GEOLOGY OF CHUNG SHAN AND ITS BEARING ON THE SUPPLY OF ARTESIAN WATER IN NANKING.

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WITH 4 PLATES AND 2 FIGURES

I. INTRODUCTION.

Chung Shan or as more popularly known, Tzu Chin Shan (紫金山) is situated to the east of Nanking about 5-15 li outside of the city gate, Chao Yang Men (朝陽門). The range has an extension from east to west of about seven kilometers, and from north to south of three kilometers. It is a place rich in scenery and relics, most popular among which is the Ming Ling (i. e. the Tomb of the Emperor of Ming Dynasty). The tomb of the late Dr. Sun Yat Sen (or Sun Ling) is now nearly completed, and after its completion, it will add, of course, still more beauty and interest to this famous mountain.

During the spring of 1928, while leading a group of students of the Central University on geological excursions, I had opportunity to study, in some detail, the geology of this region. Several discoveries of both plant and animal fossils were made and a section was taken across the mountain. The result of this work not only offers some new fact on the age and succession of the Chung Shan formation, but also throws some light on the possibility of the supply of artesian water in Nanking.

I wish to express my thanks to Messrs. C. Y. Wang and S. Y. Shen, assistants of the University, for their valuable help rendered in this work.

II. PREVIOUS WORKS.

The first one to study the geology of Chung Shan, was Baron Von Richthofen, who in 1868 came to visit this region and gave the name "Nanking Sandstein" which was supposed by him to be of Upper Carboniferous age. In 1913, Mr. Ishū, a Japanese geologist, came across this region again, but he believed the age of the "Nanking Sandstein" to be of Sinian, much older than what Richthofen supposed.

The National Geological Survey of Peking started, in 1919, a systematic mapping work in the Province of Kiangsu. This work was undertaken by Messrs. C. C. Liu and J. C. Chao*. On the ground of structural relations, they believed the formation to be of Lower Jurassic, although no fossils of any sort

* Preliminary report on the geology and mineral resources of Kiangsu Mem. Geol. Surv China, Ser. A. No. 4.

have ever been obtained by them. They gave the name "Chung Shan formation" for the whole rock sequence.

During our excursions, we were fortunate enough to secure some fossils which in spite of being poorly preserved, seem to prove beyond doubt, the Mesozoic age of this formation.

III. Stratigraphy.

In ascending order, the Chung Shan formation may be divided into the following six divisions:

1. The Huangmaching shale:—This is composed principally of thin purple shale interbedded at several horizons, especially at its upper part, with purple sandy shale and grey sandstone. Three layers of fine grained conglomerate were found in the lowest part. The pebbles, attaining only a few millimeters in size, are not very well rounded and are composed almost exclusively of limestone. The cement is also rich in lime.

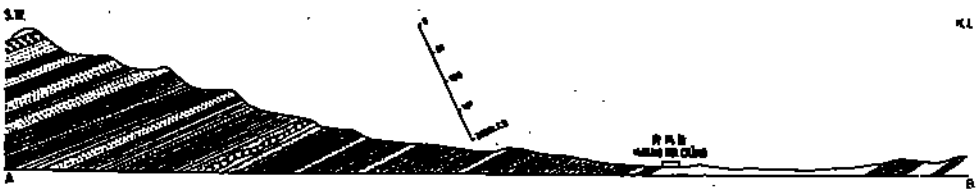

Fig. 1. Section on the Northern slope of Chung Shan (NW of Ma Ch'un)

This series is exposed chiefly on the northern slope of Chung Shan. Continuous section showing the complete rock sequence can be seen in the eastern part of the mountain, especially near the villages Ma Ch'ün (馬羣), Huang Ma Ching and Hsia Wu Chen (下五鎮). The section taken from Huang Ma Ching southward to the top of the mountain is shown in fig. 1.

An intrusive sheet of syenitic rock interbedded between purple sandstone and shale is found at about midway between Huang Ma Ching and the mountain top. The rock has been profoundly altered to yield a yellow clay.

The whole formation exhibits a brilliant purplish color; a very good view of this can even be had from the train near the Yao Hua Mên (堯化門) station looking toward the southeast. In contrast to this, the western part of the mountain does not show such a color at all; it is prevailingly dark or deep blue. This contrast is to be explained later.

According to our rough estimate the thickness of this series amounts to 600-800 m. The former figure includes only the part from the mountain top to the village of Huang Ma Ching. Beyond this village and in the alluvial plain

some outcrop of red shale has been noted, but as most of that is covered, its exact nature can not be ascertained.

2. Quartzitic conglomerate:—On the top of Chung Shan is found a layer of quartzitic conglomerate about 25 m. thick, forming here a huge hogback dipping toward the South or Southwest with an inclination varying from 20°-30°. This conglomerate is very hard and compact, showing evidently the result of some metamorphism. The pebbles consist almost exclusively of quartzite, being generally well rounded and polished. They are embedded in a siliceous cement. In size the pebbles vary from one centimeter to five or six centimeters in diameter. Their distribution is not uniform; as for instanee, in some layers, pebbles are almost absent, being really a quartzite, while in others, the whole mass is crowded with pebbles.

The existence of the conglomerate is very significant; it means a break in sedimentation. Since the deposition of purple shale, some part of the basin was uplifted and a long period of erosion was set in. This resulted in the breaking and polishing of the quartzite pebbles, the source of which is probably to be derived from the upper part of the Silurian formation. These pebbles were deposited in the near shore to form the present quartzitic conglomerate. As the period of uplifting involved neither tilting nor folding, the inclination between the conglomerate and its underlying strata maintains therefore, a parallel position; in other words a disconformity exists between these two series.

Quartzitic conglomerate is also found at Pei Chi Ko (北極閣) in the northern part of the city.

3. Tzu Hsia Tung Series:—The conglomerate is succeeded without any break by a series of shale and quartzite herewith called Tzu Hsia Tung series having a thickness of no less than two hundred meters. This series can again be divided into two parts. The lower part consists of thin bedded quartzite and black siliceous shale, the latter being frequently so bituminous as to be mistaken for coal seams. A good section of this part is exposed at Tzu Hsia Tung (紫霞洞) and a still better one is seen at the northern slope of Fu Chou Shan (覆舟山), inside the city wall. In the latter locality, moderately bedded quartzite altered to a red rusty color is intercalated with two layers of black siliceous shale. In the shale some poorly preserved plant fossils are found. Thickness of the exposed portion amounts to about 30 m. The quartzite here has been extensively quarried for road materials.

Ripple marks are quite cemmon in the quartzite, a most beautifully preserved one is seen on the southern slope of Tien Pao Cheng (天保城) not very far from the Ming Ling.

The upper part of the series consists of an alternation of thin quartzite and white clayey shale, best exposed in the excavated ground in front of Sun Ling. Fossil plants somewhat resembling the genus Zamites are very abundant in the shale. Thickness of this part alone amounts to about 150 m.

4. Lingkussu shale: This is a series of yellow, gray and black thin shale exposed at about 300 m. west of Ling Ku Ssu, so the name is derived. Its thickness is unknown. Several pieces of small shell resembling the genus Cyrena are found in the black shale. This little shell looks very similar to the one found by Mr. Chao and myself in Tzu Kwei Hsien, W. Hupeh, (2) where it occurs in the upper Hsiang Chi coal series of Lias age. Mr. Chao identified the shell as a new species and the name *Cyrena hsiangchiensis* was given.

5. Light yellow sandstone:—Overlying the Ling Ku Ssu shale comes a loose, massive sandstone of light yellow color, showing frequently cross bedding. At about the middle part, there is intercalated a fine-grained conglomerate about 3 m. thick. This conglomerate is very loose, with clayey cement and contains pebbles of only few mm. to one centimeter in diameter. They are not well sorted and are more or less angular. Above this conglomerate, twenty or thirty meters up, there comes a sandstone with abundant pebbles at certain parts. It is however not a continuous conglomerate. An arkosic sandstone is found at the topmost part. Total thickness of this series amounts to about 450 m.

6. Variegated sandstone and shale: This division about 200 m. thick consists of purple sandstone and shale in the bottom, yellow sandstone in the middle and yellowish gray shale and thin quartzite on the top. Some plant fossils were found in the yellowish gray shale. The whole series dips to N. or N. W., a direction just opposite to the general dip of the mountain. The structural relation of this contact is to be explained later. What I might mention here is the stratigraphical position of the series; it may lie just on the top of the yellow sandstone or there might be something still covered between these two.

Total thickness of the foregoing six divisions has been roughly estimated at about 1580-1780 m. Besides the Huang Ma Ching shale which is exposed on the N. slope of Chung Shan, all the rest are found on the S. slope.

A section measured along the road from Siao Wei (小衛) to Sun Ling is shown in fig. 2.

(2) C. Y. Hsieh Y. T. Chao: Geology of I-chang, Hsing Shan, Tzu Kwei & Pa Tung district, W. Hupeh, Bull. Geol. Surv. China, No. 7, p. 61.

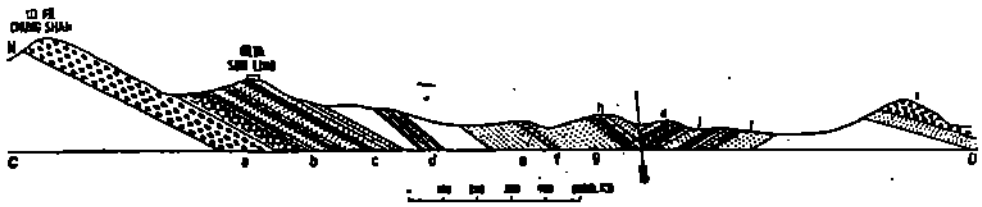

Fig. 2. Section on the southern slope of Chung Shan.

a. Quartzitic conglomerate. b. Alternation of thin-bedded quartzite and black siliceous shale. c. Alternation of thin-bedded quartzite and white clayey shale; in the latter plant fossils are found. d. Ling-kusan shale of yellow, grey or black color containing *Cysona hsiangchiensis*. e. Yellow massive sandstone. f. Conglomerate, loose and fine, about 4 m. thick. g. Yellow massive sandstone with conglomerate at certain layers h. Gray arkosic sandstone. i. Purple sandstone, loose and massive, interbedded with layers of purple shale. j. Gray to yellow compact sandstone. k. Yellow to Gray shale with several layers of quartzite on top. Some plant fossils are found in the shale. l. Conglomerate and red sandstone of Tertiary age.

Several igneous intrusions in the form of sills, dikes or lacoliths have been noted. All of them are distributed on the N. slope of Chung Shan, such as at N. E. of Tai Ping Men (太平門), N. W. of Ma Ch'ün, etc. A small lacolith is found near Chiang Miao (蔣廟). Megascopically, the rock contains abundant mica and hornblende with very little or no quartz. Therefore, it is probably a syenite.

It is a curious fact that on the northern slope of Chung Shan there is a very striking difference in color between the eastern and the western parts. The eastern part from Ma Chün to Hsia Wu Chen, consists, as has been described, of purple shale and sandstone, while the rock of the western part is chiefly a greenish sandstone. The difference is so striking that it can be clearly seen even from a great distance. The sandstone is very compact and massive, containing frequently a green and radiating mineral, probably actinolite. This mineral occurs either as veinlets or as scattered spots; it is more abundant when reaching the contact of an igneous body.

That the above controversy cannot be explained by faulting is made clear when the continuity of the quartzitic conglomerate on the top of the mountain is traced. The only possible explanation is by metamorphism. It seems to be quite possible that the bleaching of the purple color, the hardening of the rock and the introduction of the actinolite mineral, can all be accomplished by the metamorphic action of the igneous body, the latter has been noted at many localities, especially in the western part of the mountain.

IV. AGE & CORRELATION.

The exact age of the different horizons just described can not at present be determined, because the fossils obtained have not yet been identified. On the other hand, according to the lithologic characters and especially on the basis of the presence of small Cyrena, some suggestion as to the age and correlation with the stratigraphy of W. Hupeh can be roughly made as follows;

Chung Shan		W. Hupeh	Age
Yellow Sandstone, Variegated Sandstone & Shale..		Kweichou Series	Wealden
Lingkussu Shale (with Cyrena)		Disconformity	
Tzuhsiatung Series	Hsiangchi Coal Series	Upper Coal Series (with Cyrena)	Liassic
Quartzitic Conglomeratc		Sandstone & Conglomerate	
Disconformity		Lower Coal Series	Rhaetic
		Disconformity	
Huangmaching Purple Shale		Patung Purple Shale .. (with Spiriferina)	..Triassic?
Disconformity		Disconformity	
Thin bedded Limestone		Thin bedded Limestone	Permian

The Huangmaching shale can probably be correlated with the Patung series of W. Hupeh, because both of them are purple in color and are underlain by a thin bedded limestone of Permian age. The exact age of the Patung series has not yet been determined, although on the basis of the finding of spiriferina Triassic age has been suggested.

The formations from quartzitic conglomerate up to the Lingkussu shale may be correlated with the Upper Hsiangchi coal series of W. Hupeh, all belonging probably to the Liassic age. The reason for such a correlation is chiefly based on the presence of the fossil Cyrena. As to the Lower Hsiangchi coal series which has a wide distribution and forms an important coal producer in W. Hupeh it is probably missing in this region.

The strata above the Lingkussu shale may either belong to Lias or to Wealden, but because of lack of fossil evidence, this must be left undecided for the present.

V. GEOLOGICAL STRUCTURE.

The dip of strata varies from place to place; in the central portion, it has a S. dip which changes to S. W. toward east and S. E. toward west. The strike forms therefore a curve. The dipping angle varies from 20° to 60°, 30° being most common.

On the southern part of the road leading to Sun Ling, variegated shale and sandstone maintain a N. or N. E. dip which is just reverse to the general dip of the region. This change of dip seems to suggest a syncline with its axis running approximately from east to west. On close examination, however, it reveals the fact that here we have something more complicated than a simple syncline. The rock of the southern limb is composed of purple shale and sandstone, but on the northern limb, no such rocks are found; in this region it is mainly a yellow sendstone with one or two layers of fine conglomerate. In case of a simple syncline, symmetrical arrangement of rocks should be found on both limbs. This discrepancy in both dip directions and rock successions can be explained by a fault which took place after the syncline had been found. If we suppose that the purple shale and sandstone are younger than the yellow sandstone which is most likely the case, then the down-throw side will be on the south and the up-throw side on the north.

A fault occurs between Chimingssu (雞鳴寺) and Fuchowshan as is evidenced by the abrupt change in dip as well as by the discontinuity of the outcrop. The trend of the fault line is approximately from north to south.

VI. POSSIBILITY OF THE SUPPLY OF ARTESIAN WATER IN NANKING.

The water supply in Nanking is now mainly derived from private wells, ponds or rivers. They are generally impure and insanitary. No water works of modern type have yet been installed.

Since the establishment of the Nationalist Government in Nanking with the consequent expansion in both population and commerce, the need of an adequate and pure water supply becomes more and more urgent. While there are many ways to solve the problem, the development of artesian wells is one of the best methods. The artesian water as it is generally called is really of meteoric origin; but since it has passed through several layers of rock formations, any impurities the water may contain, will be filtered out and eventually the water comes out in a pure and desirable state.

1. Requisite conditions for artesian wells:—There are three requisite conditions for artesian wells:

a) The presence in the rock formation of a layer of porous or fractured bed for the storage of water; this is called aquifer.

b) Both above and below the aquifer there must be impervious layers so as to exert a sealing action to the water circulation.

c) An adequate source of pressure derived from the difference of elevation between the head and the well.

Now, the geological study of Chung Shan has revealed the fact that we have here at least two layers of conglomerate which are probably water-bearing. In the lower bed, the quartzitic conglomerate is interbedded in gray shale and thin quartzite; both are comparatively impervious. The beds incline at about 20°-30°, being steep enough to furnish the required head. Thus it seems that all requisite conditions for an artesian flow have been fulfilled, and Nanking may be considered as a region very promising for artesian well development.

2. Wells and springs in Nanking:—Wells and springs are very abundant in Nanking, some of the important ones are as follows:

a) According to the Kiangning Provincial Gazette, (江寧府志) there were seven noted springs located either near the top or on the slope of Chung Shan. At present only a few are found, as for instance, the spring behind the Ling Ku Ssu Temple.

b) A small spring is found at about 55 m. S. W. of Wan Fu Ssu (萬福寺) on the upper slope of the huge hog-back of quartzitic conglomerate. Without doubt the water here comes out from the said formation.

c) Several seepage springs are found in the caves of Tzu Hsia Tung which is composed of thin-bedded quartzite and black siliceous shale; both are rather jointed and fractured, water comes out either from the fractures or along the bedding planes.

d) Below the temple Chi Ming Ssu is a famous well called Yen Chih Ching (臙脂井). This well is said to have been in existence since the Sui (隋) Dynasty. About 38 m. W. of the well, occurs the outcrop of quartzitic conglomerate dipping 45° toward the southeast. That the water here is tapped from conglomerate admits of no question.

e) Conglomerate of Tertiary age is found at Tsing Liang Shan (清凉山) and Po Lo Shan (波羅山), at the S. W. corner of the city. The conglomerate contains unsorted pebbles of regular shape, mostly composed of limestone; to a less extent also of igneous rocks and red sandstone. In the temple of Tsing Liang Ssu, there is an abandoned well called Liu Chao Ku Ching (六朝古井). To the east of Po Lo Shan occurs the well Huang Yang Ching (黃陽井) which yields very good water. All these wells are evidently derived from conglomerate.

f) Two seepage springs which both yield good water occur on top of Yü Hua Tai, in the back yard of a tea house. The water is derived from the Yühuatai gravel which crops out just beside the spring.

g) According to a communication from the Bureau of Public Welfare (公安局), there are in the city altogether 1655 wells including both private and public ones Their distribution is roughly as follows:

Districts	Public wells	Private wells	Total
East	73	93	166
South	154	604	758
West	125	120	245
North	126	175	301
Central	123	62	185
Total	601	1054	1655

h) Several artesian wells on a modern scale have been recently dug by the Ku Lou Hospital (鼓樓醫院) and the American consulate. As reported by the Ku Lou Hospital, that well has a depth of about 300 ft. yielding only a moderate amount of water which is slightly salty. Information regarding other artesian wells is not available.

3. The Aquifer:—From previous description, it seems evident that we have here at least three horizons which might be considered as aquifers. These are:

a) Quartzitic conglomerate
b) Tertiary conglomerate
c) Yūhuatai gravel.

Most of the wells in Nanking are rather shallow; usually not more than 20-30 ft. in depth. These wells may tap their water either from conglomerate or from gravel or sandy pockets in the alluvial formation. The latter source is not considered as important, on account of its shallow nature and its possible contamination from polluted surface water.

4. Chemical composition of the ground water:—

According to the study of Mr. C. L. Wang, the waters of the well Chiu Yen Ching (九眼井) and Yen Tzu Ching are considered to be the best. Those wells in the ground of the Central University contain an excessive amount of chlorine and insoluble matter. The water from the Yūhuatai gravel is low in chlorine content but rather high in insoluble matter; it is inferior to the water of Chiu Yen Ching or Yen Tzu Ching. As we know, the water of these two wells is all tapped from the quatzitic conglomerate. It is beyond question then, that this horizon should be reckoned as the most important aquifer, because it yields the best water. Mr. Wang's analysis is reproduced here and is follows:

Analysis of well waters in Nanking.

Location of wells	Total insoluble matter	Calcium	Magnesium	Carbonate	Sulphate	Chlorine	Remarks.
Engineering work, Central University.	301	25	22	157	83	40	Deep
Science Building, Central University.	616	83	37	198	102	109	"
Gymnasium, Central University.	613	55	25	260	34	94	Shallow
Science Society.	548	113	34	257	16	67	"
Middle School of the Central University.	901	75	37	318	102	147	Very shallow
Behind Bath Room, Central University	866	100	39	312	34	143	" "
Yu Hua Tai.	485	30	3	70	83	24	
Chiu Yen Ching.	395	83	16	138	54	30	
Yen Tzu Ching.	392	117	16	121	17	17	

5. Site for well drilling:—A few notes on the geology of the city of Nanking are necessary before we can properly discuss the question of well sites.

The western part of the city starting from Shih Tzu Shan (獅子山) in the north and Tsing Siang Shan in the south is occupied by a series of rolling hills made up on the north of Tsing Liang Shan almost exclusively of loess. This interesting deposit presents nearly all the characteristic features found in northern China. It attains here about 30 meters in thickness. Outcrops of red sandstone and shale are often found underlying the loess as seen near Hai Ling Men(海陵門). Outside of I-Feng Men (儀鳳門), a small exposure of conglomerate is found to lie unconformably under the loess. Toward the south in the vicinity of Tsing Liang Shan and Wu Tai Shan it becomes the chief formation, while outside of the southern gate near Yū Hua Tai, this bed is capped by Yūhuatai gravel.

From what has been said, it becomes clear that both the west and the south part of Nanking city are deeply covered by younger formations, such as the Tertiary conglomerate or red shale and the Yūhuatai gravel. It will require a great depth, say over 500 m. or more, to reach the conglomerate beds in the Chung-shan formation.

A more favorable locality for well drilling is perhaps to be found in the region in front of Pei Chi Ko and Chi Ming Szu. Quartzitic conglomerate dipping to the south or southeast is found on the hill. By putting wells along a direction perpendicular to the dip of the conglomerate, we shall without doubt

reach the aquifer at some depth. That this region is promising for well driling can further be proved by the already successful wells such as Chiu Yen Ching and Yen Tzu Ching.

Some test wells may also be drilled in the region in front of Fu Chou Shan and Fu Kwei Shan (富貴山). Here we may tap water from the fractured quartzite, but its possibility is not so promising as the one just mentioned.

The best place for artesian well is, however, to be found on the S. slope of Chung Shan, about 200-300 m. south of Lun Ling. Starting from the Ming Ling on the west and Ling Ku Ssu on the east, this belt offers every possibility for an artesian slope. Water can be tapped from the conglomerate at probably not more than 200 meters in depth. Another belt for artesian water is located at about 500-600 meters S. of Sun Ling having also an east and west extension. Here we may tap water from the upper conglomerate; i. e. the one with a fine rain and loose texture. On account of the lack of sealing strata both above and below the conglomerate, a large and strong flow of water is therefore not to be expected.

In order to know more definitely the underground conditions, surface observation should always be supplemented and checked by actual drilling. It is urgently hoped that the municipal government of Nanking will take up this work without delay. A number of wells ranging in depth from 200-600 m should be drilled in the most favorable localities. While drilling, a carefu record of the rock succession, the number of aquifers, etc. should be made Meanwhile samples of water should be taken separately for each aquifer and the quality of each examined. The identification of rock horizons must be in the hands of a competent geologist. By doing this we shall have a complete record of the underground artesian conditions which is of value not only to the well driller but to scientific knowledge as well.

Explanation of Plate I.

PLATE I.

1. Near view of the Tertiary conglomerate shows its unsorted and sub-rounded pebbles made up mostly of limestone. Exposed on W. slope of Po Lo Shan (波羅山), S. W. Nanking. The conglomerate dips to N. N. E.

2. Excavated ground in front of Sun Ling (孫陵) shows quartzite (thicker bedded) and clayey shale in alternation. In the shale, plant fossils are found. Looking N. N. E.

3. A view of Pei Chi Ko (北極閣) and the outcrop of quartzitic conglomerate, the latter maintains a S. E. E. dip (not so well shown in the picture). In the S. E. corner of the picture is shown the well Chiu Yen Ching (九眼井) (with a man standing) which yields water of good quality.

Fig. 1

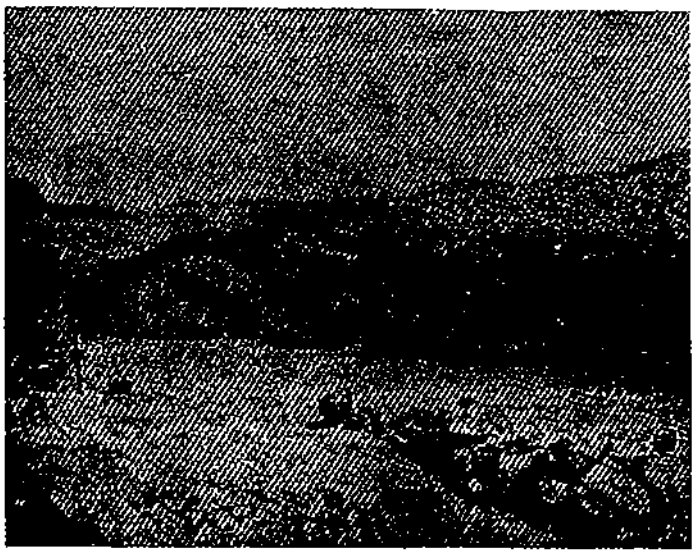

Fig. 2

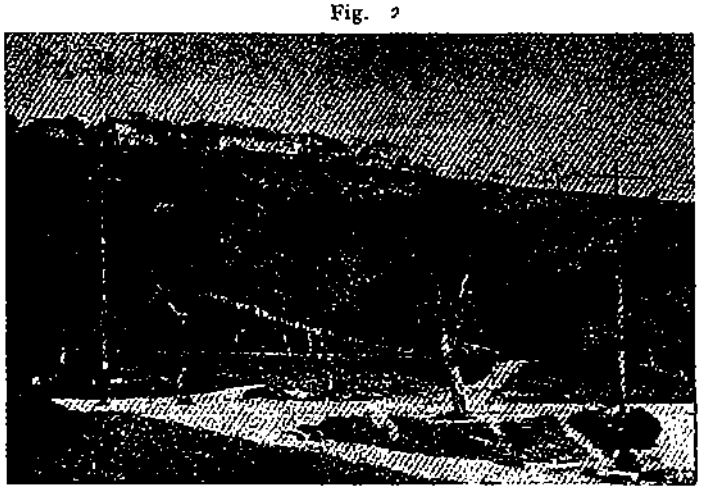

Fig. 3

Explanation of Plate II.

PLATE II.

1. A close view of the top of Chung Shan (鍾山) shows the quartzitic conglomerate and its underlying purpie beds. The conglomerate has a thickness of about 25 m. forming here a huge hogback dipping toward south several boulder showing clearly the egg-shaped pebbles. Looking W.

2. The Huang Ma Ching shale (黃馬青頁岩) of probably Triassic age. This section shows the upper part of the series exposed at N. W. of Ma Ch'ün (馬羣) on the northern slope of Chung Shan. It is composed mainly of shale and sandy shale all exhibiting a brilliant purple color. Looking N. W.

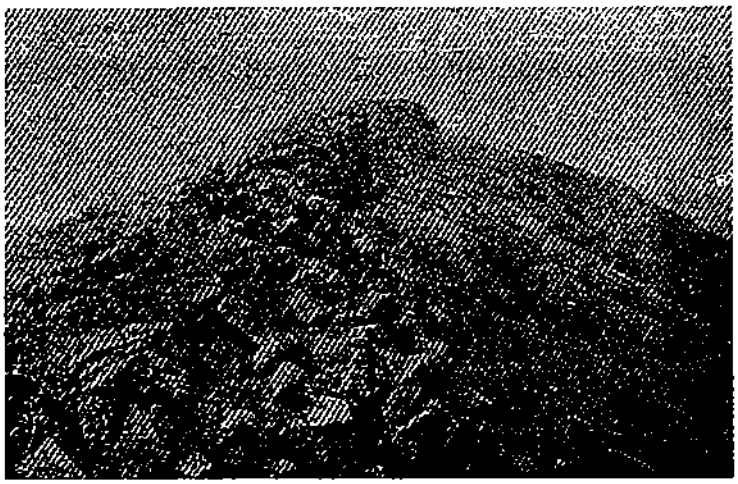

Fig. 1

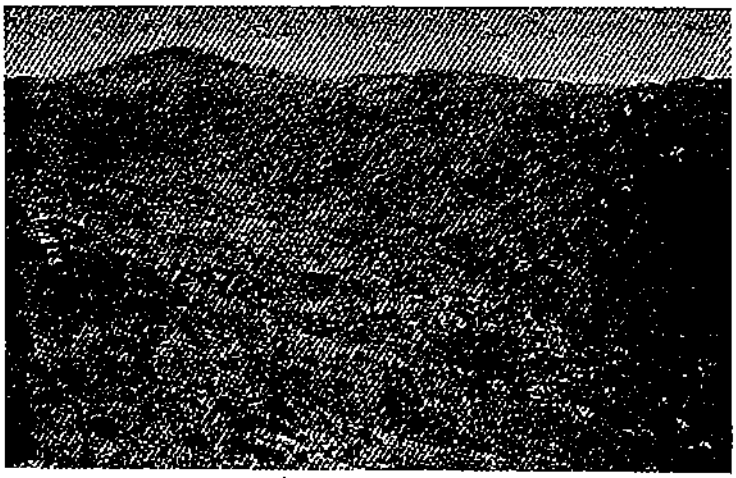

Fig. 2

Explanation of Plate III.

PLATE III.

1. This picture shows a little canyon cutting in the purple shale bed of the uppermost part of the Chung Shan formation. The beds dip to north forming therefore the southern limb of the faulted syncline. Taken at N. of Siao Wei (小衛), and on the left of the main road to Sun Ling.

2. Loess formation near I-Feng Men. A rude stratification is clearly shown in the picture. (Photo by C. S. Shen)

Fig. 1

Fig. 2