A STUDY OF THE IGNEOUS INTRUSION AND ITS METAMORPHISM AT CHUNGSHAN (鐘山), NANKING*

(With three plates)

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I. IGNEOUS INTRUSION

a. DISTRIBUTION OF OUTCROPS

In the vicinity of Chungshan (鐘山), Nanking, several outcrops of igneous intrusions are found, such as at Taipingmen (太平門), Tienpaochêng (天保城), Huangmats'ing (黃馬青), Hsiawuchên (下五鎮), Wangchiatsing (王家井) and Chiangmiao (蔣廟).

The size and form of these outcrops are various; near the top of Tienpaochêng one dike four feet wide, was observed (Pl. I, 1.). At the lower part of the northern slope of Chungshan, near Huangmats'ing, intrusive sheet with 37 feet thick occurs in the red shale. The outcrops at other places are more or less dome shaped with 50-150 feet in diameter, of which the one near Chiangmiao is the largest.

All the igneous rocks so far we have observed are extremely weathered. In some cases the surface layer has already been changed into soil. Good hand specimens are consequently very hard to collect.

The igneous rocks in general have two different colors, the one is reddish white and the other greenish gray. The former occurs at Taipingmen, Huangmats'ing, Tienpaochêng and Chiangmiao, and the latter at Tienpaochêng and Wangchiatsing. Thus by colour alone the igneous rocks can already be differentiated into two groups. The relation existing between these two groups is however not easy to say, since they form usually separate masses, although near Chiangmiao these two kinds of rocks are in contact with each other, but there is no sign to indicate their relative order of intrusion (Pl. I, 2.). As far as the field observations concerned, we have the impression that the reddish white variety is widely distributed near Nanking. It is not only found in Chungshan region but occuring also

*The writer is assisted by Mr. K. E. Chen (陳恩馥) of the same Department, to whom he should express his thanks.

at some other places, such as Ch'ilingmen (麒麟門), etc. The distribution of the greenish mass is much limited. Thus we may not be mistaken in assuming that the greenish gray variety is the off-shoot or apophythes which send out from a main mass of reddish white color. The difference in colour means certainly a difference in mineral constituents contained in the rock, and this is caused in turn by magmatic differentiation.

b. Petrographical Characters of the Igneous Rocks

As stated above the igneous rocks in Chungshan region have all been extremely weathered, so that mineral constituents such as feldspars, amphiboles, pyroxenes, and biotite have all lost their optical properties. For this reason the rock names given below can only be considered as provisional and subject to change when fresh specimens will be obtained.

(1) Locality: Near the top of Tienpaochêng (天保城)
Name: Syenite

Macroscopical examination:- This rock is extremely weathered. It is medium grained and yellowish in colour. Two kinds of feldspars are observed, the one is orthoclase and the other plagioclase. Black minerals are also weathered and can not be determined megascopically.

Microscopical examination:- Under microscope this rock contains the following minerals: Feldspar is mostly weathered and some of them show albite twin. Epidote is produced along the cleavages of some feldspar crystals. Other minerals such as kaolin and sericite are formed from the alteration of feldspar. The plagioclase always shows positive sign and is probably andesine. The ferromagnesian minerals alter to chlorite, and their original characters are entirely lost. Biotite with small quantity forms minute scales. Apatite and magnetite are also present.

(2) Locality: Chiangmiao (蔣廟)
Name: Syenite

Macroscopical examination:- This rock is medium grained with reddish colour. The chief mineral is feldspar mixed with some black minerals. Mica is present. The arrangement of the minerals are more or less in parallel lines. It indicates that the rock has been subjected to pressure.

Microscopical examination:- Under microscope it consists essentially of feldspar which is extremely weathered and fully covered with secondary minerals, sericite and secondary quartz. The crystal form of feldspar is obscured. Occasionally some forms can be recognized under crossed Nicols. In other cases a zonal arrangement of secondary minerals is also seen. From the zonal distribution of the secondary minerals and the indistinct albite twin lines, the plagioclase is certainly present. Its optical property is entirely lost. Biotite changes its colour to light green and without pleochroism. It can be recognized only from the crystal form and birefringence. Other ferromagnesian minerals as hornblende and augite may be present, but the alteration is so advanced that the mineral can not be determined.

(3) LOCALITY: Huangmats'ing (黃馬青)

NAME: Monzonite porphyry (?)

Macroscopical examination:- This rock is extremely weathered and yellowish in colour. The whole mass shows scaly structure. The feldspar is the chief mineral constituent of the rock, mixed with some black minerals. Biotite can be seen by naked eyes.

Microscopical examination:- Under microscope this rock shows porphyritic texture. The phenocrysts are feldspar and biotite. The ground mass is made of fine grained feldspathic minerals. The feldspar is covered with sericite. Biotite alters to chlorite. Magnetite with cubic form is found in the central part of biotite. The Plagioclase seems to be basic oligoclase.

(4) LOCALITY: Tienpaochêng (天保城)

NAME: Hornblende porphyry (dike rock)

Macroscopical examination:- The rock is greenish in colour weathered and soft. The grayish white substance with earthy appearance is feldspar. Biotite occasionally can be found by a lens. The green mineral forming large crystal is hornblende.

Microscopical examination:- It consists of feldspar, hornblende and biotife. The feldspar has lost its optical properties and alters to sericite and kaolin with separation of secondary quartz. Most of the crystal form is obscured by the secondary minerals. Occasionally the feldspar shows slender rectangular form with twin lines. It seems to be plagioclase rather than

orthoclase. The crystal form of hornblende is rather distinct. It is green colour with moderate pleochroism. Biotite changes to light yellow colour. Other minerals such as apatite and magnetite are also present.

(5) LOCALITY: Chiangmiao (蔣廟)
NAME: Hypersthene diorite

Macroscopical examination:- It is a greenish, weathered and medium grained rock. Feldspar and biotite are recognized by naked eyes. Pyroxene is also present.

Microscopical examination:- It contains a great deal of feldspar which is mostly plagioclase. Hypersthene with slight pleochroism has been in some part altered to hornblende. It is very often that the hypersthene forms kernel, bordered by a layer of hornblende. Biotite is also present. Other minerals such as apatite and magnetite form accessory minerals.

(6) LOCALITY: North of Chungshan (鍾山北坡)
NAME: Epidote rock

Macroscopical examination:- The epidote rock is greenish in colour, covered with a layer of iron and mixed with quartz. The epidote is oily green with vitreous luster. The fracture surface is uneven. Its crystal form is hypidiomorphic. The quartz is also hypidiomorphic and is interlocked with epidote.

Microscopical examination:- This rock composes of epidote and quartz. The form of epidote is irregular. In some cases the epidote penetrates into the quartz and enclosed by it. In other cases the phenomenon is just reversed. One large crystal of garnet showing zonal texture is grossularite. Under crossed Nicols it shows optical anomaly with very weak birefringence. One crystal of quartz contains many hair like form of rutile.

The order of crystallization of these two minerals shows a continuous and overlapping manner. The epidote may crystalize a little earlier than quartz. Before the completion of the crystallization of epidote, the quartz also begins to crystallize, thus shows an overlapping of these two minerals.

The epidote rock is found at the contact zone between the igneous rock and shale. It is reasonable to think that the residual magma, rich in silica, fuses a part of the shale so that calcium, iron, and aluminum were assimilated from the country rock for the formation of epidote rock.

II. METAMORPHISM

a. Field Observation

The rocks of the Chungshan formation have been described by Dr. C. Y. Hsieh.* It is not necessary here again to describe the different lithological characters of the whole formation. However it may not be superfluous to say something about the rocks which are in direct contact with the igneous rocks.

Below the quartzitic conglomerate is the Huangmats'ing shale, the name given by Hsieh, which consists of purple shale interbedded with sandy shale and sandstone. The colour of the shale in the eastern part is purple as already mentioned, but that in the western part below Tienpaochêng is green. These colours are quite contrast to each other.

The green shale is highly metamorphosed and is changed to compact and hard rock. The metamorphic minerals produced in the shale are epidote and actinolite, the former is more abundant.

The epidote and actinolite are distributed in various ways; (1) They are evenly and densely distributed in the rock, thus it makes the rock uniformly green. The mineral grains, except on the surface, are mostly very fine and can not be distinguished by naked eyes. Such kind of rock is frequently found in the lower part of Tienpaochêng. (2) The epidote forms green bands alternating with the violet ones of the original shale. These bands are usually parallel to the bedding planes. (3) The epidote is found on the fracture surface or bedding planes. (4) It forms clusters embedded in the shale.

The degree of metamorphism of the shale is closely related to the forms of distribution of the metamorphic minerals. In the form (1) the shale shows the highest degree of metamorphism. In the form (3) and (4) the degree of metamorphism is much less. The form (2) is intermediate between the forms (1), (3) and (4).

b. Microscopical Examination of Shales

Red shale:- The red shale which is not metamorphosed under microscope contains a great deal of iron. Small angular grains of quartz with clear

*C. Y. Hsieh, Geology of Chungshan and its bearing on the supply of artesian water in Nanking. Bull. Geological Society of China Vol. VII, 1928.

surface are distributed in the whole mass. Feldspar is extremely weathered and its surface is fully covered with kaolin, sericite, and iron particles. In some parts the large feldspar grains show albite twin, but most of them have lost their optical properties. Ferromagnesian minerals are very few and scarce. Occasionally one or two grains resembling biotite, which already alters to chlorite, are found.

Green shale:- The green shale is metamorphosed. Under microscope it does not contain any particles of iron. The green colour is due to the presence of epidote and actinolite which are variable in amount in different bands. These two minerals form small irregular grains and are mixed together very intricately. Quartz forms minute grains and is unevenly distributed in the mass. The grains of feldspar are in the same minuteness as quartz. Most of them alter to kaolin and sericite. The above mentioned different minerals are arranged more or less in parallel lines. Besides there are a few grains of apatite and magnetite.

c. Formation of Epidote, Actinolite, and other Metamorphic Minerals

The metamorphic minerals found in this region are actinolite, epidote and grossularite. The chemical Composion of actinolite is $Ca\ (Mg, Fe)_2\ (SiO_3)_4$. of epidote is $Ca_2(Al, Fe)_2\ (SiO_4)_3$ and of grossularite is $Ca_3Al_2(SiO_4)_3$. All the three minerals contain calcium, aluminum and iron (except grossularite). The iron and aluminum are originally contained in the rock, as the writer has already mentioned that the shale contains a great deal of iron particles, and the aluminum is the important chemical element of feldspar and kaolin. The calcium may be originally contained in the shale. Some layers of the unmetamorphosed shale and sandy shale show effervescence with hydrochloric acid. It is evidently that calcium carbonate is present in the rock. But the calcium can also be obtained from the basic feldspar contained in the rock. The silica is certainly supplied by the magma. These four chemical substances, calcium, aluminum, iron and silica, combine together in different proportions to form actinolite, epidote and grossularite.

The epidote is more abundant along the joint or fracture planes, as these planes are passages for the hydrothermal solution to circulate, and thus there are more chance to form the metamorphic minerals.

In the eastern part of the Chungshan Formation, the shale is not metamorphosed while in the western part it is intensively metamorphosed. This may be due to the fact that in the western part there may be a large igneous mass below the sedimentary rocks and so it gives a greater effect of metamorphism. The outcrops of the igneous rocks as we have seen are also more abundant in the western part than in the eastern part.

III. AGE OF INTRUSION

The sedimentary rocks in contact with the igneous body are purple and green shale, sandy shale and sandstone. These rocks are metamorphosed by the igneous body, especially in the western part of Chungshan formation, and their age as determined by Dr. Hsieh is Triassic. Then the time of intrusion was about Cretaceous or early Tertiary.

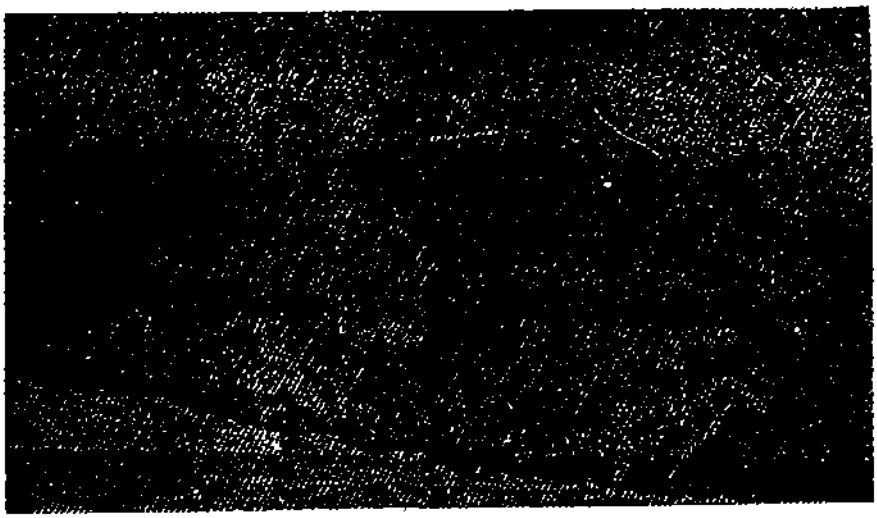
Explanation of

Plate I

PLATE I.

Fig. 1:—Diorite porphryrite dike, 4 feet wide, extremely weathered. It intruded into the green epidote shale and sandy shale. The epidote and actinolite form thin layers, parallel to the bedding planes. Seen at a road cut, N. W. of Tienpaochêng, Chungshan, Nanking.

Fig. 2.—Monzonitic diorite (right) in contact with hypersthene diorite (left). The hammer indicates the line of contact. Near Chiangmiao, Nanking.



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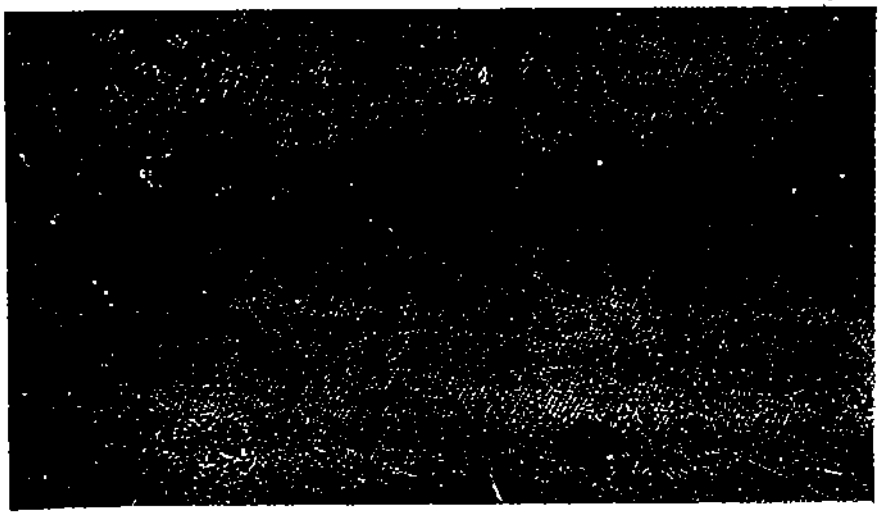

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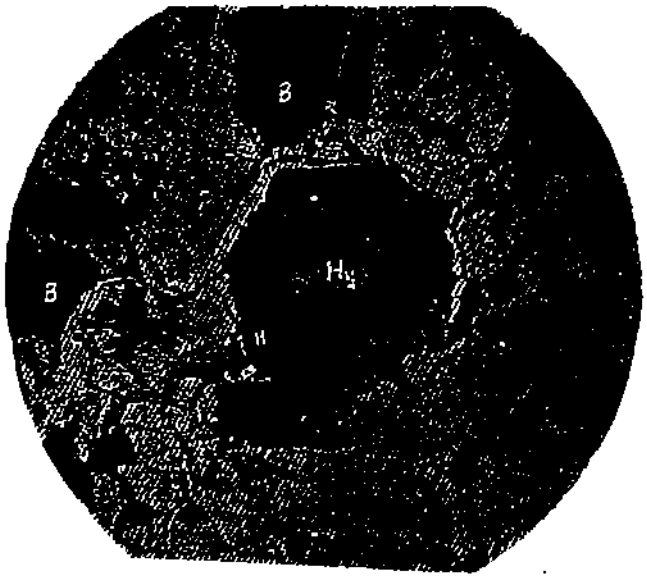
Explanation of Plate II

PLATE II.

Fig. 1.—Hypersthene diorite, Chiangmiao (蔣廟). (Hy) Hypersthene with a border of hornblende. (B) Biotite. (P) Plagioclase with minute crystals of apatite. × 82.

Fig. 2.—Monzonite porphyry, Huangmats'ing (黃馬青). (P) Plagioclase (oligoclase). (O) Orthoclase. (B) Biotite. They are embedded in a felds-pathic ground mass with fluidal texture. × 82.



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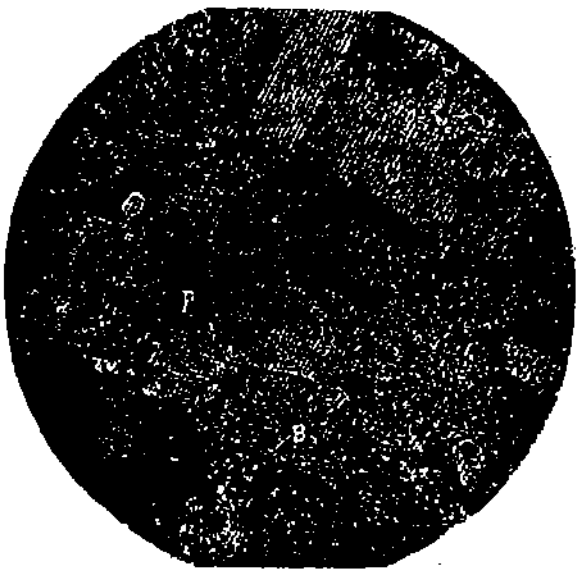

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Explanation of

Plate III

PLATE III.

Fig. 1.—Epidote shale, Tienpaochêng (天保城). Black, epidote. White, quartz and feldspar. These three minerals are intricately mixed and arranged in parallel lines. × 82.

Fig. 2.—Epidote rock, north of Chungshan (鐘山北). (E) Irregular form of epidote, (Q) Quartz. Wedge shaped of titanite (not shown in the figure) × 82.

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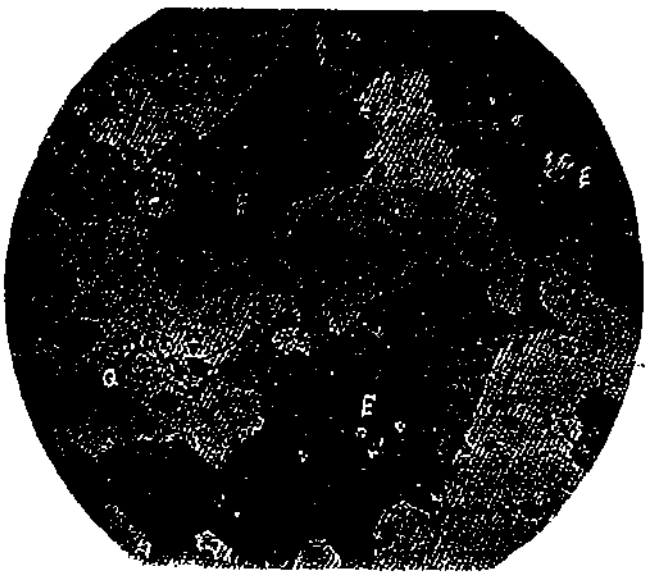

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