THE VOLCANIC ROCKS IN PEI PIAO REGION (北票)

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(With 4 plates and 1 figure)

(Also refer to Dr. Wong's map, Bull. Geol. Surv. China, No. 11, pl. I).

INTRODUCTION.

The volcanic rocks in Pei Piao region have been already noticed by different authors[1]. They were, however, only stratigraphically classified into two series known as the Upper Volcanic and the Lower Volcanic, while their petrographical characters and real rock types are yet in vague.

The Upper Volcanic Series occurs above the Mesozoic coal series, and apparently has its corresponding formations in other places[2]. But the Lower Volcanic Series, lying below the Jurassic coal formation is yet unencountered elsewhere in North China.

The present study is intended to make a general investigation about the rock types, order of eruptions, magmatic variations and geological significance and finally to make a comparison with other Mesozoic volcanic regions, if it is possible.

The specimens which the author studied in the Laboratory of the Geological Survey, were collected by Mr. H. S. Wang (王恆升) in the winter of 1928. As a result of my petrographic work and stratigraphical correlation it is possible to establish a sequence of the volcanic activities in this region, during the Upper Jurassic and the Lower Cretaceous periods. Between these active periods coal seams were formed. The magmatic variations represented by the successsive extrusions reveal themselves in beautiful analogy with

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1 H. C. T'an, Geology of the Pei-Piao coal field, Chao Yang district, Jehol, Bull. Geol. Surv. China, No. 8, PP. 30-32; W. H. Wong, Etude tectonique de la region de Pei piao et ses environs, Bull. Geol. Surv. China, No. 11, PP. 1-15.

2 The "tuff conglomerate" in Shantung.

those in Hsuan Hua (宣化)[1] and also Dalai-noor (達賚泊)[2]. The Lower Volcanic Series may be most probably contemporaneous with the older volcanic series in Hsuan Hua and the Kangtai formation (綱台火山岩系) in Pa T'ao Hao (八道壕)[3], the latter being not very far from the Pei Piao region.

STRATIGRAPHY

The geological formations of this region so far as known, are the following in descending order :

Upper Volcanic Series
Jpper Coal Series
Lower Coal Series
Lower Volcanic Series
Sinian Quartzite and Limestone

The Lower Volcanic Series. Unconformably lying upon the Sinian quartzite and limestone there are the members of this series. They have a total thickness varying from 360 to 500 meters and are widely distributed along the southern border of the coal field. All of them are dark brown in color, and belong to the same variety namely andesite; hence they are less complicated in type than those rocks in the Upper Volcanic Series.

At Pao Chü Yao (寶聚窯) as well as Yao Chia Kou (岳家溝) there are two important lava sheets observed. The one, lying in the lower portion of this series, is microscopically determined to be biotite trachy-andesite, frequently amygdaloidal in texture. The other is a hornblende trachy-andesitic lava just overlain by the Lower Coal Series. Between these two sheets, the transitional members are Lava flows and occasionally agglomerate, composed chiefly of hornblende-trachy-andesitic boulders or bombs. The latter are usually as large as pears. In the vicinity of K'ao Shan Chang (窯山廠) and the southern side of Lao Kuen Miao (老君廟) these volcanic products usually

1 H. S. Wang: The ancient volcanoes in Hsuan Hua, their rock types and geological age. Bull. Geol. Surv. China, No. 10, PP. 25-42.

2 Teilhard ; Etude geologique sur la region du Dalai-noor, Men. Soc. Geol. de France, N. S., No. 7. 1926, PP. 1-53.

3 H. C. T'an: Geology of the Pa T'ao Hao coal field, Heishan district, Fengtien. Bull. Geol. Surv. China No. 8, PP. 20-29.

spread over the quartzite mountain slopes. In general, the rocks in this series are easily distinguished from those of the Upper Series because they are both stratigraphically and topographically lower in position and more weathered in appearance.

The Lower Coal Series. It has a total thickness of over 1100 meters, and contains the principal coal seams worked by the Pei Piao Coal mining Co. According to Mr. T'an, the coal is similar to that of Ta Tung (大同) which is also of Jurassic age.

The Upper Coal Series. This series has been regarded as equivalent to the Laiyang series in Shantung (山東萊陽系). It has a total thickness of about 363 m. and is chiefly composed of sandstone and argillaceous shale, bearing insect fossils[2] of Lower Cretaceous age. Thin layers of bad coal and occasionally of conglomerate are intercalated in the shale beds. There seems no sign of unconformity between these two coal series although the existence of a disconformity is probable.

The Upper Volcanic Series. Nearly all of the mountains in the north and northeast of Pei Piao are constituted by the rocks belonging to this series. It has a total thickness of about 620 meters. As to the superposition of the members contained, there is no better section than the one drawn by Mr. H. S. Wang, along the southern river bank near Fou Chia Cha Tzu (傅家椏子). With the author's petrographic determination the successive members are the following :

1. Conglomerate: It has a thickness of about 80 meters. Its boulders are chiefly of Archaean granite and schist and less frequently Sinian quartzite. They are well rounded and occasionally over one meter in diameter.

This Conglomerate may be encountered every where if one goes from the eastern bank of Mong Niu Ho (忙牛河) southwestward to the north of Hsing Lung Kou (興隆溝). On the evidence of this persistence and also the existence of the Archaean boulders, this conglomerate should be the very base of this series. For the same reason, Dr. Wong believed that there was undoubtedly a long errosion period and an important crustal movement prior to the volcanic activity.

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1 H. C. Tan: Geology of Pei Piao coal feild. Bull. Geol. Surv. China, No. 8, P. 31.

2 C. Ping: Creta. insect fossils in China. Palaeont. Sinica. Ser. B, Vol. 13, Fasc. 1 PP. 16-31.

2. Agglomerate..... 10.0 m.
3. Lava ..... 20.0 m.
4. Tuff intercalated with shale containing insect fossils[1].. 80.0 m.

These are petrographically determined to be of trachytic varieties. They are usually pinkish grey in color and tarnished green. Besides the above localities, these are also encountered at Huang T'ow Kou (黃土溝) (Fig. 1).

Fig. 1. a—Conglomerate intercalated with shale, b—Sandstone } Upper part of the Upper Coal Series.

1—Conglomerate with boulders of Archaean schists and granite. 2—Juff 3—Lava (Biotite Trachyte) 12—Tuff (Trachy-andesitic) 13—Lava (Trachy-andesite)

This will show the continuity of existence of the volcanic rocks in the western side of Mong Niu Ho (忙牛河).

Another thing which should be noticed is that the intrusion[2] in the east of Tai Chi Ying Tsu (台吉營子) is petrographically equivalent to this lava flow and hence it was probably derived from the same source.

5. Conglomerate: Most of its boulders are quartzite and rarely volcanic tuffs..... 20.0 m.
6. Shale bearing insect fossils[3]..... 30.0 m.
7. Greenish white tuff
8. Agglomerate with silicified wood..... 20.0 m.
9. Whitish tuff..... 20.0 m.
10. Greenish lapilli and tuff..... 30.0 m.

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1 Refer to Dr. Wong's map. Bull. Geol. Surv. China. No. 11, Pl. I.

2 Refer to Fig. 6 by Dr. Wong. Abid. P. 4.

3 The insect fossils, collected by Dr. Wong have been determined by C. Ping. They are *Mesohemerobius jeholensis* Ping and *Chironomopsis gracilis* Ping. They belong to Lower Cretaceous age. C. Ping, Palaeont. Sinica, Ser. B. Vol. 13, Fasc. 1 PP. 37-43.

7 to 10 are of rhyolitic varieties. They are well developed in the vicinities of San Chia Tzu (三家子), Lan Chi Ying Tzu (藍旗營子), Huang Chia Cha Tzu (黃家柵子) and Fou Chia Cha Tzu (傅家柵子). Fragments in the lapilli and tuff are chiefly shale and occasionally quartzite.

11. Fine tuff deep grey in color..... 20.00 m.

12. Agglomerate with tuff and shale.....150.0 m.

13. Lava ..... 50.0 m.

14. Dark grey tuff and lapilli..... 50.0 m.

15. Dark brown lava..... 30.0 m.

11 to 15 are all of andesitic varieties beginning with dacitic tuff, passing through trachy-andesite, hornblende trachy-andesite, and finally ending in augite andesite. They are well developed in the southwestern side of Pei Piao, such as Yang Shou Kou (楊樹溝) and Hsing Lung Kou (興隆溝).

PETROGRAPHIC DESCRIPTION OF THE IGNEOUS ROCKS.

The Biotite Trachy-andesite; This is found in the lower portion of the lower volcanic series on the southern side of Pao Chü Yao (寶聚窯) and Lao Kuen Miao (老君廟). It is, when fresh, a grey felsitic rock mottled with black spots. Under microscope, it consists of innumerable small feldspar-laths, either simple or twinned, and a cryptocrystalline matrix giving an andesitic texture. The phenocrysts are of two kinds, namely, the feldspar and biotite. The former are more or less chloritized ; while the latter are badly decomposed and nearly completely masked by dust-like magnetite and limonite, which are also abundant in the groundmass, though not infrequently chloritized.

Judging from the extinction angle obtained by Fouque's method (when $\perp$ to C, measured from cleavage cracks, ext. $L=5°$) the feldspars are chiefly of oligoclase, being usually twinned and occasionally zonal when occurring in phenocrysts.

The specimens collected from Pao Chü Yao is a reddish brown rock, amygdaloidal with chlorite filling the vesicles. Microscopically the biotite alters by the loss of color or changes into confused aggregates of chlorite with the accompaniment of cryptocrystalline quartz, agate, limonite and carbonate. And in some cases the biotite is completely removed with its outline retained

only by having lining of magnetite. This transformation is not a decomposition due to weathering but a recrystallization of the biotite material when its surrounding rock-magma was still molten[1].

The Hornblende Trachy-andesite: It is brownish gray or greenish gray in color, porphyritic in texture; and with the white feldspars the rock is imparted a spotted appearance. In thin sections, it consists of both euhedral and anhedral inequidimensional phenocrysts of feldspars and green hornblende and a residium of dark grey, subvitreous groundmass which is rich in dust-like iron ores and shows more or less trachytic texture by the arrangement of the microlites of feldspars.

The feldspar phenocrysts are usually prismatic and are judged to be oligoclase by its extinction angles obtained by both Fougue's and Michel Lévy's statistical methods (ext. L obtained from the former method, when $\perp^{to}$ a = 2°, when $\perp^{to}$ c = 5°; that from the latter method = 5°). These are either kaolinized or chloritized with the accompaniment of the formation of quartz, and during the alteration an introduction of iron oxide takes place.

Green hornblende is the only dark-colored silicate present. It appears, in the examined sections, in irregular grains with sharp cracks crowded together, fibrous laths usually with frayed-out ends, rhombic sections showing characteristic cleavage angles, and also corroded forms. Some of them loses color and subsequently passes into pale or colorless fibrous amphibole resembling tremolite and actinolite; some changes into pyroxene and magnetite, which usually exists in dust-like form, in the interior or as a black zone surrounding the unaltered hornblende phenocrysts (Pl. III Fig. 1). This fact and the presence of the corroded forms testifies that the hornblende crystals have undergone a decomposition and recrystallization prior to the final solidification of the rock magma. Primary magnetite granules are abundant.

Two specimens have been collected in the lower parts of the Lower Volcanic series on the south of Yao Chia Kou (岳家溝) and Pao Chü Yao (寶聚窯); and in the latter place, another specimen has been taken from the upper part of the Lower Volcanic series. From the latter occurance, the hornblende trachy-andestic lava seems comparatively older than the preceeding.

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1 Idding's Rock Minerals, P 425.

Its Associated Agglomerate : Four slides have been prepared from the boulders collected in the agglomerate formation in the vicinity of Kao Shan Chang (祭山張). They are microscopically not much different from those hornblende trachy-andesites just described with the exception of the indications of quicker cooling. The skeleton crystals, shreds of hornblende and its longer columnar to neddle like individuals with frayed-out ends are more common ; their alteration to magnetite is more pronounced. Another interesting indication of rapid cooling, frequently found, is the presence of the radial aggregates of feldspars recalling the compound spherulite of Iddings[1] (Pl. III, Fig. 2).

From the above described characters, it seems very likely that these boulders were nothing else but fragments resulting from the volcanic explosion and they were, therefore, volcanic bombs. As their longest diameter reaches to 10 cm. the explosion must have been violent.

The Biotite Trachyte : When fresh, it is of flesh color, and sometimes of vesicular texture. The black shining particles of biotite impart the rock a mottled appearance. Under the microscope, it is porphyritic with phenocrysts of both simple and twinned feldspars and brownish black biotite ; the greenish crystocrystalline groundmass itself is trachytic in texture.

Following the methods of measurement made by Fouque and Michel Lévy, the feldspars are determined to be chiefly albite, more or less chloritized. The biotite occurs in columnar to needle-like individuals often with frayed-out ends, indicating a rapid cooling of the rock magma. Its primary recrystallization accompanied by separation of magnetite and subsequent alteration of the latter to limonite results in a pseudo-zonal corroded appear ance or, in other words, showing what is known as the reaction borders. (Pl. III, Fig. 3). Smaller and larger granules of magnetite of primary origin are met with both as inclusions in the feldspar phenocrysts and scattered in the groundmass.

The specimens described above are collected in the vicinities of Huang T'ow Kou (黃土溝) and T'ai Chi Ying Tzu (台吉營子). In the latter place the biotite trachyte is overlain by the Sinian siliceous limestone which is thought to be brought here by overthrust[2].

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1 Idding's Igneous Rocks, Vol. I, P. 241.

2 Bull. Geol. Sur. China. No. 11, pp. 3-5.

Its Associated Tuff: It is macroscopically a pale-green felsite mottled with flakes of biotite and is found in the lower portion of the Upper Volcanic Series on the northern side of Huang Chia Cha Tzu (黃家楂子). In thin sections, it is not much different from the biotite trachyte above stated except by the presence, though rare, of fragments of biotite trachyte which seems to be solidified just before the extrusion of this rock magma.

The Rhyolitic Tuff: This may be classified into two varieties namely the greenish and whitish. The former is found just above the shale intercalated in the lower portion of the Upper Volcanic Series as observed along the northern river-bank near Huang Chia Cha Tzu (黃家楂子). It is a fine-fragmental greenish grey rock. The fragments microscopically recognized are chiefly brown shale with fine schistose appearance, siliceous limestone and occasionally trachyte. The yellowish green matrix is composed of the curved bundles of fibrous feldspars and hornblende axiolitically arranged (Pl. III, Fig. 4). The inequidimensional euhedral and anhedral phenocrysts are more or less corroded and show no sign of decomposition. They are determined by their interference figures and positive and negative characters to be quartz and sanidine respectively. Minute granules of magnetite are met with in the groundmass which is chloritized.

Belonging to this variety there are two other specimens collected from the northern vicinity of San Chia Tzu (三家子).

In the whitish rhyolitic tuff, the fragments of all sizes are green schist, quartzite and occasionally quartz-sandstone. They are corroded, with saw-tooth-like outlines and sometimes welded out into streaks (Pl. IV, Fig. 1). The groundmass, being reddish grey and glassy, consists of subhedral and anhedral crystals of sanidine and quartz; they often show resorbed saw-tooth-like borders with inlet of the groundmass[1], and also streaked and welded appearance imparting the matrix an eutaxitic structure analogous to the rhyolitic lava in the Yellow Stone Park, U. S. A.[2]. This singular feature should be caused by the plastic or viscous magma falling and welding together in a still molten condition as in the very neighbourhood of a crater[3].

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1 This feature is very similar to the quartz phenocrysts in Niang Tze Shan rhyolite, Hsuan Hua. Bull. Geol. Surv. China. No. 10, P. 33.

2 Monograph 32, U. S. Geol. Surv. 1899, Pt. 2, P. 404.

3 Idding's Igneous Rocks. Vol. I, P. 331.

Two specimens belonging to this variety are collected on the east of Lan Chi Ying Tzu (蓝旗营子) and Fou Chia Cha Tze (傅家棚子).

The Rhyolitic Lapilli and Coarse Tuff: The former is found on the north of San Chia Tzu (三家子), the latter is collected from above the fine greenish tuff on the northern river bank near Huang Chia Cha Tzu (黄家棚子).

The fragments both vary in size and kinds to great extent. They are angular and rounded siliceous limestone, quartzite, schist, sandstone and occasionally the hornblende trachy-andesite of the Lower Volcanic Series. Rounded and corroded fragments of feldspars and quartz are not infrequently present. The cementing material is cryptocrystalline quartz and feldspars; when they occur as phenocrysts, the former is usually in allotriomorphic anhedrons showing wavy extinction, while the lattar often in twinned forms, are determined to be albite and orthoclase and occasionally oligoclase.

The coarse tuff at Huang Chia Cha Tzu microscopically has nothing special, but the fragments are smaller in size and less in number.

As these volcanic products just overlie the fine whitish tuff stated above and their fragments are of the Sinian and Archaean rocks, it shows that the volcanic activity was growing stronger.

The Dacitic Tuff : Overlying the rhyolitic tuff, this tuff is found on the north of Huang Chia Cha Tzu (黄家棚子). It is macroscopically a pinkish, deep-grey, compact felsite but microscopically fragmental in texture. The matrix, being light-grey in color, is subvitreous with small subhedral and anhedral phenocrysts of feldspars, quartz and rarely biotite in forms of columnar fibers and shreds. The fragments are almost all of the same color, same texture and nearly the same mineral composition as the matrix, except that they have no quartz. Measured by Fouque's method, on sections $\perp$ C (ext. $L = 5°$), the feldspars are chiefly oligoclase and occasionally, in the fragments, labradorite ($\perp$ C. ext. $L = 25$). Fro mthese facts and also that the fragments with frayed out outlines, it seems very likely that they were solidified from the same magma as the matrix, but only a short time before the subsequent solidification.

Minute granules of magnetite are the chief accessories in both the trachy-andesitic fragments and the matrix.

The Trachy-andesite : It is a deep brownish grey felsitic rock, occasionally vesicular; the vesicles are filled with secondary quartz or chlorite.

Under microscope, it is strongly porphyritic with large tabular phenocrysts of plagioclase on which chloritization as well as sericitization is not infrequently observed. The crystalline groundmass is found to be a felt of lath-shaped feldspars trachytically arranged. Both the phenocrysts and the lath-shaped feldspars give the extinction angles ranging from 0° to 5° when measured on sections ⊥ a and c, they are, therefore oligoclase. Their alteration-chloritization and sericitization is accompanied by an introduction of iron and magnesium and thence the formation of various ferromagnesian silicates. Magnetite which frequently decomposes into limonite is fairly abundant. Chloritized and dark bordered biotite is not uncommon.

The vesicle-filling chlorite is microscopically in the form of spherulitic aggregates (delessite) having several neucli of cryptocrystalline quartz.

Six specimens have been collected in the vicinities of Yang Shui Kou (楊樹溝), Huang T'ow Kou (黃土溝), Hsing Lung Kou (興隆溝) and San Chia Tze (三家子). In the latter place another specimen is added to the collection by its porous appearance, lesser degree of crystalinity as compared with those above described, it is undoubtedly solidified at the surface of the lava sheet. Its pores are filled with amorphous quartz, chlorite and limonite.

Its Associated Tuff: At Huang Chia Cha Tzu (黃家椰子) this tuff, intercalated with the above described lava sheet, is found overlying the greyish dacitic tuff. Seven specimens are collected from Huang T'ow Kou (黃土溝), Hsing Lung Kou (興隆溝) and Yang Shui Kou (楊樹溝). In general, they are brownish grey in color, compact or amygdoloidal in texture, with fragments sometimes about 2 cm. in diameter. Under microscope, the fragments are chiefly trachyte, trachy-andesite as judged by its oligoclase phenocrysts, green schists, quartzite and siliceous limestone. The matrix is brown glass or cryptocrystalline and frequently shows more or less flow-structure. Phenocrysts are largely, brocken, corroded and occasionally curved crystals of oligoclase (Pl. IV, Pig. 2) which are apparently less turbid than those in the fragments of trachy-andesite. Small shreds of biotite and minute granules of magnetite are not uncommon in the matrix.

From the facts that the fragments are usually sharp angular, larger in size, of Archaean and Sinian rocks and also from the trituration of the phenocrysts by the explosion, we may conclude that the eruption was as violent as that producing those rhyolitic tuffs.

The Hornblende Trachy-andesite: This, belonging to the Upper Volcanic Series, is like that found in the Lower Volcanic Series, both in texture and mineral composition. The only difference is that the former is less weathered and hence macroscopically deep grey, not brownish grey, is in color, because its iron-constituent is still in oxide state (Fe_3O_4, magnetite) while in the latter it has already been oxidized and hydrated ($2\,Fe_2O_3 3H_2O$). Microscopically, besides the primary alteration caused by recrystallization just prior to the final consolidation, the hornblende in the older rock is more often badly chloritized and its iron color completely leached; and again, the secondarily originated hornblende, being fresh in appearance, is more common. Furthermore the basaltic variety of hornblende is more frequently observed in the younger hornblende-trachy-andesite. In concordance with the hornblende the chloritization of the feldspars is also in a higher and lower degree respectively.

This type of rock is found in the vicinities of Lan Chi Ying Tzu (藍旗營子) and Hsing Lung Kou (興隆溝).

It is worthy to note that another specimen collected at Yang Shui Kou (楊樹溝) is somewhat microscopically different from that above stated. It is strongly porphyritic with occasionally large crystals of oligoclase and colorless hornblende (tremolite). These two minerals frequently mutually include each other with an outline of either the feldspar or the hornblende thus forming what is known as the poikilitic texture[1] (Pl. IV, Fig. 3). The hornblende which is perhaps talcosed or chloritized, shows fine parallel cleavages, weak pleochroism, and gives extinction angles from 19° to 25° and a negative character in convergent polorilized light.

Granules of magnetite are also abundant in the matrix which is partially crystalline and partially glassy.

The Andesite of Lan Chi Ying Tzu (藍旗營子). It is a dark brown porous rock. In thin sections, it is porphyritic with very well crystallized phenocrysts of tabular feldspars, not much varied in size. They all show polysynthetic twins with broader lamellae. Judging from the extinction angles obtained by both Fougue's and Michel Léoy's statistical methods, the feldspars are chiefly labradorite.

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1 Idding's Rock Minerals P. 69.

Chloritization has fairly commenced. The ground mass is subvitreuos and rich in iron.

The Hornblende Andesite and Augite Andesite. These are collected in the vicinity of San Chia Tzu (三家子). Both are compact dark grey rocks, poorly porphyritic in texture under the microscope. The former consisted of a cryptocrystalline deep grey matrix, anhedrons of feldspars and columnar to needle like hornblende, belonging to basaltic variety. They usually show frayed out ends. but no black borders. The feldspars are largely labradorite, of which the microlites show abnormal crystal habits—small stout prismatic forms finished by fibrous sproutings at their corners. Minute pale green to colorless grains of augite and dust-like magnetite are the mafic accessories; the latter, with its decomposition product, limonite, perhaps occupy 20% of the field of view when quantitatively examined under the microscope.

In thin sections the augite andesite is also fairly porphyritic with a crystalline groundmass, pale green in color, trachytic in texture. The feldspars are labradorite. The augite occurs in pale green minute grains, skelton crystals and short prismatic phenocrysts. The latter usually alter to minute aggregates of green hornblende at their borders and quartz in their interior where they are again stained by limonite (Pl. IV, fig. 4). In concordence with the presence of quartz vein, which is easily observed macroscopsically, this alteration is believed to be due to the action of hot vapors or strong acids[1], and the limonite is perhaps, introduced by the replacement. Magnetite is abundant, both in the matrix and in the phenocrysts.

The quartz vein is microscopically composed of small patches of opal and minute aggregates of quartz. The latter exists on the vein walls.

The Andesitic Lapilli and Tuff: The former is a dark grey fragmental rock found above the trachy-andesitic tuff at Huang Chia Cha Tzu (黃家椏子). Under the microscope the fragments are biotite trachyte, hornblende trachy-andesite and siliceous limestone etc. They vary in size and are often sharp angular. They are cemented by a brown subvitreous matrix, showing more or less flow structure, in which there are many euhedrons and anhedrons of feldspars of notable size. The feldspar phenocrysts which are recognized to be chiefly labradorite and occasionally oligoclase, are frequently broken,

1. Idding's Rock Minerals P. 301.

corroded, and eventually penetrated and expelled each other thus indicating the trituration by explosion.

The augite andesitic tuff at Hsing Lung Kou (興隆溝) microscopically consisted of the fragments of augite andesite and a pale-green crystalline matrix, the latter itself is composed of anhedral feldspars and irregular grains of augite which has altered to hornblende, chlorite and quartz. Both in the fragments and the matrix, the augite belongs to the basaltic variety. The columnar feldspars are also badly decomposed.

ORDER OF ERUPTION AND MAGMATIC VARIATION

Through the light of facts described under the preceding headings, it is clear that the volcanic activity was opened by an eruption of biotite trachy-andesitic lava overflowing on the eroded Sinian limestone surface. Subsequent to this eruption there came a violent explosion which resulted in forming the lower hornblende trachy-andesitic agglomerate, often with large bombs. Following this explosion the hornblende trachy-andesitic lava flow finally occurred. And then the Lower Volcanic Series was completed.

After the periods of coal formations and tectonic disturbance-the first phase of the Yenshan movement—another active period followed. It began by an explosion which was immediately followed by a biotite trachytic lava. The trachyte found across the coal seams at Tai Chi Ying Tzu (台吉營子) is believed to be the hypabyssal phase of this extrusion. Then a quiescent period came and the fossil-bearing shales were deposited.

But the silence was no longer kept untill another explosion took place more violently than before. The rhyolitic tuffs intercalated with lapilli and occasionally agglomerate were then resulted. This was continueously followed by the successive explosions and eruptions of basic magmas with their basicity successively increased. Finally the volcanic activity was closed by an augite-andesitic lava.

This order of events as above described clearly demonstrates the magmatic variation. If we make the coal-forming interval a longer quiescent period, the variation in composition will constitute a complete cycle; beginning with the lesser basic magma (trachy-andesite), passing through acidic and finally ending in the more basic one (augite-andesite).

Similar magmatic differentiation has been observed in other

regions such as Hsüan Hua[1] (宣化) and Miao Feng Shan[2] (妙峰山) in the Western Hills of Peiping. The volcanic rocks of these regions show under the microscope, the same associated minerals and the same abundance of magnetite in all the older biotite andesite and hornblende andesite. From this fact, as well as from the order of eruption, the author will conclude to the analogous magmatic variations in these regions, though they took place within longer or shorter periods. The same is true in Dalai-noor (達賴泊),[3] north west of Pei Piao, northeast of Hsüan Hua. The accompaning table (Pl. I) will be served to illustrate this analogy.

GEOLOGICAL AGE

With the aid of the insect fossils[4], the age of the Upper Volcanic Rocks has been actually determined. It is of Lower Cretaceous. The petrographic analogy with those Lower Cretaceous rocks in Hsuan Hua, as shown in the preceding table, is perhaps, a further proof for the age determination.

It was Dr. Wong's opinion[5] that this Upper Volcanic Series is corresponding to the Chingshan Series (山東青山系), which is not uncommon in North China, well developed in Shantung and is known as the "Tuff-conglomerate" by Mr. H. C. T'an[6] This correlation may be proved quite right, if we compare the stratigraphical and lithological evidence between them and also mutually with the "Conglomerate Formation" in Pa Tao Hao (八道壕)[7] not very far from the Pei Piao region (Pl. II, Section 1). Thus the author may conclude that the Upper Volcanic Series here is nothing else but only a local phase of the common "Tuff conglomerate formation", caused by a local volcanic activity during the middle of Yenshan movement[8]

1. H. S. Wang: The ancient volcanoes of Hsuan Hua, their rock types, and geological age. Bull. Geol. Surv. No. 10, 1928, PP. 26-42.
2. H. S. Wang: Igneous rocks of Miao Feng Shan & Tiao Chi Shan in the Western Hills of Peking. Bull. Geol. Surv. No. 11, 1928, PP. 17-30.
3. Teilhard: Etude Geol. Sur la Region du Dalai-noor, Mém. Soc. Geol. de France, N. S. No. 7, PP. 1-53.
4. Refer to the foot note on P. 346.
5. W. H. Wong: Bull. Geol. Surv China. No. 11, 1928, P. 21.
6. H. C. Tan: New research on the Mesozoic and Early Tertiary Geology in Shantung. Bull. Geol. Surv. China. No. 5, Pt. 2, P. 115.
7. H. C. Tan: Pa Tao Hao Coal Field. Bull. Geol. Surv. China. No. 8, P. 25.
8. W. H. Wong: Crustal movement and igneous activities in Eastern China. Bull. Geol. Soc. China, Vol. VI, PP. 12-14.

(燕山). If this is true, then the Chingshan Series in Shantung and the Conglomerate formation in Pa Tao Hao will be all of the Lower Cretaceous age.

A special feature in the Peipiao region is the occurrence of the Lower Volcanic Series below the main coal series. This is very unusual in North China. This Lower Volcanic Series chiefly consists of andesitic lavas, tuffs and agglomerate ; no sedimentary beds have been encountered and hence the age of this series cannot be palaeontologically determined.

We remember that the Upper Volcanic Series is to be correlated with the conglomerate formation at Pa Tao Hao[1]. The latter is underlain by Heishan cool series (黑山煤系) to which Cretaceous age was asigned by Mr. H. C. T'an, on the basis of fossil contents (section 1). According to Dr. Kryshtofovich[2] also, the plant fossils from the middls part of Heishan series indicate Lower Cretaceous age. This conclusion is well in agreement with the insect fossils[3] collected from the Upper Coal Series in the Pei Piao region.

Like the Lower Volcanic Series, the Kangtai formation (糠台火山岩系) (section 1) is also apparently conformable with the coal series and directly overlying upon the Sinian quartzite or limestone. It consists chiefly of dark brown and purple lavas and dark green and violet tuffs. When examined under the microscope, they show almost the same petrographic characters as the hornblende andesite in the Lower Volcanic Series of Pei Piao. Another similarity is the absence of intercalated sedimentary beds. This formation was considered to be of Jurassic. The same age may be probably asigned to the Lower Volcanic Series in Pei Piao. (compare sections 1 & 2)

Again, on the basis of petrographical characters, order of eruptions and magmatic variations, the volcanic rocks in Pei Piao are for the most part analogous to those in Hsuan Hua. Thus the biotite andesite and the hornblende andesite here, would be contemporaneous with the Wu Chia Kou biotite andesite (武家溝雲母安山岩) and the Lei Kung Shan hornblende andesite (雷公山角閃安山岩) in Hsuan Hua region[4]. The Hsuan Hua

1 Refer to page 356.

2 Kryshtofovish, A. Remains of Jurassic plants from Pa Tao Hao. Bull. Geol Soc. China, Vol. III, No. 2, PP. 105-108.

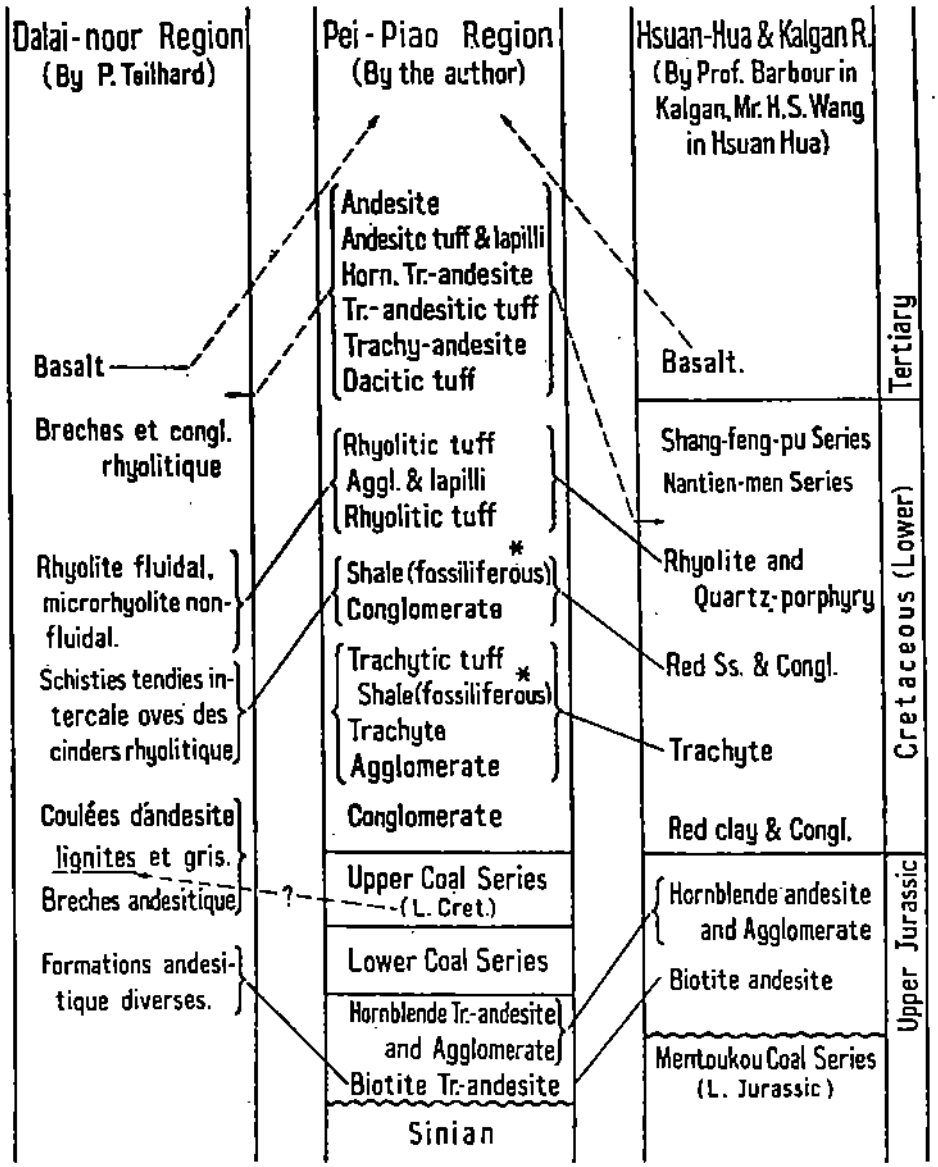
3 Refer to the stratigraphy previously described.

4 H. S. Wang : The Ancient Volcanoes in Hsuan Hua. Bull. Geol. Surv. China, No. 10, P. 79.

andesites however overlie the Jurassic Coal Series in stead of underlying as is the case with the Lower Volcanic Series in Pei Piao (Section 2). This difference can be explained, if we assume that the Upper and Lower Coal Series in Pei Piao as well as the Hei Shan series in Pa Tao Hao, were deposited during the same interval (early Lower Cretaceous) represented by the disconformity between the older and younger volcanic series, in Hsuan Hua (compare the sections 1, 2 & 3); but in Pei Piao there also occurred some gaps within the two coal series and between the Lower Coal Series and the Lower Volcanic Series

From the above discussion, the Lower Volcanic Series may be well considered as Upper Jurassic, evidence by both petrographical characters and stratigraphical correlation.

Table Illustrating the Analogous Magmatic Variations in the following Ancient Volcanic Regions.



* *The fossils collected and examined are Lower Cretaceous insects.*

Columnar Sections Illustrating Stratigraphical and Petrographical Relationships. (much generalized)

Section 1

Pa-Tao-Ho Coal Field, Heishan District, W. Fengtien.

(According to Mr. H. C. Tan)

Section 2

Pei-Piao Coal Field, Chao-Yang, Jehol.

(By the author)

Section 3

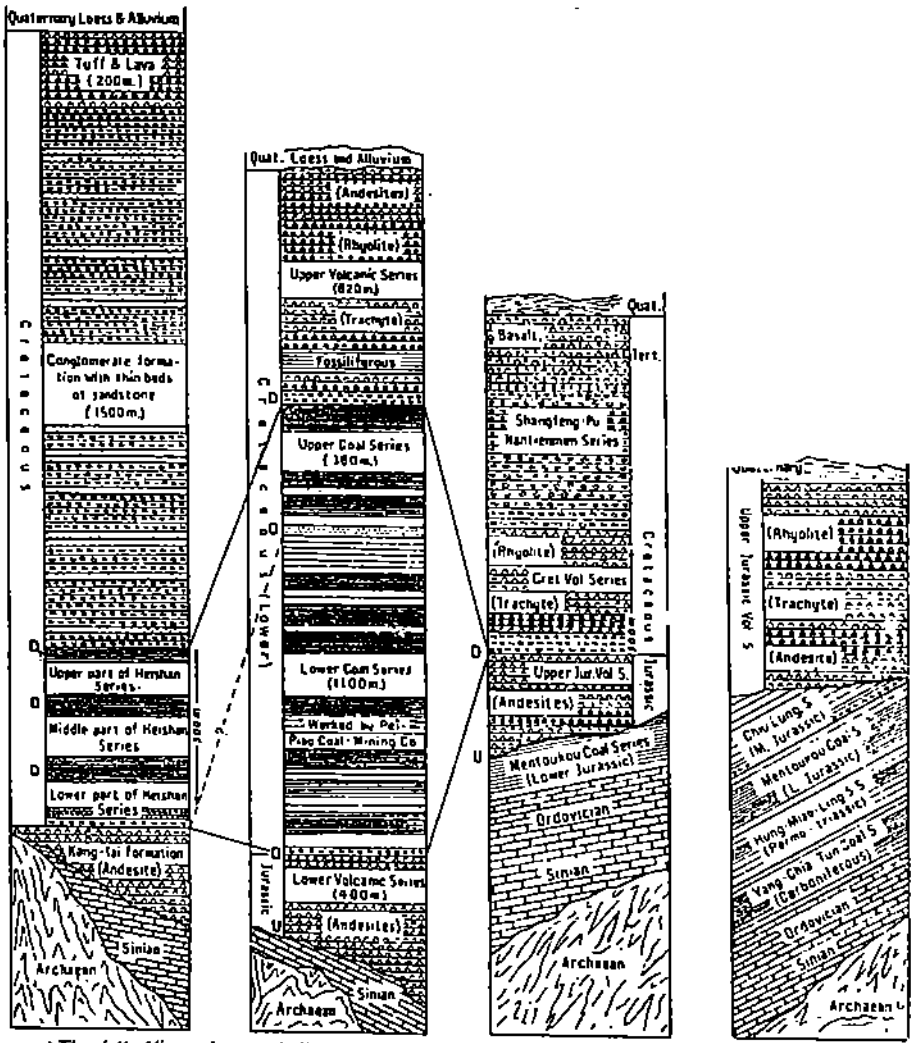
Hsuan-Hua & Kalgan Regions.

(According to Mr. H. S. Wang)

Section 4

Miao-Feng-Shan & Tiao-Chi-Shan, Western Hills of Peiping.

(According to Mr. H. S. Wang)



? The dotted line is drawn to indicate the classifications of the strata, as given by Mr. Tan, basing on the lithographic characters of the sedimentary beds and the coal qualities.

Explanation of Plate III

PLATE III.

Fig. 1.—Hornblende Trachy-andesite, Pao Chü Yao (寶峪窯). Hornblende phenocrysts altered to dust-like magnetite at the border, and colorless amphibole, probably tremolite, in the interior.

Fig. 2.—Boulder or bomb of the Hornblende Trachy-andesitic agglomerate, Kao Shan Chang (高山張). Radiating feldspar-aggregates indicating rapid consolidation.

Fig. 3.—Biotite Trachyte, Hsi Tai Chi Ying Tzu (西台吉營子). Phenocrystic biotite showing reaction borders, trachytic structure in the ground-mass.

Fig. 4.—Rhyolitic tuff, San Chia Tzu (三家子). A subvitreous matrix showing axiolitic structure composed of microlitic feldspars and hornblende.

Fig. 1.

× 62.

Fig. 2.

× 62.

Fig. 3.

× 62.

Fig. 4.

× 62.

Explanation of Plate IV

PLATE IV.

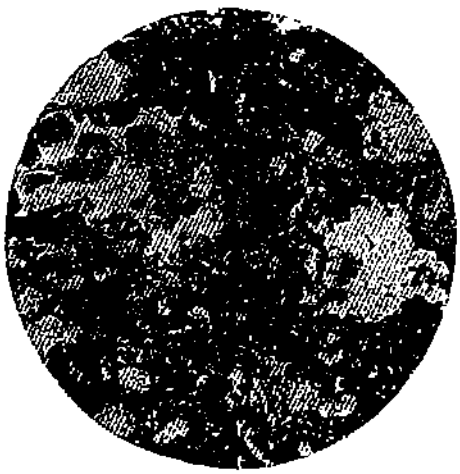
Fig. 1.—Rhyolitic tuff, Lan Che Ying Tzu (藍旗營子). Saw-tooth-like fragments sometimes welded out into streaks.

Fig. 2.—Trachy-andesitic tuff, Yang Shui Kou (楊樹溝). A sub-glassy matrix with curved phenocrystic feldspars probably oligoclase.

Fig. 3.—Hornblende Trachy-andesite, San Chia Tzu (三家子). Hornblende (tremolite) poikilitically enclosed by feldspar.

Fig. 4.—Augite Andesite, San Chia Tzu (三家子). Phenocrystic augite completely altered to hornblende at the border, and quartz in the interior; groundmass composed of microlitic feldspars trachytically arranged.

Fig. 1.



× 62.

Fig. 2.

× 62.

Fig. 3.

× 62.

Fig. 4.

× 62.