

# NOTE ON THE GEOLOGY OF CHANGSINTIEN-TUOLI AREA, S. W. OF PEIPING\*

(With 3 Plates, 5 Text figures)

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## 1. INTRODUCTION

Changsintien is a station on the Peiping-Hankow railway and is situated about 20 km S. W. of Peiping. Further S. W. for about 15 km is the town of Tuoli where begins the Tuotsin aerial ropeway for transporting coal and at the same time it is the terminal station of a branch line of the Peiping-Hankow railway from Lianghsiang. For about 8 km N. W. of Changsintien is the town of Tahuichang, a district famous for its lime-burning industry.

In the geological map of Western Hills accompanying the Memoir of Prof. L. F. Yih published in 1919, the Tuoli-Tahuichang area was entirely mapped as Tiaochishan formation. In his study of the Cenozoic deposit of Northern China, Dr. J. G. Anderson<sup>1</sup> has noticed in about 1924 an excellent section of gravels and purple shales exposed right inside the station yard at Changsintien. From the highly tilted position (dip to 7° or more) and litholo-

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<sup>1</sup> Anderson, J. G. Essays on the Cenozoic of Northern China, Mem. Geol. Surv. China, Ser. A. No. 3, 1933, p. 148.

gical character, Dr. Andersson has rightly concluded that these beds belong to Eocene or at least early Tertiary age. In 1929 Mr. W. C. Pei while travelling with P. Teilhard and C. C. Young back from Choukoutien found some fossil mammal teeth near Wengchuangtze which seem to confirm the age of the Changsintien deposits as predicted by Dr. Andersson, but more fossils are needed for a conclusive determination.

In view of the importance of the early Tertiary deposit in this region, a group of geologists including Y. S. Chi, L. C. Chang & T. Li was sent by the Geological Survey of China to make detailed mapping of geology and topography. The result of this study, unfortunately not yet published indicates a wide distribution of the gravel beds which extend towards west as far as to Tahuichang.

In the summer of 1932, while in an excursion to revise the geological map of Western Hills, Mr. L. C. Lee together with Mr. W. H. King were sent to Tahuichang and vicinity to complete the sheet. During this work Mr. Lee found for the first time the mollusca shell bed at N. W. of Hsiachuang (The Hsiachuang series or K<sub>4</sub> bed of this report). From the general appearance of the fossils, the beds in question can not be younger than Cretaceous.

Now in order to solve the stratigraphical problem of the region, the writer together with Messrs. K. Chen and L. C. Lee were sent there for a short time visit. We spent altogether about a week in the field which lasted from May 4th to 11th. In this work we not only established a definite stratigraphical succession for the whole late Mesozoic and early Tertiary beds, but discovered in addition an *Estheria* fauna which undoubtedly are of lower Cretaceous age. Besides, we have established two unconformities, one is between the Lower & Upper Cretaceous (between beds K<sub>3</sub>-K<sub>4</sub>) while the other is between the mollusca bed and the Changsintien gravel, the latter being most probably of Eocene age. Thus within this limited area of only 200 sq. km. we have a full development of the Late Mesozoic and Early Tertiary formations which was found no where else in the region around the Western Hills slope.

In the summer of this year (1933) Prof. H. C. T'an and Dr. T. H. Yin of the Geological Survey together with a party of students from the National

University of Peking including V. Y. Chang, V. C. Juan & C. Y. Wang went again to this region for collection of more fossils. Three horizons of plant fossils were discovered with two in the Lushanwen bed ( $K_3$ ) and one in the Hsiachuang bed ( $K_4$ ). These plant fossils are to be described in the next article by Mr. C. H. P'an.

At about the same time Messrs. Y. C. Chen & Y. P. Chi of the Geographical Department of Tsinghua University made also some geological study of the Changsintien Area, with special attention paid on the nature and origin of the Changsintien gravel. They found in addition at S. W. of Changsintien a mollusca fossil bed somewhat similar to that of Shichuang.

In preparing this paper I have been much benefited from the discussion with Prof. T'an and Mr. K. Chen; besides I have freely used the material contained in the report<sup>2</sup> submitted by the students of the National University of Peking as well as the report by Y. C. Chen of the Tsinghua University; to these gentlemen, the writer should acknowledge his indebtedness.

## 2. TOPOGRAPHICAL FEATURES

The Changsintien-Tuoli area is characterized by rolling hills and maturely dissected valleys. It is bordered on the west by the great limestone range of Maanshan in the north and the quartzite range of Nantachai and Peitachai in the south. Towards east it is truncated by the river Yungtingho whence it gradually merges into the great plain of Peiping. The area in question occupies therefore the foothill region of the great Western Hills.

From topographical point of view, the region may again be divided into several divisions. Thus in the north-east it is essentially a platform of Changsintien gravels which has been dissected by two prominent valleys. Consequently, if one goes from Changsintien to Tahuichang, he will come across two valleys and three parallel ridges with a uniform elevation of 80-90 m above the sea level (or about 30 m above the adjacent plain). The top of the platform as well as the valleys are filled to some extent by yellowish colored loess-like material; one of the most prominent mass of this nature is seen at N. E. of Leechiayu.

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2. This report was chiefly written by Mr. V. Y. Chang.

This platform-topography persists westward to as far as Tahuichang and from here onwards the elevation becomes higher and higher until we arrive at the limestone range of Maanshan, which stands about 700 m above sea level. In the vicinity of Tuoli a long spur of rolling hills trending from N. W. to S. E. is the most characteristic feature. These hills present a mild aspect consisting of rounded tops and gentle slopes, and with a rather uniform elevation of 110-130 m above the sea level (or about 50-60 m above the neighboring valley). They are composed essentially of conglomerate which is rather compact and massive and are interbedded frequently with thin layers of sandstone and shale. Owing to their comparatively resistant nature, these rocks have escaped from erosion and form a long spur projecting away from the quartzite mass of Peitachai. Between these two topographic divisions, there occurs a wide plain built up by re-deposited loess as well as flood plain deposits of the recent rivers. Projecting out from this alluvial plain here are several isolated low hills or ridges such as the hill of Chaoyangshan attaining 80-90 m in elevation and the long ridge between Hsiachuang and Tafuchuang, 120-130 m in elevation. A small hill of Sinian limestone at east of Lianghsiang station represents the eastern-most extension of this topographic division. And lastly there is the foothill region lying between the Maanshan and Peitachai in the west and the low hills to the east; in this belt a great variety of geological formations such as Sinian limestone, Ordovician limestone, Permo-Carboniferous coal measure, Cretaceous volcanics etc. are found. It is also in this belt that faulting and thrusting occurred repeatedly during the later part of the Mesozoic period.

In summing up the topographic features above described, we may say that the area in question is composed of a foothill belt in the west, a gravel platform in the northeast and a long spur of conglomerate and sandstone in the southwest, while between the last two named there occurs a wide alluvial plain with scattered isolated hills and ridges.

### 3. STRATIGRAPHY

We shall describe in the present section only the late Mesozoic and Tertiary stratigraphy as they form the bulk of the region concerned. The older formations as the Sinian limestone, the Ordovician limestone, the Yangchiatun coal measure etc. which form continuous outcrops in the foothill belt as well

as the main range in the west will not be considered. In ascending order the formations may be described as follows: (See also the accompanied columnar section Pl. 1).

1. Tiaochushan formation (or  $K_1$ ). A series of volcanic rocks composed of alternating agglomerate and lava flow is extensively developed northwest of Tahuichang. A section taken from Hsinchuang to Houchuang shows the following succession in descending order:

Sedimentary rocks of the overlying formations.		
Somewhat deeply weathered andesite ... ..	1	m
Fresh andesite ... ..	75	m
Andesite containing numerous pebbles which increases in number towards the top ... ..	50	m
Agglomerate ... ..	55	m
Andesite with amygdaloidal fillings ... ..	30	m
Agglomerate ... ..	25	m
Andesite with green ash beds ... ..	60	m
Agglomerate rich in porphyrite pebbles perhaps interbedded with one layer of lava ... ..	160	m
Agglomerate rich in limestone pebbles ... ..	15	m
Rhyolite flow ... ..	1.5	m
Red clay ... ..	7	m
Volcanic breccia with limestone fragments ... ..	10	m
unconformity		
Sinian limestone		

The volcanic series dips at  $20^{\circ}$ - $30^{\circ}$  to S. E. Its total thickness as can be seen from the above section amounts to 490 m. It lies unconformably on a thrust mass of Sinian limestone; the evidence for this interpretation is afforded by the presence of limestone pebbles in the basal part of the agglomerate and moreover by its apparent overlying position on the Sinian limestone. More detailed discussion on this contact will be given in later paragraphs.

Another noteworthy fact shown in the above section is the presence of a somewhat deeply weathered andesite, only about 1 m thick. This indicates perhaps an erosion interval between the volcanic series and the next sedimentary beds.

From its general lithological character, this volcanic series can roughly be compared with that of the Tiaochishan formation, typically developed in the high peaks of the Western Hills; close comparison must not be made without having a careful petrographical study.

2. Tahuichang Series (K<sub>1</sub>)—After perhaps a slight erosion interval there occurred the deposition of the Tahuichang black shale and sandstone which lies almost immediately above the volcanic series. A section taken at north of Hsinchuang shows the following succession:

- |  |      |
|--|------|
| 1) Alternation of conglomerate & purple shale, Hsinchuang Series ... ..  |      |
| 2) Covered interval ... ..   | 30 m |
| 3) Fine grained green sandstone with agglomerate pebbles and a thin layer of purple shale on top, the whole series is much contorted and crushed. .... | 8 m  |
| 4) Black shale with <i>Estheria</i> ... ..   | 5 m  |
| 5) Greenish yellow sandstone ... ..  | 5 m  |
| 6) Green shale with limestone nodules ... ..   | 3 m  |
| Erosion interval? ... ..   |      |
| 7) Weathered andesite ... ..   |      |

Bed No. 3 contains frequently a great number of small concretions or coatings of dark brown color. This looks in some respect as fish scales but its exact nature can not be determined. The sandstone contains also some pebbles of a conglomerate or agglomeratic rocks derived from the older volcanic series. The contact of this series with the overlying Hsinchuang conglomerate and sandstone is obscured by a covered interval of about 30 m so that its relationship cannot be ascertained. On the other hand, in another section observed S. W. of Tahuichang, the black shale series is succeeded by a sequence of yellow tuffaceous sandstone, sandy shale and purple shale interbedded with several layers of agglomerate of distinctly volcanic origin. The whole series measures about 80 m in thickness. According to the map of Messrs. V. Y. Chang, V. C. Juan & C. Y. Wang this was interpreted as a part of the Hsinchuang series, but in view of its distinct volcanic origin this sequence seems to show more affinity

with the lower beds rather than with the Hsinchuang series which is a formation of entirely sedimentary origin.

In order to explain the above controversy between the two sections observed, we may assume that there was a recurrence of volcanic activity after the black shale phase has been deposited, and before the deposition of the Hsinchuang conglomerate and sandstone, part of the upper volcanic rocks had been eroded away resulting in the direct contact of the Hsinchuang beds with the black shale as we see at present northeast of Tahuichang. This implies an erosion interval or disconformity between the two formations. If this be true we can further conclude that the Tahuichang black shale series of only about 20 m in thickness represents merely a sedimentary phase among the great Tiaochishan volcanic epoch, and both of them must fall together under the same geological period.

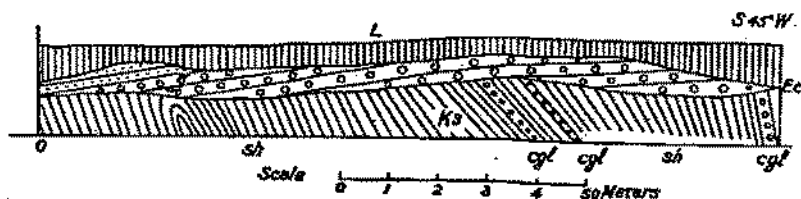


Fig. 1. Section showing unconformity between the Hsinchuang Series and the Changsintien gravel, N. of Hsinchuang. L, Loess; Ec, Changsintien gravel; Ks, Hsinchuang Series; Sh, purple shale; Cgl, conglomerate.

3. Hsinchuang purple shale and conglomerate (Ks)—This is composed of purple shale and sandy shale with frequent intercalations of conglomerate the latter attains usually a moderate bed of about 2-4 m in thickness. The lower middle part is rich in shale while its upper part abounds in conglomerate and coarse sandstone. The series, especially the shale beds are frequently tilted and contorted showing consequently a steep dip sometimes nearly vertical. It is best developed in the vicinity of Hsinchuang where is also shown beautiful unconformable relation with its overlying Changsintien gravel (see fig. 1). The thickness of exposed part amounts to about 300 m. According to the map of Chang, Juan & Wang, the same series extends southwestward to as far as north of Peitzuwei where it is overlaid unconformably by the Tuoli conglomerate.



The pebbles in the conglomerate are composed almost exclusively of igneous rocks among which andesite, porphyrite, etc. predominate; they are evidently derived from the Tiaochishan formation. That these beds are of sedimentary origin is clearly shown by their perfectly rounded pebbles, the kind of rock association as well as the nature of the cement. Pebbles of sedimentary rocks are very rare in the conglomerate, a remarkable fact indicating that during its formation, the neighbouring hill slopes were largely covered by the Tiaochishan volcanics.

4. Tuoli conglomerate ( $K_1$ ).—In the vicinity of Tuoli there exposes a mighty sequence of thick bedded conglomerate (attaining sometimes 10 m or more in a single bed) intercalated frequently with thin layers of gray and purple shale in which plant impressions of mostly undeterminable nature are abundant. The conglomerate is firm and compact containing sub-rounded pebbles of rhyolite, trachyte and some andesite. Pebbles of sedimentary rock like quartzite and limestone are also found but they are extremely rare. The conglomerate and the shale are as a rule highly tilted up to  $20^{\circ}$ – $40^{\circ}$  in inclination.

This conglomerate and shale are now called the Tuoli formation. It has a wide distribution towards southeast to as far as Wuchuang W. of Lianghsiang city. According to the map of Chang, Juan and Wang, this same formation has been traced northeastward to Hsiaoerhying where it unconformably overlies the Hsiangchuang shale. The entire thickness of the formation has been estimated by the same authors to be about 500 m.

The rarity of sedimentary pebbles in the Tuoli conglomerate points again to the conclusion that volcanic rocks of Tiaochishan formation formed at that time prominent outcrops of the hill slopes towards west. On the other hand the occasional presence of limestone and quartzite pebbles evidently of Sinian age indicates that the thrust Sinian mass became already uncovered in some part of the region during the deposition of the Tuoli conglomerate.

5. The Lushangwen shale and sandstone ( $K_2$ ).—The Tuoli conglomerate grades upward into a shale and sandstone series in which only five or six layers of thin conglomerate are intercalated. Both the shale and sandstone show different colors of purple, gray and yellow and are usually thin to moder-



ately bedded. Owing to the transitional nature of the formation both towards the top and bottom, its upper & lower limit can only be arbitrarily determined. According to Chang, Juan & Wang the detailed succession is as follows:

- 0) Purple shale & gray sandstone of Hsiachuang formation ... ..
- 1) Purple, green, gray shale with few layers of yellow & gray sandstone ... .. 100 m
- 2) Conglomerate ... .. 5 m
- 3) Yellow sandstone and shale ... .. 50 m
- 4) Purple shale and sandstone with several intercalations of conglomerate ... .. 80 m
- 5) Purple shale with a thin layer of yellow sandstone containing an *Onychiopsis* flora ... 15 m

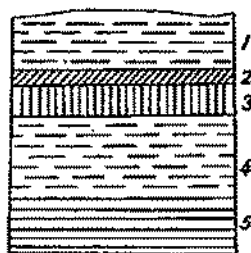
The total thickness is about 250-300 m. The *Onychiopsis* flora was found by Chang's party at a place just west of the village Shangyuan, N. E. of Tuoli. Its geological age was considered by H. C. P'an to be nearer to Lower Cretaceous (Wealden) rather than Upper Cretaceous. But since this formation is in perfect continuation with the next one which carries some flora and fauna of probably upper Cretaceous age, so we are justified to think that both of them may belong to upper Cretaceous.

6. The Hsiachuang Series ( $K_2$ )—Although conformably overlaid on the formation just described, this series is composed of most complex rocks of different composition in which purple shale, clay, yellow conglomerate, sandstone, marls, limestones etc. are all present. The calcareous sediments are especially abundant in the lower part of the series in which, at west of Hsiachuang, fossil gastropoda and bivalves have been found. Two fossil localities have been located, one lies along the road just west of Hsiachuang, while the other is a little towards northwest where a steep cut is shown. Fig. 2 is a sketch showing the occurrence of these two fossil localities.

Whether these two fossiliferous beds are identical or not it is difficult to ascertain; so far as the succession of rocks is concerned, it appears that they belong to different horizons although not widely apart, as their fossil contents are essentially similar.

At west of Liutaichuang some fossil plants (*Podozamites lanceolatus*) together with an insect-like fossil were found in a paper shale lying probably above the calcareous bed at Hsiachuang. Another fossil horizon evidently lying also above the bivalve horizon is a purple shale in which *Cyparisidium*, *Elatocladus* sp., *Pityophyllum* have been found. All these fossils indicate probably an upper Cretaceous age.

I



II



Fig. 2. I. Fossiliferous beds exposed in a cut N.W. of Hsiachuang, total thickness 3 m. 1, Grayish white marl with black streaks; 2, Yellow mud; 3, Dark gray marl; 4, Alternation of gray and yellow marls; 5, Yellowish gray shale, thin and fissile.

II. Fossiliferous horizon exposed along a trail west of Hsiachuang. 1, Fossiliferous marl, half a meter thick; 2, Compact limestone; 3, Alternation of yellow sandstone and grayish yellow thin shale.

7. Changsintien gravel (Eg).—The Changsintien gravel is widely distributed between Changsintien and Tahuichang where it forms a moderately dissected platform. In the vicinity of Hsingchuang, this bed was seen to lie unconformably on the Hsingchuang conglomerate and purple shale, while near Hsiaochangkochuang, according to Chang's party this was again seen to lie

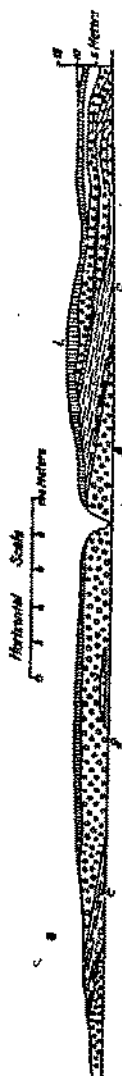


Fig. 3. Section of the Changsintien gravel formation showing the interbedded purple clay and sand lenses, Changsintien Station yard. g, Gravel; c, Purple clay; a, Sand; L, Loess.

unconformably on the Hsiachuang beds. Therefore it is younger than all other formations so far described.

The gravel is intercalated by several layers of purple clay and thin lenses of yellow sand. A beautiful section of a part of the gravel is exposed right inside the Changsintien station yard besides the railway track and another one is near Wenchuangtze (See Fig. 3 & 4). As can be seen from the sections at least three layers of purple clay ranging in thickness from 5-10 m are intercalated. In the section at Changsintien there shows also the frequent occurrence of sand lenses or pockets in the gravel. A distinct dip amounting to 15° or more is seen at both sections. Same kind of purple shale is again met with in the valley of Taipingting, E. of Tahuichang.

The gravel is usually roughly stratified and may be quite indurated at certain places. The pebbles<sup>3</sup> are composed essentially of igneous rocks among which agglomerate, rhyolite, trachyte, andesite are all represented. Limestone and quartzite of Sinian age are also found though they are much less in quantity. The size of pebbles varies within wide limit, the largest boulder observed has a diameter of about half a meter.

Owing to lack of complete exposure the detailed succession in the Changsintien gravel is not clear. Roughly speaking we may divide it into three parts: both the upper and lower parts are characterized by the presence of several layers of purple clay while the middle one seems to almost exclusively consist of gravel. For the same reason its total thickness is also difficult to ascertain, though an approximate estimate of 100 m or so may be made.

3. A detailed study on the Changsintien gravel with special reference to its origin and nature of the pebbles will soon be published in this bulletin by Y. C. Chen.

A piece of fossil mammal was collected by Mr. W. C. Pei near Wenchuangtze; according to the provisional determination of Dr. C. C. Young, this fossil indicates very probably an Eocene age.

8. Red clay, loess and alluvium.—Distinctly colored red clay probably of Pliocene age was met with at west of Hsichungtien as well as in the vicinity of Houfuyin. Primary loess with basal gravel is abundantly distributed on the slope all the way from Tahuichang to Tungshihfu; the gravel contains essentially limestone pebbles indicating that Ordovician limestone formed then prominent outcrops towards the west. The wide valleys between the Changsintien platform and the long spur at Tuoli are all filled by loessic material, probably the re-deposited loess. Along many of the recent river courses alluvial deposits of sand, silt as well as gravel are found. At Lukouchiao a prominent gravel bed



Fig. 4. Changsintien gravel with its intercalated clay beds and sand lenses exposed at north of Wenchuangtze. g, Gravel; c, Purple clay; s, Sand lenses; L, Loess.

was seen containing besides limestone & quartzite, also abundant pebbles of volcanic rocks evidently derived from the reworking of the Changsintien gravel as well as from older volcanic and sedimentary rocks (the Hsingchuang conglomerate for instance). This gravel represents no doubt the old alluvial deposit of the Hungho.

9. Igneous Rock.—A dike of dolerite is found at about half a km. S. W. of Tahuichang. The field occurrence indicates clearly that this rock is intruded into the Changsintien gravel formation and by its contact effect the later gravel has been much indurated or so to say metamorphosed. Therefore the post Eocene age of the intrusion seems to be proved beyond doubt. It is interesting to note that although dolerite or its related rocks are widely distributed in Northern China, conclusive evidence on the date of intrusion such as here furnished by the occurrence at Tahuichang is in fact the first instance that has ever been noticed. The outcrop shows a length of about 100 m and an

exposed width of about 5 m. According to Chang's party this dolerite dike is traceable much further towards southwest for a greater distance.

Under the microscope the dolerite is seen to be made up chiefly of plagioclase, augite and some amount of olivine. All these minerals are remarkably fresh and not much alteration can be detected.

#### 4. GEOLOGICAL STRUCTURE

The most important geological structure is the Fenghuangshan-Nantaichai-Peitaichai thrust which trends in a N.E.-S.W. direction and can be traced in the field for a distance of about 22 km. Its field character and relationship with the older formations will be fully discussed by K. Chen.<sup>4</sup>

The contact between the Tuoli conglomerate and the Sinian quartzite at Sinkaukou may be explained by a normal fault as the former dips against the latter. Another fault though not yet clearly established seems to occur at south of Hsiachuang, by which the calcareous beds at Hsiachuang and Chaoyangshan becomes separated and displaced. It is evidently a dip fault with the north-west block as the upthrow side.

Folding is commonly observed and is of different nature. First of all we must mention the intense folding and contortion in the Hsingchuang beds which was probably brought about by a stress from southeast. In the upper Cretaceous beds we found only gentle and open folding. A gentle anticline of small scale may be clearly seen on the hill just back of the Tuoli station. In the long spur of the Tuoli conglomerate there shows frequent variation of dip directions, some of which assume the shape of a flat dome. The same may be said of the Lushangwen beds in which anticlines and synclines of small scale are frequently encountered. As will be mentioned below, this folding has probably resulted from a stress due to the granitic intrusion at Fanshan.

#### 5. DATE OF TECTONIC MOVEMENT

The exact age of the great Fenghuangshan-Peitaichai-Nantaichai thrust remains still unsettled. From the evidence that limestone-bearing agglomerate of the Tiaochishan formation lies apparently above the thrusting Sinian

4. Paper in preparation.

mass, it seems well justified to think that the thrusting took place prior to the formation of the volcanic series. In a section at northwest of Tahuichang, (see Fig. 5), Sinian block was seen to lie on an extremely pressed and contorted purple shale as if the latter beds were squeezed and compressed by the thrusting mass. If this be true, then the thrusting must be younger than the beds of purple shale. Now the important question is whether the purple shale beds belong to Hsingchuang i.e. of Cretaceous age or older. Since all the beds here show a southeasterly dip, and since a little distance towards southeast we found the typical Tiaochishan volcanics, the purple shale beds therefore could not be Hsingchuang but belong to some older horizons. Possibly it is the upper part of the Yangchiatun coal measure or some lower part of the Hungmiaoling

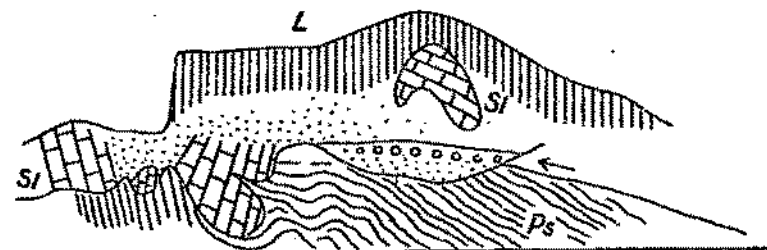


Fig. 5. An interesting contact showing Sinian limestone thrust over a purple shale formation, the latter is extremely contorted and squeezed. Exposed in a valley N. W. of Tahuichang. L, Loess; Si, Sinian limestone; Ps, Purple shale probably of Permo-Triassic age.

sandstone formation. Should this assumption be true, then we have here a thrust over a series of Permo-Carboniferous sediments which, owing to intensive stress, has become extremely contorted and squeezed. It points therefore to the same conclusion that the development of the thrust antedates the volcanic formation.

Granting the unconformable contact between the volcanic series and the Sinian mass, Prof. H. C. T'an has proposed a different theory in favor of the younger date of the thrusting. Prof. T'an thinks that the whole sequence of Sinian limestone as well as the volcanics, the black shale and the Hsingchuang conglomerate might have been thrust and pushed along on an older floor composed of the same Cretaceous sediments, but the latter are entirely covered



by the thrust so that they are not exposed. He emphasizes the fact that since the Tuoli conglomerate and its following strata have been only slightly tilted while that of the Hsingchuang and older beds strongly squeezed and folded, thrusting must have occurred at a time between the two. Although Prof. T'an's explanation may be good, but in view of the mechanical difficulty for a complex series of strata of greatly varying hardness to be involved in overthrusting, without disrupting or dismembering I rather hesitate to accept his theory. Furthermore we have not yet been able to observe direct contact of the Siquan limestone with its underlying Cretaceous sediments. Pending more evidence I would believe tentatively that the thrusting took place before the volcanic series i.e. of Pre-lower Cretaceous or upper Jurassic time. The direction of stress has probably come from the southeast.

Another important structural feature is the intense folding and contortion observed in the Hsingchuang conglomerate and purple shale. As the next younger bed—the Tuoli conglomerate—has been only slightly folded, so we must argue that this represents a distinct period of orogenic movement which occurred just between Lower and Upper Cretaceous time. The stress has come again from the southeast as can be inferred from the decreasing of intensity of the folding as we come towards northwest.

Now since the Upper Cretaceous sediments from  $K_1$  to  $K_4$  have been also gently folded, so we must assume a third period of tectonic movement taking place in post-Upper-Cretaceous time. The trend of strata has changed now from a northeast to northwest direction, consequently the direction of stress must have come from a different direction i.e. either from S. W. or from N. E. Now we know that S. W. of Tuoli in the vicinity of Fanshan Hsien there lies a big mass of granite. It would then be only natural to think that the third period of tectonic movement was brought about as a result of the granitic intrusion. In order to prove this theory, we need however more field evidence, especially as the age of the Fanshan granite intrusion has not yet been clearly fixed.

The last epoch of tectonic movement is a gentle warping resulting in the tilting of the Changsintien gravel. Since the latter lies unconformably on all other formations observed except the red clay, loess and other younger



deposits and since no clear folding has yet been observed in the Changsintien gravel, so a period of movement different from that of the folding of the Tuoli age must be assumed.

The existence of a dip fault south of Hsiachuang is yet uncertain. Should this be true, then we must assume a Pre-Eocene faulting which affected only the upper Cretaceous sediments but not the latter one.

In summing up what has been discussed we may tabulate the date of tectonic movements as follows:

Geological Age	Character of movement	Direction of stress
Pre-Lower Cretaceous	Overthrust	From S. E.
Between Lower & Upper Cretaceous	Intense folding	From S. E.
Post Upper Cretaceous	Gentle folding	From S. W. probably brought about by granitic intrusion.
Post Upper Cretaceous	Normal faulting	
Post Eocene	Warping	From S. W.

## 5. GEOLOGICAL HISTORY

In order to illustrate the geological history of the region, I have drawn a series of diagrams to show the successive development of deposition, denudation and tectonic movement in this region (Plate III).

In Pl. III, Fig. 1 is shown the thrusting of Sinian mass on Permo-Carboniferous rocks which took place probably at a Pre-Lower-Cretaceous time.

The next event was the outpouring of volcanic lava, bombs etc. for the formation of the agglomerate beds. The bed  $K_1$  which is a sedimentary phase with the fossil *Estheria* represents a short period of quiescence which was however again succeeded by volcanic eruption. The whole series filled up both the thrust mass as well as the older floor. (II).

Then the volcanic mountain was subjected to a far reaching denudation perhaps after a warping. Most of the volcanic material above bed  $K_1$  was eroded and redeposited on the hill slope to form piedmont gravel, with interbedded shale beds. They formed the Hsingchuang Series. ( $K_2$ ) (Fig. III).

Fig. IV shows the intense folding of the Hsinchuang as well as older beds due to a stress acting from SE. On their eroded surface occurred the

deposition of the 2nd piedmont gravel  $K_2$ , (the Tuoli conglomerate) with material again chiefly derived from the volcanic rocks. As the volcanic mountain in the west became gradually lowered down to form a rather low and gentle topography, the torrential action on the slope became also less active, with the result that the deposition gradually merged into a shale phase and finally lacustrine condition developed in the midst of the piedmont slope. This change in sedimentation may have been due also partly to climatic change though no exact proof is yet available (See Fig. V).

The next event was the gentle folding in the Upper Cretaceous sediments probably brought about by the granitic intrusion at Fangshan. The direction of stress has come now from SW.

After another period of warping the volcanic mountain in the west was subjected again to a far reaching denudation resulting in the formation of a third piedmont gravel; this is the Changsintien gravel. It was deposited on the truncated surface of the Cretaceous sediments. The complete removal of the volcanic cover in the Western Hill slopes occurred only at the close of the Changsintien gravel formation, since in the latter beds still nothing else but volcanic pebbles enter as important constituents. It was only at the end of the Eocene time that we have before us in this part of the country a topography somewhat similar to the present one. The Hills Maanshan and Fenhuangshan composed respectively of Ordovician limestone and Sinian limestone come first into their existence at this end of the Changsintien gravel formation. (Fig. VI).

In the vicinity of Tuoli the geological history has proceeded on rather differently. Here either the Changsintien gravel has never deposited, or it has been entirely removed by later erosion, so that older sediments come into view.

The next event was the gentle tilting of the Changsintien gravel by a stress coming again from SW. Whether this has any relationship with the granite intrusion is not ascertained. The dolerite dike was intruded evidently at a post-Eocene time.

The red clay, basal gravel of the loess etc. were deposited at a time when the limestone range to the west has become already uncovered so that in the gravel, limestone pebbles entered as important constituents.



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**Explanation of  
Plate III.**

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### PLATE III.

- I. Sinian block was thrust on Permo-Carboniferous rocks.
- II. Formation of Volcanic Series with its interbedded Shale phase ( $K_2$ ) on the eroded surface of the thrust mass as well as old floor.
- III. Denudation of  $K_1$  and  $K_2$  and the formation of Piedmont gravel ( $K_3$ ) with material chiefly derived from  $K_1$  and  $K_2$ .
- IV. Intense folding of  $K_2$ ,  $K_3$  and  $K_4$  and on their eroded surface took place the deposition of second Piedmont gravel ( $K_5$ ) the Tuoli conglomerate with material again chiefly derived from the Volcanic rocks.
- V. Piedmont gravel merges gradually into Shale phase and finally into a lacustrine phase with the formation of fresh water limestone ( $K_6$ ).
- VI. Further denudation of the Tiaochishan volcanics resulted in the formation of Changsintien gravel which was deposited on the truncated surface of  $K_4$ - $K_5$ . The thrust Sinian mass as well as the Ordovician limestone range became for the first time uncovered.
- VII. Tilting of  $K_4$ ,  $K_5$ ,  $K_6$  as well as  $Eg$  by a force from S. W. which was probably brought about by the granitic intrusion near Fangshan Hsien.

Hypothetical diagrams showing successive stages of development during the Late Mesozoic and Early Tertiary times. Tilting and denudation of strata older than Cretaceous are not represented in the diagrams.

