrysts of anorthoclase and soda pyroxene. Fragments of pre-existing lava and plagioclase crystals are also found in abundance. The thickness of the mud lava exceeds 150 m along the Erh-tao-pai-ho.

The properties of lava

The chemical composition of rocks collected during the geological survey in 1943 are given in the following table. They are classified into six groups according to the order of eruption and lithologic character: (I) basalt, (II) alkaline trachyte, (III) pantelleritic trachyte, (IV) pantellerite, (V) glassy pantellerite, and (VI) basalt of parasitic cones. It can be seen from the table that the composition of the rocks gradually changed from basaltic to acidic. (Table 8).

Conclusion

Chang-pai-shan is a strato-volcano standing on a wide plateau of basalt, and has a big caldera lake on the summit. The original eruption laid a foundation of alkaline trachyte; the greater part of the mountain was formed after a great eruption of pantellerite and glassy pantellerite; subsequently, several basaltic cinder cones were formed on the sides of the mountain. Later, a major eruption of pumice created a large caldera on the summit, and from the caldera numerous mud flows issued and flowed down the north and west slopes. With this, the first volcanic activity came to an end. At the same time as the formation of the Tien-chih caldera, an explosion crater half its size was formed in its northern part, and filled with water to make a crater lake. This lake collapsed, however, before long, and its remains can be seen in the crater bottom near Chang-pai hot spring. This volcano is not only the highest mountain in Manchuria and Korea, but it has the biggest crater lake, the hottest spring, the highest waterfall and in comparable scenery.

All these features would certainly qualify it as an outstanding national park for Manchuria.

Table 8

	I	II	III			IV		V	VI
	1	2	3	4	5	6	7	8	9
SiO_2	50.43	61.68	64.42	64.78	65.04	64.89	67.84	70.95	49.05
TiO_2	2.90	0.65	0.55	0.50	0.40	0.40	0.35	0.30	3.19
Al_2O_3	15.18	17.36	16.26	15.00	16.66	15.42	15.27	12.23	14.35
Fe_2O_3	2.77	1.79	2.26	3.73	2.36	2.94	2.22	1.22	3.02
FeO	8.92	4.03	3.77	2.55	2.93	3.68	2.38	4.13	10.57
MnO	0.21	0.13	0.12	0.07	0.09	0.12	0.05	0.09	0.27
MgO	4.98	0.37	0.17	0.13	0.02	0.12	0.04	0.05	4.25
CaO	8.96	1.53	1.24	1.21	0.99	1.23	0.82	0.47	8.66
Na_2O	3.13	4.68	5.44	6.28	6.08	5.46	5.32	5.46	3.23
K_2O	1.52	5.10	4.74	4.90	4.88	4.74	5.02	4.60	1.40
P_2O_5	0.49	0.03	0.02	tr.	tr.	tr.	0	tr.	0.57
$+H_2O$	0.01	0.27	0.10	0	0	0	0	0	0.34
$-H_2O$	0.11	0.39	0.22	0.20	0.14	0.12	0.14	0.04	0.20
CO_2	0.29	1.80	0.28	0.40	0.16	0.58	0.22	0.36	0.73
Total	99.90	99.81	99.59	99.75	99.75	99.70	99.67	99.90	99.83

I. 1. Olivine-augite basalt: Shih-erh-tao-kou, Chang-pai Pref.
II. 2. Yellow augite-anorthoclase trachyte: Ma-an-shan, Chang-pai Pref.
III. 3. Fayalite-soda diopside-anorthoclase trachyte: Mo-tien-yu, Chang-pai-shan.
4. Fayalite-soda diopside-anorthoclase trachyte: near Chang-pai spring.
5. Anorthoclase-soda augite trachyte: south of Tseng-yen, Chang-pai-shan.
IV. 6. Alkali amphybole-fayalite-soda diopside-anorthoclase pantellerite: Tseng-yen.
7. Aegirine augite-soda diopside-anorthoclase pantellerite: Mo-tien-yu.
V. 8. Quartz pantellerite: Pai-yen, Chang-pai-shan.
VI. 9. Olivine basalt: Ta-yen-chih-feng, Chang-pai-shan.

7. Da-li-no-erh Volcano

This volcano is situated west of Dalinor Lake near the boundary of Jehol and Chahar Provinces. It consists of about 10 cones, standing on a basalt plateau, and arranged along NE-SW fissure lines. These cones are truncated, about 100 m high, with craters on their summits. They are formed from volcanic ejecta, and reddish-brown bombs are scattered on the slopes. This volcano is not actually within Manchuria, but is described here for the sake of convenience.

8. Erh-ko-shan Volcano

Erh-ko-shan volcano lies in Ko-tung Prefecture, Lung-chiang Province, at Long. 126°18′ E. and Lat. 48°05′ N., southwest of Pei-an station. The writer, accompanied by the staff of the Ryojun College of Engineering, carried out a geological survey in the district in early April of 1936.

Topography

A hilly land, 300–360 m high stretches from Hai-lung—Pai-chuan to Pei-an—Wu-ta-lien-chi in northern Manchuria. Erh-ko-shan stands on this highland and consists of three cones with an average height of 120 m. The highland is formed of basalt, and the gentle slopes of Erh-ko-shan with their 1–2° inclination, are characteristic of a shield volcano. On this highland stand three truncated cones, Tung-shan, Hsi-shan and Hsiao-ko-shan. Measurements of the cones are given below. (Table 9).

Table 9

	Height above sea (m)	Relative height (m)	Diam. of base (m)	Diam. of crater (m)	Depth of crater (m)
Tung-shan	450	110	700	230	35
Hsi-shan	425	75	550	250	50
Hsiao-ko-shan	358	18	210	80	5

Tung-shan, situated in the southeast, is the largest of the three. The crater bottom is flat, and several buildings of a temple called Shenghsienkung are found there. Hsi-shan is 650 m northwest of Tung-shan, is very similar to it in form. The horseshoe shaped crater wall is broken in the northeastern part of Tung-shan and in the northwestern part of Hsi-shan. Hsiao-ko-shan is a low cone, standing 1,200 m southwest of Hsi-shan. The form of its crater is very imperfect.

These three cones were formed by the accumulation of ejecta in a brief eruption. Erosion is not very advanced, but gullies are developed on the slopes. There is no record of any eruption.

Geology

The foundation of the volcano is the Diluvial gravel and clay bed exposed in the southwestern part. The highland consists of basalt and is covered by surface soil over 10 m thick. The basalt is exposed along the valleys. It is dark gray, fine-grained and porous rock and consists of microphenocrysts of olivine and leucite. The groundmass is composed of feldspar, augite, micaceous ilmenite, magnetite and biotite with glass. The rock is of the leucite-basanite type. The lower part of this lava flow is often represented by jet black, compact glassy rock which has less feldspar and more glass than the other rock. The cones are formed from fist-sized, porous, scoriaceous rock and agglomerate. These rocks are gray-brown or black, porous, and consist of olivine and leucite microphenocrysts, the groundmass being composed of anorthoclase, augite and glass. The presence of leucite is a characteristic feature of this volcano, as in the case of Wu-ta-lien-chi volcano. The plateau basalt and cone basanite are nearly the same in mineralogical composition and the difference in appearance is caused only by the mode of eruption. The chemical composition of these two rocks is shown in the following Table 10.

Table 10. Chemical Composition (%) of the Erh-ko-shan Rocks.

	1	2
SiO_2	51.12	50.99
TiO_2	2.45	2.48
Al_2O_3	13.76	14.19
Fe_2O_3	1.28	4.53
FeO	6.70	4.20
MnO	0.12	0.10
MgO	6.95	5.95
CaO	6.44	6.15
Na_2O	4.22	4.28
K_2O	5.61	5.23
P_2O_5	1.06	1.08
H_2O	0.49	0.98
Total	100.20	100.16

I. Plateau basalt: Ho-chia-tun, west foot of Erh-ko-shan.
II. Average composition of 3 lavas of 3 cones.

Conclusion

Erh-ko-shan consists of three cones standing prominently on the northern great plain of the Sung-hua-chiang. The rock constituting the volcano is leucite basanite, which is very rare in Manchuria. In this and other respects, this volcano provides a good subject for volcanic research.

9. Wu-ta-lien-chi Volcano

For centuries this volcano was known as Uyunhordongi, but the name changed to Wu-ta-lien-chi volcano after a joint expedition by the Ryojun College of Engineering and the South Manchuria Railway Company in 1935. The center of the volcano is situated at Long. 126°07′ E and Lat. 48°43′ N in Pei-hsiang, Te-tu Prefecture, Lung-chiang Province. Volcanic activity in 1720 produced two cones, Lao-hei-shan and Huo-shao-shan. So unique an event naturally made the name of this volcano familiar to the people of northern Manchuria.

Topography

The land in the district is undulating and hilly and 300–400 m above sea level. There are fourteen volcanic cones, two of which occur on the shih-lung lava field in the central part. The land is covered with shield volcanoes, over 100 m high, and with gentle slopes having a 1–2° gradient. These shield volcanoes consist of trachybasaltic lava. The shih-lung lava field has a racket outline with the handle to the south, and covers an area of 68 km². In spite of its very gentle slope, the lava field presents remarkable microtopographic aspects. Pahoehoe lava occupies the greater part, and block and spiny lavas are piled up on each other.

The shih-lung lava is a jet black obsidian-like glassy rock. The surface of the lava is variable in appearance, it may be smooth, striated, mounded reptilian, ropy, wavy, bark-like, etc. according to the state of consolidation. Puff cones, called hornitos have a conical shape and are 1–2 m high and 1 m in diameter,

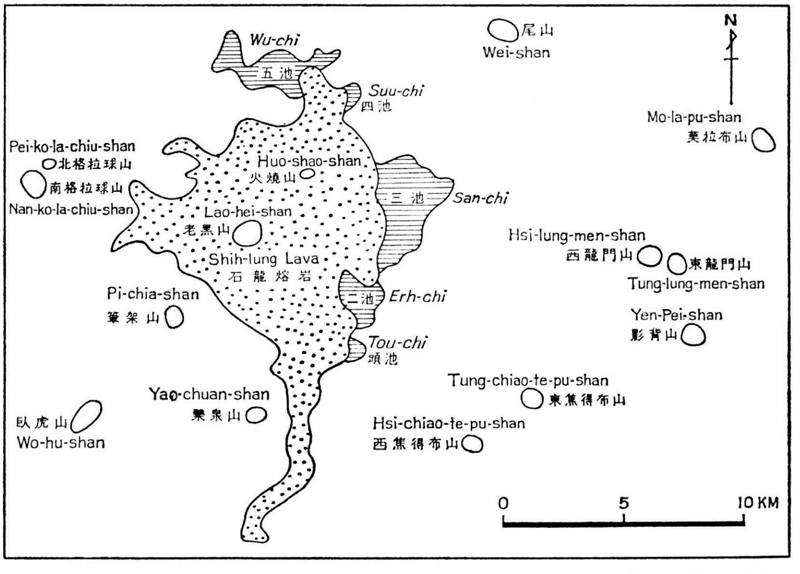

Fig. 4. Map Showing the Distribution of Cones in the Wu-ta-lien-chi Volcanic District.

with a hole on the top. These cones occur in two groups, and are a very unusual sight. There are also great crevices, depressions and lava tunnels in the shih-lung lava field (Fig. 4).

The shih-lung lava erupted from the central part of the lava field, flowed down in all directions, and dammed river waters, forming five connecting lakes along the north to east rim of the lava field. The lakes are Wu-chi, with an area of 6.5 km^2, Ssu-chi, 0.56 km^2 San-chi, 8.4 km^2 Erh-chi 2.8 km^2 and Tou-chi, 0.18 km^2 from north to south; the deepest is Erh-chi, with a maximum depth of 8 m.

At present, 14 volcanic cones are distributed throughout the volcanic region; seven are situated east of the Wu-ta-lien-chi lakes and the others west. Their measurements are given in the following table (Table 11).

The volcanoes stand mostly on the shield plateau. They are truncated cones, with a base diameter of 828 m and a relative height 100 m on the average. There

Table 11

Measurement / Name of cone	Height above sea (m)	Height of base (m)	Relat. height (m)	Volume (km^3)	Dia. of base (m)	Dia. of crater (m)	Depth of crater (m)
East side							
Wei-shan	518	415	103	0.021	800	320	41
Mo-la-pu-shan	524	417	107	0.026	900	240	44
Tung-lung-men-shan	578	440	138	0.046	950	445	108
Hsi-lung-men-shan	584	425	159	0.045	925	300	64
Yen-pei-shan	459	389	70	0.014	660	380	40
Tung-chiao-te-pu-shan	545	435	110	0.032	770	330	37
Hsi-chiao-te-pu-shan	482	387	95	0.012	670	230	27
West side							
Nan-ko-la-chiu-shan	602	487	115	0.056	100	470	50
Pei-ko-la-chiu-shan	543	506	37	0.001	500	230	—
Huo-shao-shan	393	320	73	0.015	670	415	63
Lao-hei-shan	516	350	166	0.100	1200	350	136
Pi-chia-shan	508	400	108	0.033	800	380	63
Wo-hu-shan	499	390	108	0.051	1200	350	36
Yao-chuan-shan	357	292	65	0.003	550	230	32

are 1–4 craters on the summit, with diameters of 330 m and a depth of 54 m on the average, and a slope of 28–32° on the sides. Parts of the crater walls are broken by explosion, except for Lao-hei-shan. In general, the craters keep their original forms without explosion or erosion.

The characteristic features of these 14 cones are given in detail in the following pages.

Wei-shan is situated in the northern part of the district. It stands on the shield plateau and has a typical homate form.

Mo-la-pu-shan is 11.7 km ESE of Wei-shan, and is similar to the former in shape. It has a crater on its summit 240 m in diameter. The bottom of the crater is flat and it turns into a lake in the rainy season.

Tung-lung-men-shan is 1 km away from Hsi-lung-men-shan. Both cones have elliptical craters and the mountains and neighboring district are covered with thick forest, favorite hideout for bandits in earlier days.

Yen-pei-shan is a comparatively small cone.

Tung-chiao-te-pu-shan is situated to the northeast of the district near Hsi-chiao-te-pu-shan. Both are typical cones. The craters are circular and flat on the bottom and that of the latter is shallow and flat, resembling an amphitheater.

Nan-ko-la-chiu-shan is in the northwest part of the district and is the highest cone in the area. Its crater, 470 m in diameter, is also the biggest; the bottom is flat, and forms a crater lake in the rainy season. A certain "reverse scaled" fish is said to inhabit the lake but we were unable to catch any on our expedition.

Pei-ko-la-chiu-shan is northeast of Nan-ko-la-chiu-shan. It is the smallest cone, in the distirct being 37 m in relative height.

Huo-shao-shan, together with another cone, Lao-hei-shan, is a relatively new cone on the shih-lung lava, but it is badly broken. The cone has an imperfect conical shape, 670 m in basal diameter, 73 m in relative height, and there is a great crater 415 m in diameter on the top. The top of the crater wall is uneven and several vertical crevices can be seen in the wall. Blocks of lava and scoria are piled against the inner and outer walls of the crater. The vegetation on this cone is less profuse than on other cones.

Lao-hei-shan is situated 4 km southwest of Huo-shao-shan and is often called Hsien-jen-shan. In the Ninguta Journal edited in 1721, the following description occurs: "There was a great eruption in the area 50 li northeast of Tsitsihar in June and July, 1720 and a mound was formed by ejected black rocks and sulphur. . . ." Judging from tradition, this statement corresponds to the eruption of Lao-hei-shan and Huo-shao-shan. Lao-hei-shan has the greatest relative height, depth of crater and volume of lava of the 14 cones. The diameter of its crater is half that of Mt. Fuji (600 m) but the volume of the mountain is 0.1 km^3 incomparably which is incomparably smaller than Mt. Fuji's. The crater wall is well preserved. There are three funnel-shaped craterlets about 10 m in diameter on the northern rim of the crater, and a round explosion crater, 80 m in diameter and 20 m in depth, on the ENE slope. On the northern slope, two great fissures can be seen, 300 m long and 40 m wide. There seems to be a greater abundance of explosive phenomena in Lao-hei-shan and Huo-shao-shan than in other cones, and naturally the features of the mountains are more complicated. Volcanic lapillis and fusiform bombs are scattered around the slope near the foot.

Pi-chia-shan is 4 km southwest of Lao-hei-shan. The summit splits into three peaks. The bottom of the crater is triangular and flat, but the slope has been eroded and deep gulleys are present.

Wo-hu-shan is situated 4.5 km southwest of Pi-chia-shan. The basement is 1,400 m long, running northeast to southwest, and four cones with four craters unite to form this mountain. The southwest crater forms a shallow round amphitheater, 350 m in top diameter, the diameter of the bottom being 250 m and the depth 20 m. Three other craters lie together irregularly in the northeastern part.

Yao-chuan-shan is relatively near the town of Te-to, and many mountain climbers come here and stay at a small village called Chung-ling-ssu at its southern foot. The cone has a typical truncated shape and its crater is round and 230 m in diameter. On the flat bottom of the crater, five buddhist temple buildings were erected and a number of bronze statues were installed, but many of these statues were stolen in 1943.

The arrangement of these 14 cones is remarkably regular and oriented northeast-southwest and northwest-southeast. In the eastern district, Tung-lung-men-shan and Tung-chiao-te-pu-shan, and Mo-la-pu-shan, Hsi-lung-men-shan and Hsi-chiao-te-pu-shan sit on two parallel lines northeast to southwest, and Wei-shan, Hsi-lung-men-shan and Yen-pai-shan are on a straight line northwest to southeast. In the western district, Huo-shao-shan, Lao-hei-shan, Pi-chai-shan and Wo-hu-shan are arranged on a line northeast to southwest at 4 km intervals. Pei-ko-la-chiu-shan, Pi-chia-shan and Yao-chuan-shan lie on a line northwest to southeast. The tendency of volcanic cones to be arranged in such a manner can be observed in several places in Manchuria and is related to the tectonics of the district.

Geology

The basement of the volcanic district consists of granite sparingly cropping out in the northern and southern parts. Mesozoic clay, shale and sandstone are widely distributed in the northern central part, and Diluvial sand and gravel are developed in the northern, western and southern parts.

The greater part of the district is composed of basalt covering the basal rocks, the basalt is of two types, one forming hilly lands and the other shield volcanoes. The former basalt is gray to black anorthoclase-olivine trachybasalt and is generally fine-grained. The latter is reddish brown porous anorthoclase-olivine trachybasalt without macroscopic olivine.

The shih-lung lava in the central district is composed of black obsidian-like glassy rock, hard but very brittle. Components are mostly glass, over 80% in volume, and microphenocrystic and microlitic olivine and augite scattered in the glass base. Quartz grains and granite blocks characteristically occur as xenolith in the rock. Anorthoclase and leucite microcrysts are also frequently observed. A chemical analysis of the shih-lung lava is shown below (Table 12-1). On the basis of its mineralogical and chemical composition the rock is a basic alkaline type called leucite-basanite, but the writer named it "shihlunite" for its unique characteristics. The leucite in this rock was first discovered in Manchuria. It is microphenocryst, 0.08 mm on the average and 0.15 mm in maximum size. Such leucite-bearing rock was found in other cones of the district as well as in other volcanoes such as the Erh-ko-shan volcano and other northern volcanoes.

Table 12. Chemical Composition (%) of the Wu-ta-lien-chi Rocks.

	1	2
SiO_2	52.7	50.76
TiO_2	1.9	2.38
Al_2O_3	14.5	14.37
Fe_2O_3	1.2	2.96
FeO	7.8	6.10
MnO	—	0.11
MgO	6.2	7.02
CaO	5.9	6.60
Na_2O	3.3	3.72
K_2O	5.2	4.76
P_2O_5	—	1.04
H_2O	—	0.51
Total	98.7	100.33

1. Shih-lung lava.
2. Average composition of 19 kinds of shield and cone rocks.

The lava of the twelve older cones, except for that of Lao-hei-shan and Huo-shao-shan, is generally reddish brown or black, compact or porous, and is represented by fist-sized scoria or lava flows. The lava is composed of olivine, augite and glass and sometimes leucite as well as anorthoclase. These rocks formed scoria cones in relatively small and brief eruptions.

The new cone lava which formed Lao-hei-shan and Huo-shao-shan is composed of black or brown porous scoria and lava flows. Many volcanic bombs are found.

The rock consists of a glass base in which olivine and augite microphenocrysts are scattered, it is similar to the older cone lava in character, but the new cones seem to be built by relatively severe eruptions and explosions.

The volcanic rock of the Wu-ta-lien-chi district is all alkaline basaltic. Depending on the time and mode of eruption, various topographical features—hilly highlands, shield volcanoes or cones and shihlung lava field—were formed, but from the point of view of mineralogical and chemical composition the lavas are very similar to each other, differing only in name according to the mode of eruption. The average chemical composition of 19 kinds of volcanics which formed shield volcanoes and cones in the district is shown on the Table 12-2.

Conclusion

The Wu-ta-lien-chi volcano is a dormant volcano which erupted in 1720 and which has characteristic leucite-containing rock. At present no post-volcanic activity can be seen in this district, but evidence of activity in the Kanhsi era remains at Lao-hei-shan and Huo-shao-shan. The many kinds of volcanic phenomena sculptured on the shih-lung lava field provide valuable natural monuments which cannot be observed even in so volcanic a country as Japan. Fourteen cones are arranged like stepping stones in the wilderness of the north Manchurian highland, clad in dense forest, and reflected in the waters of the Wu-ta-lien-chi lakes. Thus the district ranks high in terms both of natural beauty and scientific interest.

Chien-shan volcano

This volcano is situated on the southern side of the No-mo-erh-ho River, 35 km west of the prefectural town of Te-tu. It has a gentle conical shape and stands on the basalt shield volcano. Its height is 425 m above sea level and the relative height is about 100 m.

In the upper course of the No-mo-erh-ho River, east of Te-tu, is found the No-mo-erh volcano which consists of two cones, but no details about it are known.

10. Ko-lo Volcano

The Ko-lo volcanic group is situated near the village of Ko-lo-chan along the road from Nen-chiang (Mo-erh-ken) to Ai-hun on both sides of the Hsiao-hsing-an-ling Mts. and the cones are scattered over a distance of 30–50 km to the east of Mo-erh-ken. The cones are Tuan-tzu-shan, Ko-lo-nan-shan, Ta-i-shan, Hsiao-i-shan and Ta-hei-shan.

Tuan-tzu-shan is situated nearest to Mo-erh-ken, and is a big cone, 650 m above sea level and 200 m in relative height. Ko-lo-nan-shan is 6 km southeast of Ko-lo-chan, 550 m above sea level and 120 m in relative height. On the summit there is a crater and the crater wall is broken in the southern part. Ta-i-shan is 11.5 km northeast of Ko-lo-chan, 570 m above sea level. Hsiao-i-shan is 6 km northeast of Ta-i-shan, 610 m above sea level and 50 m in relative height, and the northeastern part of its crater wall is broken. Ta-hei-shan is 9 km north of Ta-i-shan and 630 m above sea level. The depth of its crater is estimated at about 100 m. These cones can be clearly seen from the northern part of Wu-ta-lien-chi volcano.

Six km southeast of Ssu-chan, and 30 km northeast of the Ko-lo volcanic group, there is a rounded cone called Hsi-shan which is 750 m above sea level and 230 m in relative height. A cone is believed to exist in the upper course of the Tsao-lai-ho River, SSW of Ko-lo-chan.

All the cones mentioned above are arranged on a NE-SW line.

11. Ka-tsung Volcano

Along the road from Mo-erh-ken to Ai-hun, northeast of Ko-lo volcano, on the east side of the Hsiao-hsing-an-ling Mts. and 12 km north of Erh-chan, is the Ka-tsung volcano, consisting of 2 cones 150 m high. There is also a cinder cone west of San-chan, southwest of the Ka-tsung volcano. These 3 cones are arranged in NE-SW direction.

There is also a cone 100 m high on the right side of the Amur River, 40 km southeast of Ai-hun.

12. Kankuei Volcano

Kan-kuei volcano is 70 km northwest of Mo-erh-ken and 52 km northwest of Pa-yen-chieh, which is near the confluence point of the Kan-ho and the Kue-i-ho tributaries of the Nen-chiang River. There are four or five cones with relative heights of about 170 m. Details are not known.

13. Sha-tu Volcano

Sha-tu volcano is a collective name for eight cones situated 125 km northwest of Mo-erh-ken, and scattering for nearly 170 km along the far upper course of the No-min-ho, a tributary of the Nen-chiang. These cones are arranged in a NNW-SSE direction. Sha-ti-erh-shan and Tu-hu-lu-shan are the two principal cones. Sha-ti-erh-shan is in the northernmost part, on the left side of the No-min-ho, it is 686 m above sea level, and 100 m in relative height. On the summit there is a crater 400 m wide, the northwestern part of whose wall is broken. Tu-hu-lu-shan is 40 km south of Sha-ti-erh-shan, 10 km west of the No-min-ho, and 845 m above sea level; it is the highest cone of the 8. There are 3 cones on a line connecting Sha-ti-erh-shan and Tu-hu-lu-shan. The first cone is situated 15 km north of Tu-hu-lu-shan and is 300 m high; the second is 8 km north of the first and has a flat summit 300 m in diameter; and the third is north of the second, 250 m high, and has a flat elliptical summit. Two other cones stand on a line parallel to Sha-tu in the east. Its relative height is about 40–50 m. These 7 cones are truncated cinder cones. Another cone, 5 km west-north-west of Sha-ti-erh-shan, is 100 m in relative height. It has a crater on the summit, 200 m in diameter and 50 m in depth, and there is a central cone within the crater. A double volcano of this sort is rarely seen in such a small cone.

14. Ha-r-hin-tun Volcano

This volcano was studied by Mr. Nobuo KIYONO. It is located on the east side of Ha-lun-erh-shan hot spring, in the central Ta-hsing-an-ling Mts. The volcano is a mountainous mass with a base 1,000 m in diameter and a summit consisting of several peaks. The summit is about 200 m above the river floor of Ha-lun-erh-shan plain. There are two central cones within the crater, to the north and south, and the southern one contacts the somma. The volcano is formed from quartz trachyte intercalated with tuff and obsidian, and thus differs from other volcanoes. It apparently has some genetic relation to the Ha-lun-erh-shan hot spring. This hot spring issues from 44 points within a distance of 700 m in a N-S direction. Its maximum temperature is 45° C, and there are 6 springs which maintain a temperature over 40° C. These springs are simple or carburetted types.

15. O-ne-nor Volcano

East of the Ta-hsing-an-ling Mts. and about 100 km north of So-lun along the upper course of the Cho-erh-ho, there is a lake called O-ne-nor, in a liparite area. Its diameter is 2 km, but the lake proper is crescent-shaped. The lake is surrounded by 250–300 m heights inclining at a 40° angle toward the lake. The lake water pours out through a break in the heights and originates the upper course of the Cho-erh-ho River. Judging from the topography of the environs this is a crater lake and the heights are the crater walls composed of liparite.

16. Along the Sung-hua-chiang

Along the right side of the Sung-hua-chiang from I-lan, in San-chiang Province to Fu-chin via Chia-mu-ssu, there are four basaltic domes, one of which reaches a height of 100 m. Two of the domes are in a NE-SW direction.

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