THE MESOZOIC OROGENIC MOVEMENT IN EASTERN CHINA.

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INTRODUCTION.

In a previous paper[1] on the crustal movements in Eastern China I have laid emphasis on the importance of a Mesozoic orogenesis which I called the Yen-shan movement. The present note is to record some additional data on the distribution and the age of the movement with special reference to the regions where overthrusting is predominant. The latter type of structure which represents the

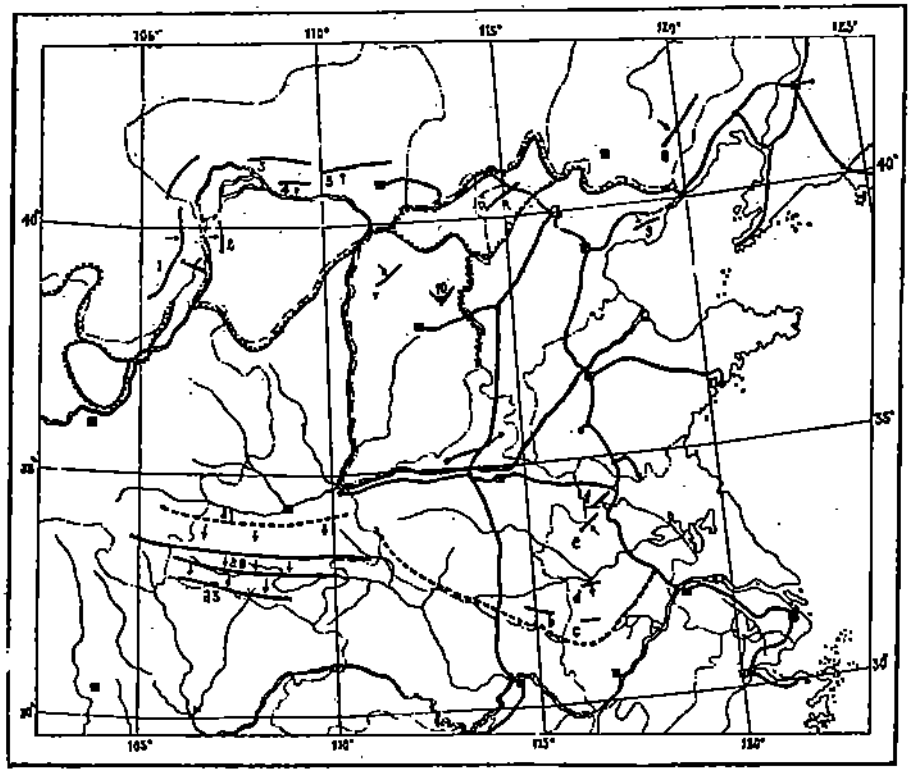


Fig. 1. Location map.

1 Ho-lan-shan 2 Arbus Ula 3 Scheiten Ula 4 Ula shan 5 Ta-ching-shan 6 South of Hsuan-hua 7 Hsi-ma-fang 8 Pei-piao 9 Kaiping 10 Ki-chou-shan. a_1 Tsinling Proper, old crystalline axis. a_2 Anticlinorium and synclinorium with overthrusts a_3 thrust zone. b Kuang-shan. c Hua-shan d Shun-keng-shan e Lieh-shan f Pai-tu-chai.

1. Crustal movement in Eastern China Proc. Pan. Pacif. Sc. Congres, Tokyo, Vol. I, pp. 467-475, 1926.

last phase of a long period of lateral compression, has been of late extensively recognized in the principal orogenic zones and seem to be characteristic of the Yen-shan (燕山) orogenesis.

As far as our present knowledge goes, there are at least two mountain ranges (fig. 1) in which the Yenshan orogenesis has played an important role. The northern range consisting of a series of chains, bordering the Mongolian plateau, is known in Chinese geography under the name of Yin-shan[2]. The southern range is usually called the Tsin-ling range, which probably includes several distinct elements.

THE YEN-SHAN RANGE.

This is a mountain range which constitutes the natural boundary between Mongolia and China Propor. From the Ho-lan-shan (賀蘭山) range in SSW-NNE direction, the folded and thrust zone turns to W-E and appears as Scheiten Ula and Ta-ching-shan (大青山) surrounding the Ordos plateau on the north and west. The overthrust of Ho-lan-shan has been early recognized by Obruchef[3]. Only the geological age of the thrusted limestone has to be changed from Carboniferous (as he believed) to Pre-Cambrian or Sinian. The Ho-lan-shan overthrust probably has a N-S extension of hundred kilometers. The direction of the thrust is from west to east. East of the Yellow River, in the Western Ordos, Teilhard[4] has discovered the Arbus-Ula thrust in the same direction as the Ho-lan-shan overthrust. The general structure of both the east and west sides of the Yellow River can be broadly represented by fig. 2.

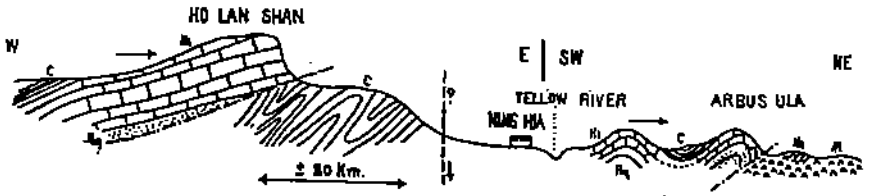


Fig. 2. Generalized section of Ho-lan-shan range (Wong, Teilhard).
R=Archæan gneiss. Hq=Sinian quartzite. Hl=Sinian limestone (partly including Ordovician in Ordos). C=Carboniferous and Permo-Carboniferous.

Crustal movement and igneous activities in Eastern China since Mesozoic time. Bull. Geol. Soc. China Vol. VI, pp. 12-23, 1927.

2. The Chinese name (陰山) was often stransliterated In-shan. But Yin-shan is in better accord with the current mode of stransliteration.
3. V. A. Obruchef: Central Asia, North China and Nanshan Vol. I, pp. 312-333, 1901.
4. P. Teilhard de Chardin: On the Geology of the N, W, and S, borders of Ordos, Bull. Geol, Soc, China, Vol. III, p. 38, 1924.

North of the Yellow River, the structure of Scheiten Ula (色爾騰山) and Ula shan (烏拉山) chains has been also studied by Teilhard[4] and is shown by fig. 3 reproduced from his paper. To the east these chains are replaced by Ta-

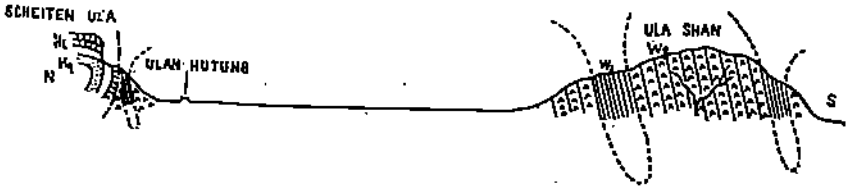


Fig. 3. Structure of Scheiten Ula and Ula shan (Teilhard).
Wg=Wutai gneiss. Ws=Wutai schists. Hq=Sinian quartzite. Hl=Sinian limestone.

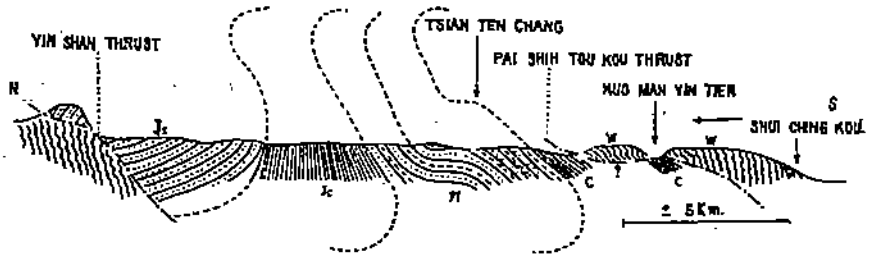
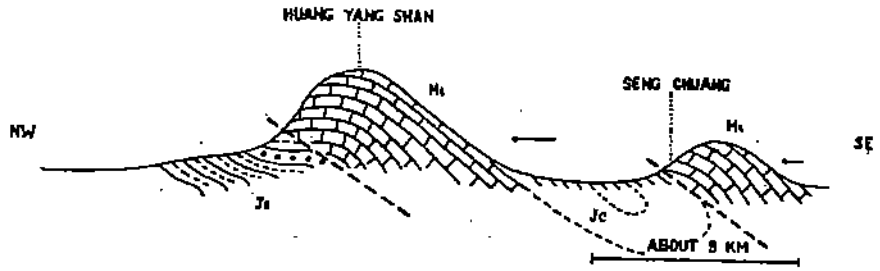


Fig. 4. Generalized section of Ta-ching-shan (C. C. Wang).
W=Wutai system. C=Carboniferous. PT=Permo-Triassic. Jc=Lower Jurassic (coal bearing). Js=Jurassic sandstone.

ching-shan of which C. C. Wang[5] has mapped out the general structure. The numerous sections which Wang has observed can be summarized in a single sketch (fig. 4). From the strong overturning of the strata and the extensive overthrusts of Pre-Cambrian formations over the Permo-Carboniferous coal series or the Jurassic sandstone, Wang concluded that the lateral compression had a northward direction and thought that this conclusion could be generalized and applied to the more western chains, i. e. Ula shan and Scheiten Ula. The southern overthrust in Ta-ching-shan which brings the Pre-Cambrian schists and marble over the Jurassic sandstone is called by C. C. Wang the Pai-shih-tou-kou (白石頭溝) thrust and has a E-W extension of sixty kilometers. The more northern one named Yin-shan thrust has an extension twice as long.

South-west of Ta-ching-shan, a thrust zone is again found in the Hsuan-hua (宣化) region between Kalgan and Peiping. In this region all the higher hills are constituted by the Pre-Cambrian limestone thrusted over the Jurassic beds which

5. C. C. Wang: Geology of the Ta-ching-shan range and its coals fields Bull. Geol. Surv. China, No. 10, pp. 4-13, 1928.



ig. 5. A re-interpretation of the structure south of Hsuan Hua (Wong).
Hl=Sinian limestone. Jc=Jurassic coal series. Js=Jurassic sandstone.

are frequently overturned as shown in the generalized and simplified section (fig. 5) made by re-interpreting the geological map by H. C. Tan[6] and others. According to this map the rock-sheet brought by the overthrust has a known extension of 35 kilometers. The direction of the thrust in this region is the same as has been observed by C. C. Wang in Ta-ching-shan, i. e. from south to north.

In the north-western corner of Shansi province between Wu-chai (五寨) and Tsing-lo (靜樂) districts[7], Y. L. Wang and C. T. Wang[8] have found in the Hsi-ma-fang (西馬坊) iron ore region, a recumbent fold of Pre-Cambrian quartzite and Cambro-Ordovician limestone thrusted upon the Mesozoic sandstone from NW to SE (Fig. 6).

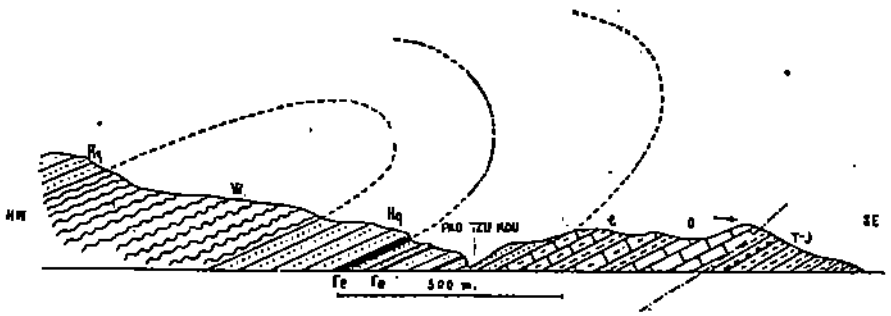


Fig. 6. Section at Pao-tzu-kou, near Hsi-ma-fang (C. T. and Y. L. Wang).
Wu=Wutai schists. Hq=Sinian quartzite. C=Cambrian. O=Ordovician.
T-J=Mesozoic sandstone. Fe=Iron ore beds in the quartzite.

6. H. C. Tan: Geology of Hsuan-hua, Cho-lu and Huai-lai districts, N. W. Chihli, Bull. Geol. Surv. China, No. 10, 1928.
7. See geol. map of China 1:1,000,000 Taiyuan-Yulin sheet by C. C. Wang.
8. Manuscript not yet published.

In south-eastern Jehol, an interesting region has been recently studied by the author[9]. In the country round the Peipiao (北票) coal mine there was found a series of overthusts striking a general direction of NE-SW. (Fig. 7). The Nan-tien-men (南天門) thrust which is the main one has a known extension of 30 kilometers. But similar structure probably extends further to southeast of Chao-yang (朝陽) district as has been observed by Teilhard[10]. That will then add further

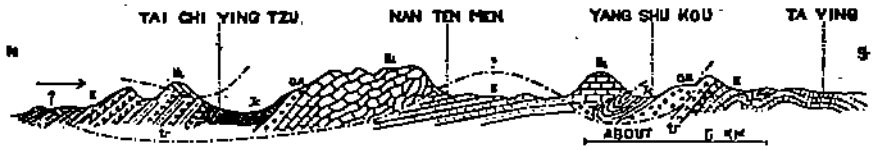


Fig. 7. Generalized section of Pei-piao region (Wong and H. S. Wang).
He Sinian limestone. Jc=Jurassic coal series (partly including upper Jurassic coal).
K=Lower Cretaceous tuff-sandstone. An=Andesite. tr=Trachyte partly rhyolite.

25 kilometers at least to the extension of the thrust. The youngest formation here affected by the tectonic movement is a thick sandstone-tuff series with rhyolitic lava beds. The latter series is considered to be of Lower Cretaceous age.

The foregoing summarizes the available observations on the Yen-shan folding and thrusting in North-China. As regards the direction of tangential stress to which such structure is due it seems that two sub-regions can be distinguished; one on the north including Ta-ching-shan and South Hsuan-hua where the lateral pressure seems to have been exerted chiefly from south to north; the other a little further south-east where the overthrusts are all directed from NW to SE as is evidenced by the structure observed in Peipiao and Hsi-ma-fang region. Still further south and east the lateral compression gradually dies out although local overturnings and thrust are still here and there observable. Thus the well known Kai-ping basin[11] is strongly overturned to the south with its northern limb almost vertical in all locally broken into overthrust and its southern limb more gently dipping to the north. The same direction from north to south seem to prevail in

9. W. H, Wong: Etude tectonique de la region de Pei-piao et ses environs, Bull, Geol. Surv. China No. 11, 1928.
10. P. Teilhard: Etude geoloique sur le region de Dalai-nour. Mem. Geol. Soc. France Nov. Ser. Tome IIf, Fasc. 3, carte geol. 1926.
11. Y. T. Chao etc: Geology of the Kaiping basin. Bull. Geol. Surv. China. No. 12, 1929.

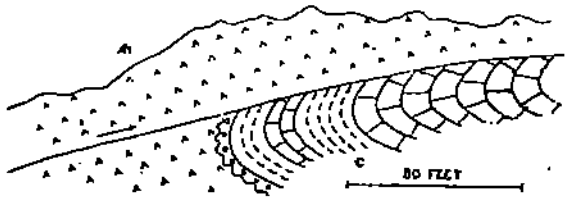


Fig. 8. Local overthrust in Ki-chou-shan (Willis). A=Archean. C=Cambrian.

all local thrusts for instance those (fig. 8) observed by Bailey Willis[12] along the Tai-hang-shan block mountain, and the Chang-kou-yu thrust[13] observed by Ting and Tan in the Western Hills of Peking.

There can be no doubt that the orogenic features above outlined were produced, broadly speaking, in the middle or later part of the Mesozoic time. But the exact age of the movement requires some preliminary stratigraphic discussion. The character of the Mesozoic formations and their relation as observed in more typical regions may be represented by the following table:

Region	West hills, Peking	Hsuan-hua	Pei-piao	Shantung
Authority	(L. F. Yih)	(H. C. Tan)	(Tan, Wong)	(Tan)
Upper Cretaceous	Absent	Absent	Absent	Wangshih series
Unconformity B				
Lower Cretaceous	Tiaochishan lava congl.	Sands. congl. & lava.	Congl. lava.	Mengyin or Chingshan series (tuff conglemerate)
Unconformity A				
Upper Jurassic	Chiulungshan sands. and shale.	Sandstone	Upper coal series (often absent)	Laiying sands. (often absent)
Lower & Med. Jurassic	Mentoukou coal series	Coal series.	Lower	Fangtzu coal (often absent)

The slight modifications made in the geological column seem to bring the stratigraphical sequence in different regions into better harmony and are also better in accord with palæontological evidence. Uncertainty in age lies mostly with the Upper Jurassic sandstone which was often classed as Lower Cretaceous in Jehol and Shantung but as Lower or Middle Jurassic in the Western Hills. In Jehol it is characterized by the local development of lignitic bituminous coal seams and a flora which is mostly upper Jurassic. The unconformity A is as a rule not marked by great angular discordance. Indeed sometimes it is almost unobservable. But its existence is established beyond doubt by stratigraphic evidence. Thus the tuff-conglomerate formation of Lower Cretaceous overlies various older formations from

12. B. Willis: Research in China pt. I, pp. 124-137, 1907.
13. L. F. Yih: Geology of Hsishan, Mem. Geol. Surv. China, Ser. A, No. 1, p. 97, 1920.

Archean up to Upper Jurassic. The latter is often missing undoubtedly because of the intense erosion which preceded the depossition of the Lower Cretaceous conglomerate. The latter conglomerate as a rule contains at its base large boulders of gneiss and granite of Archean age. This is of common observation in all the mentioned regions. It was to this interval, i.e. that between Upper Jurassic and Lower Cretaceous which I referred, in my previous paper on the crustal movement in eastern China, as the main phase of the Yen-shan movement. This conclusion is however to be modified in the light of my recent observation in the Pei-piao region in eastern Jehol and my re-interpretation of the structural geology of the Hsuan-hua area (fig. 5). The main phase of the Mesozoic movement characterized by the intense overthrusting must be later than or at the end of Lower Cretaceous since in these regions the Pre-Cambrian limestone is overthrown upon the tuff-sandstone of this age. The last overthrusing can not be younger than upper Cretaceous because Locene deposits have been observed unaffected by the orogenic movement, and it is most probably older than Upper Cretaceous as can be proved by stratigraphical observation in eastern Shantung where the unconformity below the Wang-shih series has been well established[14] although the orogenic movement is there already much attenuated, being out of the main zones of folding and thrusting. As the geological age of the formations both above and below the unconformity B has been well established by pelecypods, insects[15] and reptile[16] fossils, we can safely conclude that the age of the main tectonic movement in North-eastern China was Middle Cretaceous. We are thus lead to the following conclusions regarding the successive phases of the Mesozoic movement which may still be called the Yen-shan movement:

Yen-shan movement

Phase A: Broad folding or warping producing important change of levels, corresponding to unconformity A, at the end of Upper Jurassic or rather the beginning of the Lower Cretaceous.

Intermediary phase: Intense volcanic eruption. Beginning by andesitic lava, locally in Upper Jurassic and widely in Lower Cretaceous, followed by trachytic and rhyolitic lava, probably ending by granitic and dioritic intrusions.

Phase B: Sharp folding and overturning in the orogenic zones, ending by intense overthrusting. Broader and gentler folding outside these zones, corresponding to unconformity B.

14. H. C. Tan: New research on the Mesozoic and Early Tertiary Geology in Shantung Bull. Geol. Surv. No. 5, 1923.
15. A. W. Grabau: Cretaceous fossils from Shantung, id.
16. C. Wiman: Die Kroide-Dinosaurier aus Shantung. Palæontologia Sinica Ser. C. Vol. VI, fasc. 1, 1929.

THE TSIN-LING RANGE.

The Tsin-ling Proper that is the mountain range south of the Weiho valley in Kansu and Shensi provinces, may be distinguished into several parallel zones of different geological significance. All the observations by Loczy[17], Richthofen[18] and Willis[19] agree in establishing the existence of a northern-most zone of Pre-Cambrian metamorphics, intruded by large granite masses generally rising to high altitude. South of it is a strongly folded zone in which the Palaeozoic strata are generally so metamorphosed as to become very difficult to identify with their non-metamorphosed equivalents. The folding is very complex, but in broad line, it is possible to recognize an anticlinorium overturned toward the south and succeeded to the south by a syncline or a synclinorium. The axis of the anticlinorium extends from south of Feng-hsien (鳳縣) more or less continuously to near Wu-kuan (武關). The synclinal axis may be traced with local variation from north of Lio-yang (略陽), through Liu-pa (留壩) to between Ching-tzu-kuan (荊紫關) and Tze-chuan (淅川). A third zone is situated south of a line passing through Han-chung (漢中) and Shih-chuan (石泉) and extends southward to a line passing though Chao-tien (朝天) and Chen-ping (鎮坪). In this zone situated in the Han river valley, the Palaeozoic rocks, though still disturbed and altered, are more easily recognizable. They are often so snarply folded as to become isoclinal, dipping in most cases to the north. Overthrusts are of common occurrence; the displacement of the thrusts are constantly from north to south and often of great magnitude, bringing, the Cambro-Ordovician limestone (perhaps including Pre-Cambrian) in tectonic contact with the Mesozoic sandstone as the case south of Han-yin (漢陰). The thrust zone extends further south to the Szechuan border, with the thrust movement always directed to the south. Recent research in north Hupeh has also found in the Han river valley a series of overturned folds and overthrusts directed in a general way from north to south.

That the orogenic movement in the Tsin-ling range is at least Post-Carboniferous is proved by the disturbance and metamorphism of Carboniferous formation throughout the range from South Shensi to the Honan border. The unconformity, observed by Richthofen and Loczy, between the folded and thrusted Palaeozoic and the Permo-triassic yellow limestone underlying the Kuan-yuan series in North

17. L. von Loczy: Reise des Grafen Bela schechenyi pp. 428-438 Sect. II, Pl. VI, 1.
18. F. von Richthofen China Vol. II, pp. 563-620.
19. B. Willis op. cit. Vol. I, pp. 209-316, 1907.

Szechuan, has so far made geologists to consider the Tsin-ling as a Hercynian range. In the more eastern sections, however, the unconformity lies higher, between the Kuei-chou series and Shih-chuan sandstone according to Willis' observation. Sandstone similar to Willis' Shih-chuan sandstone has been also observed by Richthofen in Han-chung and Loczy at Sang-hsien (商縣) and between Ching-tzu-kuan and Tze-chuan, unconformably overlying folded older strata. Now Willis' Kueichou series has been poved[20] to include Lower Cretaceous in its typical locality in the Yangtze valley. The Shih-chuan sandstone is probably equivalent to Lee's Tunghu sandstone[20], being unconformable with all the folded formations. The exact age of this sandstone is not known for lack of fossil evidence, but by comparison of rock character and stratigraphic relation, Lee was inclined to make it early Tertiary. There is of course no difficulty in considering it as Upper Cretaceous before the discovery of any fossils. Thus interpreted, the main orogenic period in these ranges of central China well falls between Lower and Upper Cretaceous, in complete accord with the conclusion we have reached on the Yen-shan movement in North China. Here again the phase B seems to be the more important.

The Pre-Cambrian crystalline zone is continued eastward by the Funiu range in soutern Honan and Huai-yang range in north Anhui but very little is yet known about the structural conditions south of it. On the northern slope of this old crystalline axis, Lower Jurassic coal series and Lower Cretaceous tuff conglomerate occur in Kuang-shan (光山) and Sang-cheng (商城) is SE Honan[21] and Huo-shan (霍山) in N. Anhui[22]. Both series are strongly disturbed, but the angular discordance between them is here marked as can be seen from fig. 9 reproduced from Tan's paper. In this region therefore, both the phases A and B have been periods of strong folding.

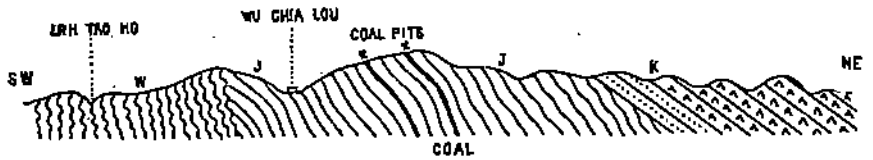


Fig. 9. Section south of Kuang-shan showing the unconformity A (Tan).
W=Wutai metamorphics. J=Jurassic coal series. K=Lower Cretaceous lava conglomerate.

20. J. S. Lee: Geology of the gorge district of the Yangtze valley. Bull. Geol. Soc. China, Vol. III, pp. 379-880, 1924.

21. H. C. Tan: Mesozoic formation in S. E. Honan and their bearing on the date of Tsinling folding. Bull. Geol. Soc. China Vol. IV, p. 252, 1923.

22. C. C. Liu: Geology and mineral resources of N. Anhui and N. Kiangsu Bull. Geol. Surv. China No. 1, 1919.

Further east the old crystalline axis makes a marked turn to the north-east as if it were pushed by a force from the south-east, and all the later formations take the same direction. In the scattered hills half buried by the Huai and Huang river alluvium, overthrusting are often observed with the lateral pressure constantly directed toward the north or north-west, that is always away from the crystalline axis. Thus at Shun keng shan (舜耕山)[23] close to the Huai river, the strata from Cambrian to Carboniferous are all inverted in superposition (fig. 10) along a E-W

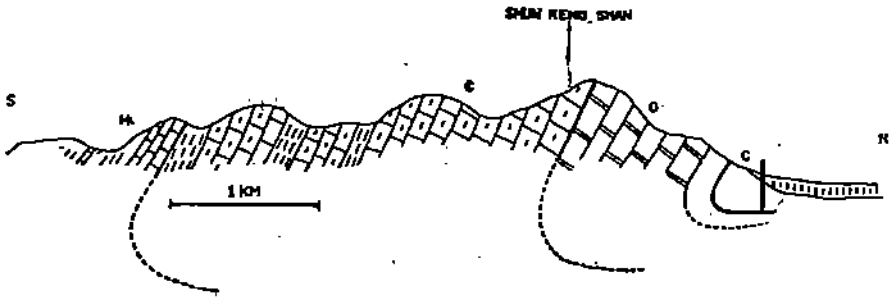


Fig. 10. Section at Shun-keng-shan (Liu C. C. Wang).
He=Sinian limestone. C=Cambrian limestone. O=Ordovician limeste
C=Carboniferous coal series.

distance of over 10 kilometers. In the Lieh-shan (烈山) coal field;[24] the Ordovician limestone is overthrown upon the Carboniferous coal series (fig. 11). With the data obtained by the under-ground mining work and the borings through the limestone, it has been possible for me to determine the dip angle of the Lieh-shan thrust plane to be 21° toward SE. This overthrust has been recognized along a distance of five kilometers and probably extends much further.

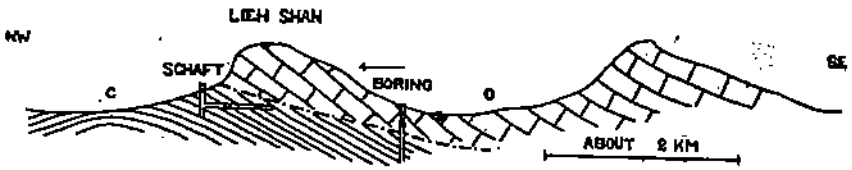


Fig. 11. Section at Lieh-shan (Liu, Wong).
O=Ordovician limestone. C=Carboniferous coal series.

A litter further north east from Lieh-shan, in the bordering region of Kiang-su province, is the Pai-tu-chai (白土寨) coal field[24] where the outcrops of the coal

23. C. C. Wang: Geology of the S. W. part of Huai-yuan district, N. Anhui Bull. Geol. Surv. China, No. 6, 1924.
24. C. C. Liu op. cit.

series are repeated twice (fig. 12) by two successive thrusts from SEE to NWW. The upper thrust has a minimum extension of sixteen kilometers.

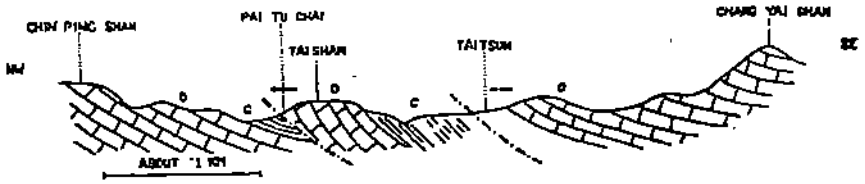


Fig. 12. Section at Pai-tu-chai (Liu).
O=Ordovician limestone. C=Carboniferous coal series.

It is not possible directly to determine the exact age of the overturnings and thrustings above described owing to the absence of strata later than the Carboniferous. There can be however little doubt that these structures are produced by either or both of the two phases—End of Jurassic or Middle Cretaceous—of the Yen-shan movement.

Owing to the much worn down and half buried conditions, the detailed geology in the Huai valley is not well known except in a few coal fields. But all the scattered observations seem to agree in proving the existence of a much sheared zone with the pressure always come from the south or south-east.

SUMMARY AND CONCLUSION.

The Yen-shan movement in eastern North China includes two phases, A and B, which may be boradly correlated with the Jurassice and Laramide revolutions respectively of western North America. These two orogenic periods are here separated by a intermediary period represented by tuff-conglomerate. The latter, although of great thickness does not probably represent a very long time interval, as it is mainly constituted by products of active erosion and rapid volcanic outpouring.

These conclusions seems to be well applicable to the mountain making in Central China, although stratigraphic data are not yet as complete as could be desired.

The phase B of the Yen-shan movement is characterized by intense folding and thrusting. Overthrust is a common feature in the orogenic zones of this period. The direction of the lateral pressure is variable from one region to another. Any definite statement as to the exact distribution of the tangential stress is premature in the present state of our knowledge. But there seems to be often remarkable constancy in the direction of overturning and thrusting in a given orogenic zone.

Thus in the southern chains of the Tsin-ling range, between shensi and Szechuan and in North Hupeh (mostly in the Han valley), the tangential stress is constantly directed to the south while in north Anhui and Kiangsu the strata are always pushed from south or south-east to north or north-west. This, however, does not necessarily justify the formulation of the rule that the thrusts are always directed away from the crystalline axis, for south of it, in the lower Yanytze valley, local overturning to the north has been recently observed. The direction of the tangential stress in the Yin-shan ranges is still less clear. C. C. Wang has given in his paper on the geology of Ta-ching-shan an interesting explanation to the divergence of the tangential stress in North China, but it fails at least to take account of the conditions in eastern Tsin-ling.

The Yen-shan movement has been also active in South China especially on the south-east coast, but discussion has better be postponed pending the extensive field work which is now being carried on.