GEOLOGY OF THE CHIUHUASHAN REGION IN SOUTHERN ANHUI.*

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Introduction.

The area surveyed (Pl. I) is in south Anhui, on the south side of the Yangtze River, between the district city of Kueichih and the Chiuhuashan range. The mountain of the latter name is one of the four Buddhist sacred mountains in China and well known for its sceneries.

Stratigraphy.

In the small area under consideration, almost all the important sedimentary formations of lower Yangtze valley can be observed except the Jurassic and the Cretaceous. Owing to the existence of successive synclinal and anticlinal folds and a fault, the same formations are often repeated in outcrops. These formations do not represent a continuous stratigraphic sequence but are separated by several rather pronounced breaks. They are recognized in descending order as follows:

Tayeh limestone	Lower Triassic to Upper Permian
Lungtan coal series	Middle Permian
Disconformity (possibly unconformity)	
Chihsia limestone	Lower Permian
Disconformity	
Wut'ung quartzite	Devonian
Fengchu shale	Silurian
Yenwashan limestone	Ordovician

Yenwashan limestone: In the region of Taipingtsao, the limestone is mostly massive dark grey or greyish white in color and very pure in composition,

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usually traversed by a multitude of fine calcite veins. Only its upper portion sometimes contains intercalations of greyish yellow shale. The same limestone at Huangchü (磺局) (Sulphur Bureau), Hengt'aoan (橫桃庵) etc. lies in contact with the granite intrusive, so it has been converted into more or less white marble which, in some cases, contains crystals of pyrite. Near Tangliyao (潘里窯) the formation consists of massive greyish white limestone, at the upper part with intercalations of grey or yellow shale. The former yields Ordovician *Orthoceras*.

In the belt from Yehchitien (野雞店) to T'aopô (桃坡) occurs greyish black, sometimes silicified, massive limestone which underlies Silurian Fengchu shale to be treated later. Both on a lithologic and stratigraphic basis, the limestone is the exact equivalent of that in the place above mentioned.

The base of the formation is not exposed in the district surveyed, but the exposed thickness is estimated at about 300 meters.

Fengchu shale: This occurs at Liuchieh (劉衙), Huangchü, Taluyang (大路揚), etc. and conformably overlies the Ordovician limestone. The total thickness is estimated at about 100 meters. The green and grey sandy shale predominates. The thin sandstone or quartzite is intercalated in it. This represents the same character as that in other parts of lower Yangtze valley. However, in Huangchü region near the granite body the rock here resting upon Ordovician limestone is of a quite different nature. This is composed principally of greyish green and black slate and light grey silicified phyllite with thin layers of quartzite and crystalline limestone, striking in a NE-SW direction and dipping towards the northwest. At Tzuyenshan (紫岩山) not far S. W. of Huangchü, the pyrite deposit which has been worked is included in this metamorphic series (the deposit occurs as veins in the silicified phyllite).

Wutung quartzite: At Chouchiachung (周家冲), Youtsok'o (油榨柯), Paiyang (白楊), etc., the Fengchu shale is conformably followed by a great mass of Wutung quartzite. The thickness of the formation changes very much from place to place. In Chouchiachung region its thickness seems to vary from three to four hundred meters, while at Paiyang it reaches a figure between 500 m. and 800 m. Being estimated from the dip of the sediments

at a place E. of the said village, it is 600 m. thick, under the assumption that there occurs no disturbance.

At Chouchiachung following the Fengchu shale is white quartzite, then after an interval of reddish quartzite, comes another division of purple fine-grained quartzite with which the sandy shales are interstratified. At Youtsok'o the condition is generally similar to that observed at Chouchiachung. In Pai-yang region the main mass of the quartzite is built up of reddish white or white, sometimes grey banded and medium grained quartzite. Thin beds of purple or grey shale occur not infrequently in the formation. Although the profound metamorphism has almost effected its original character, the quartzite has, in some places, the appearance of sandstone. The principal mineral composition of the sandstone are felspar, quartz and other substances which are sometimes observed to be distinctly waterworn. This formation is very probably equivalent to the quartzite from which H. M. Hsu and K. M. Wang of the Geological Institute of the Academia Sinica have found Devonian plant fossils at Tingshan, Yihsing Hsien, Kiangsu.

Chihsia limestone: The Devonian Wutung formation is followed by a hiatus and by the Permian Chihsia limestone which amounts to a thickness of about 400 meters. Here the limestone retains principally the same character as that in other parts of lower Yangtze valley. The basal part of the limestone exposed at Hsuchialing (許家嶺) is dark coloured, of pure character and medium-grain and richly fossiliferous. This is followed upward by a well-bedded, fine textured greyish blue limestone (this is often interstratified with black shale). With more or less irregular layers of black flints, then follows essentially another light grey limestone of coarse texture without any flint, which is located immediately below the coal series. The grey limestone is often full of crinoid stems.

A little east of Panchiach'iao (潘家橋), the formation begins with light grey, fine grained highly compact limestone of no great thickness; then after an interval of well bedded, dark blue, bituminous impure limestone with rich flints, comes another division of thin bedded, grey pure limestone forming

the upper part. In the bituminous limestone there is a horizon which abunds in corals.

This limestone is also developed in Fangchia village (方家村), but the exposures are rare. The detailed succession of the limestone here, therefore, still needs further investigation. However some outcrops and the fallen debris along the route help us to know that the flinty limestones play an important rôle in the succession.

Lungt'an coal series: The series lies immediately above the Chihsia limestone or Wutung quartzite and is followed by the thin bedded limestone. The thickness measures at about 100 meters. The lower part of the series exposed at Hsuchiatang (許家塘) consists of shale and thin beds of sandstone. In the middle part, coarse grained sandstone predominates, containing thin beds of limestone and a coal seam about 4 ft. to 1 ft. thick. In the upper part occurs a dark grey sandy shale which yields the Gastrioceras fauna.

In the region of Fangchia (方家) and Nantangwan (南塘灣) the series is composed, as in the locality just mentioned, of sandstones and shales with a coal seam of 2 ft. to 8 ft. thickness. Here the thin bed of limestone, however, is not observed. The shales are predominating and some of them bear poorly preserved impression of *Gigantopteris*.

Tayeh limestone: Lying conformably on the Lungt'an coal series is the Tayeh limestone which is well developed at Hsuchiatang and Fangchia. The basal part of this limestone is generally thick bedded, fine textured and highly compact. This is succeeded upward by a thin bedded limestone which contains thin layers of yellow and purple shales. The uppermost part of this limestone has been eroded away. The remnant thickness varies in different places. In the vicinity of Hsuchiatang it is measured at about 400 m. At Fangchia village it is about 200 m.

Geological Structure.

Though below the Lungt'an coal series there is a so marked gap in sequence that the Chihsia limestone often gradually thins out and consequently

the Wutung quartzite and the Lungt'an coal series come into direct contact, no noticeable unconformity has as yet been observed in the field.

The present structure of the area surveyed is mainly originated by a comparatively late orogenic movement. The geological structure is controlled chiefly by three synclines and two anticlines together with several minor folds and a big fault. The different structural units will be described as follows:

Taipingtsao anticline: In the vicinity of Taipingtsao village, the geological structure is represented essentially by an anticline with its axis trending in the direction of E and W. The anticline assumes the form of semi-dome, dipping almost to every direction of compass except the eastern part where it is deformed by the granitic intrusion. In the center of the anticline is exposed Ordovician limestone which is surrounded on the west, the north and the south by the Fengchu shale. In a place not far S of Tangliyao, the Ordovician limestone abruptly appears from Fengchu shale, here forming a hummock. The hillock is evidently the eroded apex of a dome-shaped anticline with its axis in a NE and SW direction. It is highly probable that this anticline is the western extention of Taipingtsao anticline. However, between them near Liushan (劉山) there is a gentle depression, so that here the limestone cannot come into exposure upon the present surface.

Hsuchiatang syncline: In the central part of the mapped area occurs a more or less symmetrical syncline which characteristically develops at Hsuchiatang. There the syncline has its axis trending in the direction of ENE and WSW. The youngest rock exposed in the center of the syncline is the Tayeh limestone which is followed towards the south and the north by Lungtan coal series, Chihsia limestone, Wutung quartzite, Fengchu shale and Yenwashan limestone forming the two limbs. The whole structure is shown in the accompanying section (Pl. 1) between Taluyang (大路場) and Huangchü.

The inclination of the beds on the two limbs is rather steep with the dipping angle varying from 45 to 65 degrees. The syncline continues westward with gradually decreasing magnitude to a place E of Paochiach'iao, where the syncline is formed only by the Chihsia limestone and Wutung quartzite. However, further west at Wangchiat'ang (王家塘) beyond the district surveyed

this syncline, according to report of S. Chu[1], again assumes the same character as at Hsuchiatang.

Fangchia Syncline: North of Hsuchiatang syncline, the Fangchia region is an interesting place for the study of structure. The geologic structure is a northeast southwest syncline which is overturned towards the northwest as shown in the section (Pl. I.). The strata of the northwestern limb of the syncline dip regularly towards the southeast, the dipping angle varying from 25 to 30 degrees. At Paiyang the inclination of the strata is very steep with the dipping angle ranging from 70 to 80 degrees towards southeast, but from here towards the north they gradually become very gentle, being only about 30 degrees. Consequently the Chihsia limestone appears above the Lungt'an coal series in a reversed order. This is distinctly noted in the vicinity of Fanchia village.

Yehchitien anticline: Between the two syncline above mentioned there is anticline of Yehchitien (see section). The anticline strikes ENE. and WSW. The Ordovician Yenwashan limestone is exposed in the center of the anticline, with its succeeding formations forming the two limbs. The dip of the beds on the southeastern limb is comparatively gentle, being about 55 degrees, while the strata on the northwestern limb are vertical and often even dip towards the southeast. The anticline is apparently overturned towards the northwest, over-riding the Fangchia syncline.

The same anticline extends apparently to T'aopo and Sinkailu (新開路) where it is separated on the south from the W extension of Hsuchiatang syncline by a normal fault of comparatively younger age.

Summarising the above facts, it is apparent that the compression force forming the folds came from the southeast. That the age of the fold is post-Triassic is also clearly borne out by these facts, but how young it can be needs further evidence. However, since in the Mantoushan (饅頭山) region N. of Kueichih Hsien near the area surveyed, from Tertiary red beds upward no strong orogenic movement ever occurred, we may reasonably suppose that the fold represents a phase of Yenshan movement.

1 A phase of Hercynian Movement. Bull. Geol. Soc. China, Vol. II, No. 2.

Igneous Rocks.

Igneous rocks, especially granitic intrusions, play rather an important rôle in the constitution of the geological formations in this particular region. There were encountered in the field three main bodies which, when mentioned in the order from east to west, are the main granitic dome of Chiuhuashan (九華山), the Hsiaomailing (小麥嶺) granitic intrusion and the Lishan (梨山) granite. They do not only give scenic grandeur of some hills, but also intensely metamorphosed the intruded sedimentaries, accompanied at place by metallic deposits of economic importance. The following is a brief summary of their petrographical characters and the mode of occurrence.

The Chiuhuashan Granitic Dome.

Chiuhuashan is one of the four sacred mountains highly celebrated by both tourists and Buddhist pilgrims. It is situated about 90 li to the southeast of Kueichih (貴池) city and about 80 li to the south of Tatung (大通). Its elevation rises at about 1000 meters above the sea level and about 950 meters above its adjacent plain. On the north and east it is abruptly terminated by vertical cliffs and sharp peaks while on the south and west it gradually descends to the hilly regions of Shihti (石棣). On a clear day, the mountain can be seen far away on a Yangtze boat appearing in multitude of sharp peaks protruding upward into the air whereas when mounting on its top, the Yangtze River appears at the horizon as a white band winding on a brownish carpet. It occasionally takes various fascinating forms hidden in changing clouds, the latter usually appears in a flat stripe hanging below its top, dividing the whole height into two parts. Splendid and beautiful temples on high and low rocky terraces near the very top (Pl. II, Fig. 1) are another wonderful scenery with few other comparable examples.

As shown on the accompanying geological map (Pl. I) such a scenic splendour corresponds wholly to an extensive granitic intrusion bordered on the west by the Yenwashan limestone of Ordovician age. So far as revealed by the relation of the intruding mass with the Ordovician limestone which dips steeply away from the intrusive mass with apparent parallel boundary (Pl. I), it

suggests a broad dome structure. However as the other three sides lie beyond the scope of the surveyed area, further study is indeed required to confirm such an assumption.

The granite is typically developed in Chiuhuashan proper. Its prevalent colors are light brown or pinkish brown. Being a rock of medium grain and compact in texture containing predominating feldspars and quartz with only subordinate mafic minerals, it is normally highly resistant to weathering and erosion and protrudes upward above the country rocks in precipitous cliffs, rugged peaks (Pl. II, fig. 3) and bold ridges (Pl. II, fig. 2).

Microscopically quartz in nearly equal abundance to the feldspars, occurs either in large lenticular aggregates, or in small grains. In the latter case, it not infrequently shows allotriomorphic contour filling the interstitial spaces between the other constituent grains.

Feldspars usually tabular in form consist of two kinds, namely orthoclase and oligoclase-albite, the latter being by far the most abundant. Oligoclase-albite is usually characterized by multiple twinning, zonal structure, and an earthy appearance. When highly magnified, minute flakes of secondary sericite and epidote are distinguishable in the altered mass. Orthoclase, on the other hand, appears, in general, comparatively fresh either simple or with carlsbad twins. It has a decidedly lower refringence, which distinguishes itself unmistakably from the other plagioclase.

Among the few mafic minerals, biotite is more prevalent than magnetite. When weathered it alters into chlorite, or bleaches to sericite.

Toward the margin, near Tzuyenshan for instance, a change takes place both in texture and in composition. The constituent grains decrease in size and occasionally parellelly arranged, giving a rude gneissic structure. Muscovite flakes, instead of biotite, become prevalent. In addition to the above two kinds of feldspars, orthoclase and oligoclase-albite, small grains of microcline characterized by grating structures in association with quartz, surround the other large constituent minerals. Quartz shows either large lenticular aggregates or as small round inclusions in the feldspars, with a corroded saw-like border. Such are the only dynamic evidences so far as shown by the granite.

There are, however, certain grayish varieties characterized by more compact texture, coarser grain, apparent freshness and fairly abundant dark spots containing biotite flakes and prismatic hornblende. These are the only stones worked for building purposes by the natives at accessible places, for example, as at Yaochiatang (姚家塘) on the western slope of Chiuhuashan.

Under microscope the predominant constituents including feldspar and quartz are essentially of the same character (Pl. III, Fig. 1) and in nearly equal abundance as those of the above normal granite. It differs, however, from the latter in two points: (1) the increasing amount of the mafic minerals containing greenish hornblende and biotite flakes; (2) the fairly abundant in accessory minerals such as apatite, magnetite and sphene or titanite; sphene occurs either in isolated wedge-shaped crystals or co-exists with magnetite, apatite and hornblende. Apatite occasionally occurs as inclusions within the feldspars. The greenish hornblende is an ordinary type showing marked pleochroism and twinned crystal-form. When weathered, it alters to chlorite and epidote.

Mineralogically, a rock of such a composition is properly termed a hornblende granite. It might represent a later phase of intrusion or a local modification of magmatic consolidation. Besides, the whole mass seems to be rather homogeneous in constitution, because, dykes and veins are exceedingly few. So far as our observation goes, only one dyke of granite porphyry was found about one li to the southeast of Taipingtsao (太平曹), a small village near the western contact. Being very weathered, the feldspathic constituents completely alter to secondary sericite with some other undeterminable substance, embedded in a heterogeneous groundmass. Clear phenocrystic quartz more or less corroded is, occasionally, present.

Contact: As shown on the geological map this granitic body is surrounded in the west by a thin rim of Ordovician limestone which in turn is overlain by the Fengchu shale of Silurian age. Near Huangchü, the pure limestone has been mamorized, at the very contact, into white marble, while variegated metamorphic rocks with parallel bands containing quartz granules and chlorite were formed from the impure limestone or argillaceous sediments. About 500 meters northeast of Huangchü, a small temple called Hengtaoan,

was built just at the contact. Here, the argillaceous limestone was metamorphosed into a brown rock characterized by parallel bands containing flakes of wollastonite, feldspars and grains of garnet (Pl. III, Fig. 2). Wollastonite usually aggregates in large lenticular masses through which grains of garnet are occasionally scattered along the major axis. Feldspars earthy in appearance show often no definite form. When arenaceous bands occur at the margin as xenocrystic inclusions, they were intensely metamorphosed into gneissic structure with abundant muscovite (Pl. III, Fig. 3). So far as shown by the field observation, the limestone decreases however rapidly in degree of metamorphism when further apart, the effect having never exceeded 100 meters.

Contact metasomatic iron deposits, though occurring here and there at the very contact, for example, as on the eastern slope of Tzuyenshan, are usually of poor quality and possess, therefore, no economic importance. Farther from the contact, veins of both galena and pyrite of mesothermal origin were found. About 100 meters northeast of Taipingtsao, an abandoned cave is said to contain galena in the unaltered limestone with a pyritic vein about 1 meter thick invading into the Silurian shale on the southern foot hill of Tzuyenshan. The authors were originally appointed to give a survey of the latter pyritic deposit which has yielded several thousand tons of sulphur in the past.

The Hsiaomailing Granite.

This is a small granitic body intruding into both the Ordovician limestone and the Silurian shale. Only a part of its southern border falls within the area surveyed, and so far as its petrographical characters are concerned it is essentially similar to the normal type of the Chiuhuashan intrusion. Toward northeast, beyond the scope of the surveyed area, it comes rather near to the main intrusion indicating that both are connected together underneath. At the margin metallic deposits such as galena also occur beside the normal contact effect upon the country rocks.

The Lishan Porphyritic Granite.

Lishan is a small hill rising abruptly at about 100 meters above the low undulations about 10 li to the southeast by south of Kueichih city. It covers

another area of granitic intrusion which intruded on the south into both the Devonian quartzite and the Chihsia limestone. As most of the contact boundary is concealed by alluvials, the relation of the igneous body with the intruded rock is rather obscure. However as revealed by the metamorphosed character of the Devonian quartzite as well as the invading quartz veins, it is beyond doubt that it is of intrusive origin.

The rock has a remarkable porphyritic texture with large tabular crystals of fleshy feldspar, attaining occasionally 1 cm in length. Quartz usually in grayish grains scatters interstitially between the phenocrysts (Pl. III, fig. 4); it is inferior in quantity to that in the main mass of Chiuhuashan. Microscopic study shows that most of the phenocrysts are orthoclase either simple or with carlsbad twins. It certainly predominates in quantity over the plagioclase. Plagioclase often multiple-twinned and with zonal structure is identified to have a composition corresponding to oligoclase-albite. Among the ferro-magnesian minerals, including hornblende and magnetite, biotite is by far more preponderant. Wedge-shaped crystals of sphene occur as accessories.

There occurs, however, a medium grained variety which possesses a decidedly light color. Under the microscope, it seems to be richer in quartz. Feldspars usually characterized by perthitic laminations are most probably anorthoclase (Pl. III, Fig. 5). Quartz occasionally occurs as inclusions in the feldspar in graphic growth. Sphene or titanite is also present as the accessory mineral. This rock usually disintegrates rather easily and consequently constitutes low lands surrounding the protruding mass of the compact porphyritic type.

The age of these Intrusions: Microscopic studies as well as megascopic examinations show that the three igneous masses are essentially similar in character except, the porphyritic texture and comparative abundance of potash feldspars in the last two small masses. Such an apparent variation is easily conceivable if we suppose that they were originally connected to a common magmatic basin but consolidated under different conditions. As shown on the accompanying geological map, the biggest is the Chiuhuashan granitic body which intruded into the Ordovician limestone, the oldest formation known in this region.

Being in large mass under thick cover of sedimentary rocks and slowly cooled, a fairly uniform texture was resulted. The Lishan granite, on the other hand, rose as high as to the Permian limestone and was therefore the most shallow one. As porphyritic texture is usually characteristic to hypabyssal rocks, it consolidated into a remarkable porphyritic appearance in contradistinction to the uniform texture of the deep-seated mass. The Hsiaomailing granite intruded into the Devonian quartzite, occupying an intermediate position. Like the Chiuhuashan intrusion, it is characterized by a uniform texture but rather fine in grain. Mineralogically, however, it looks more like the Lishan intrusion.

As far as can be observed in this region, the youngest formation which has been affected by the intrusions is the Chihsia limestone of lower Permian age. This implies a post-Chihsia age of these intrusions. Observations elsewhere have, however, shown that granitic masses of such a composition widely spread in central China are mostly dated back to upper Jurassic, and possibly to Cretaceous. This inclines the authors to attribute a Mesozoic age to these intrusions. As pointed before, the folding has been correlated with the Yenshan movement, the active period of which lasted also from Jurassic to Cretaceous, the igneous activity is very probably closely associated with that period of orogenesis.

Explanation of Plate II.

Fig. 1. Panoramic view of Chiuhuashan (九華山); looking south.

Fig. 2. View of Môpanfeng (磨盤峰) showing bold peaks and precipitous ridges of the granitic intrusion.

Fig. 3. Tienchufeng (天柱峯) or Heaven Pillar, the top peak of Chiuhuashan; looking south.

Fig. 1.

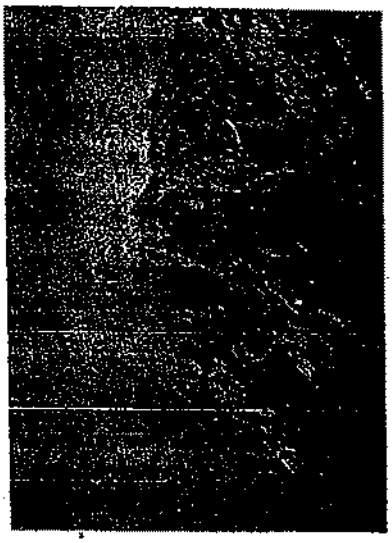

Fig. 3.

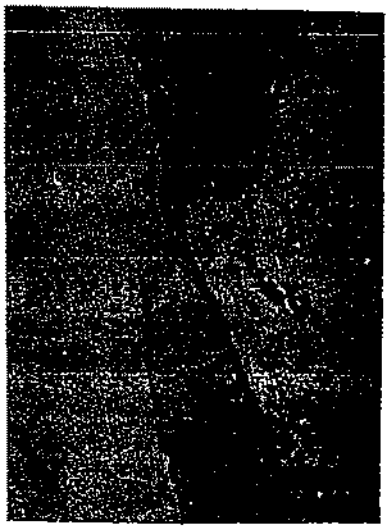

Fig. 2.

Explanation of Plate III.

Fig. 1. Hornblende granite—Multiple twinning and zonal structure of oligoclase—albite; specimen from Yaochiatang (姚家塘). × 18 and N +.

Fig. 2. Contact rock—Grains of garnet embedded in sericite and wollastonite; dark irregular patches being feldspars. Specimen from Hengtaoan (横桃庵). × 18 with parallel nicols.

Fig. 3. Muscovite sandstone—Grains of quartz and flakes of muscovite in rude parallel arrangement. It occurs as lenticular inclusions in the granitic body. Specimen from Shinchiachung (沈家冲). × 18 and N +.

Fig. 4. Porphyritic granite—Quartz filling the interstitial space between the phenocrystic feldspars. Wedges-shaped sphene. Specimen from Lishan (梨山). × 18 with parallel nicols.

Fig. 5. Granite—Perthitic structure of anorthoclase and its graphic intergrowth with quartz. Specimen from Lichiatien (栗家店). × 18 with parallel nicols.

Fig. 1.

Fig. 2.

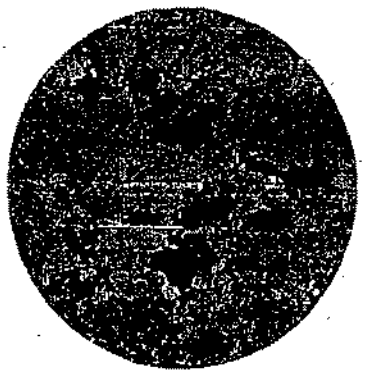

Fig. 3.

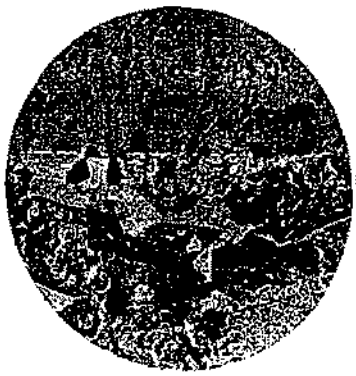

Fig. 4.

Fig. 5.