ON THE MIGRATION OF THE TSINLING GEOSYNCLINE.

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I. INTRODUCTION.

Geosynclines are gradually subsiding, major depressions on the surface of the earth, in which submarine or subaerial sedimentation continues for long geological periods and at a relatively uniform rate. Such a geosyncline is bordered on the one hand by an oldland and on the other by a marginal plain. Geosynclines were characteristic of certain parts of the continents throughout geological times, but the great majority of these have been transformed into mountain ranges while the bordering oldland has subsided to form a new geosyncline. This transformation is designated by Prof. A. W. Grabau[1] "migration of geosynclines." This implies that the oldland collapses and sinks below the sea-level at the time when the sediments in the geosyncline are folded into mountain ranges, and that the newly sunken area becomes the centre of deposition, that is, the new geosyncline, while the new mountains constitute the oldland of the latter. This interpretation seems to furnish a key to many difficult problems of palæogeography as well as stratigraphy, though in some cases a modification will be required. In the following pages the writer ventures to explain the clearly shifting rather than migratory behavior of the Tsinling geosyncline[2], a type of movement already pointed out by Grabau for the Siwalik geosyncline in northern India.

It should be noted that Prof. Grabau emphasizes the idea that it is the oldland that becomes the new geosyncline, or to quote his own words, "the geosyncline migrates into the oldland." A number of examples have been cited

1. Grabau, Migration of Geosynclines, Bull. Geol. Soc. of China, Vol. III, 1924.
2. This term is proposed for the east-west submarine trough occurring in the region of the present Tsinlingshan in Palæozoic times.

by him. The modification of the Tsinling geosyncline, however, is not in accordance with this rule. Instead of migrating into the oldland it shifts toward the marginal plain. If we consider the migration toward the oldland as backward, that toward the marginal plain will be forward. And it is the forward migration or better, shifting, that characterizes the Tsinling geosyncline.

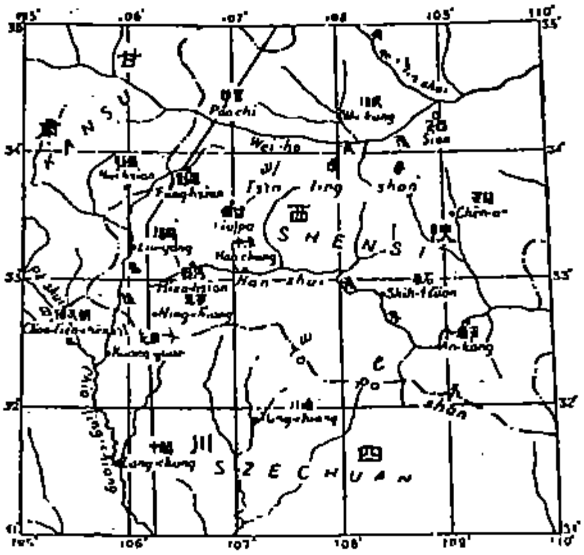


Fig. 1.—Map of the Tsinlingshan, scale 1/6,000,000. The heavy lines mark the approximate position of the section showing in Fig. 2.

II. SUMMARY OF THE STRATIGAPHY OF THE TSINLINGSHAN.

As the result of the geological investigations by the late Mr. Y. T. Chao and the writer[1] in the Tsinlingshan in 1929, a stratigraphical succession for that region was established, and this is briefly given below.

ARCHÆAN AND WUTAIAN;—Granite, granite gneiss, mica schist, and chlorite schist form a continuous belt in the northern slope of the Tsinlingshan just south of the Weiho valley (see Fig. 2). These metamorphic rocks are partly like the Wutai System of Shansi and partly like the Taishan Complex of Shantung, yet they form an unbroken series. To distinguish them from

1. Chao and Huang, Geology of the Tsinlingshan and Szechuan, Mem. Geol. Surv. China, No. 9 (in press).

Fig. 2.—Section through the Tsinlingshan showing geological formations and general structure, vertical scale greatly exaggerated. WT—Tsinling System (early Pre-Cambrian) EP—Sinian and Cambro-Ordovician undifferentiated, ЄO—Cambro-Ordovician, S—Silurian, D—Devonian, DC—Devono-Carboniferous (Kôtaszu Slate), C—Carboniferous Lioyang Limestone, Cm—Metamorphosed Carboniferous and possibly Permian strata of the Pêshui Series, Pn—Permian (and possibly including Carboniferous) coal-bearing strata of the northern facies, P—Wushan Limestone, T—Triassic, TJ—Tishuip'u Series of Triassic-Jurassic age, J—Jurassic coal-bearing formation, K—Cretaceous red beds, L—early Quaternary, mostly eolian loess, gr—Intrusive granite.

other Pre-Cambrian terrains we apply to them the name Tsinling System. Everywhere on the northern slope of the Tsinlingshan one finds them in abundance but nowhere do they occur on the southern slope of that range which is the domain of Palæozoic strata.

SINIAN AND CAMBRO-ORDOVICIAN:—Sinian and Cambro-Ordovician limestones are widely distributed north of the Weiho valley. In the Tsinlingshan there is a thick sequence of slates and quartzites older than the Silurian and younger than the Wutai. Thus it may partly belong to the Sinian and partly to Cambro-Ordovician. This is the Heishui Series of Willis.[1] In the Tapashan region on the borders of Shensi and Szechuan the Cambro-Ordovician is predominantly limestones, the Ichang Limestone of J. S. Lee[2].

SILURIAN:—The Silurian is well developed in the Tsinlingshan proper. It is chiefly a limestone formation of more than ·800 meters in thickness. We have named it the Shihwengtzu Limestone. It furnishes a rich marine fauna of compound corals mostly *Favosites* and *Halysites*. In the Tapashan and in Szechuan the Silurian is represented by 500-600 m of the Sintan Shale.

DEVONIAN:—In the Tsinlingshan proper the Devonian is equally well represented. It is termed by us the Kutaoling Limestone, about 600 meters in thickness. In the Tapashan region Devonian is wanting though it is known in northern Szechuan. In the latter region a distinct unconformity

1. Bailey Willis, Research in China, Vol. I.
2. Lee, Geology of the Yangtze Gorge, Bull. Geol. Soc. China, Vol. III, 1924.

separates the Devonian from the Sintan Shale, but elsewhere only a disconformity is observed.

CARBONIFEROUS:—The Carboniferous is typically developed in the Tsinlingshan. The lower formation is a thick limestone, the Lioyang Limestone, carrying a Lower Carboniferous fauna of corals and brachiopods. The upper formation is shaly and contains occasional coal seams. We have named it the Chenan Series. The total thickness of the Carboniferous cannot be less than 3000 meters. It is separated from the Devonian by a transitional series of slaty shale about 3000 meters in thickness. In the Tapashan the Carboniferous is wanting.

PERMIAN:—Definite marine Permian strata are not known from the Tsinlingshan north of the Hanshui. They may be altogether absent in this region or they may be represented by the upper part of the Chenan Series. The Permian is however typically developed in the Tapashan and in Szechuan where limestone predominates. This is the Wushan Limestone which carries *Tetrapora* and *Tachylasma* in the lower and *Gastrioceras* in the upper part. The limestone usually disconformably overlies the Silurian, or in some cases the Ordovician. The total thickness is about 800 meters.

TRIASSIC:—The Triassic of the Tapashan and of Szechuan allows of a two-fold division. The lower part is a purple calcareous shale, the Feisienkuan Shale, and the upper part is a thick limestone, the Chialing Limestone. Both are marine and overlie the Permian conformably. Their total thickness is 1100 m. In the Tsinlingshan the Triassic seems entirely wanting though the Tishuipu Series[1] of green sandstones and shales of the southern Tsinling may in part belong to the Triassic.

JURASSIC:—Jurassic coal-bearing sandstones of about 500 meters thickness occur in the Tapashan and in Szechuan. They are not known in the Tsinlingshan excepting what we have termed the Mienhsien Series near Mienhsien. They are entirely non-marine and are equivalent to the Hsiangchi Series of the Yangtze Gorges.

CRETACEOUS:—Cretaceous red sandstones and red clay shales occur extensively south of the Tapashan region. They are not seen north of it with the

1. This name is given to an early Mesozoic formation of metamorphic sandstone and slate occurring at Tishuip'u north of Ningch'ianghsian.

exception of one or two isolated occurrences. Pelecypods mostly *Unio* and *Cyrena* of the Wealden type are found in the lower part of the sandstones. The entire thickness of the systems is 1500 meters.

EOCENE:—Eocene is also characterized by red beds chiefly red clay, sandstone and conglomerate. These are only gently tilted and lie unconformably on the older formations. They occur sporadically in the Red Basin and in the Tsinlingshan as well.

III. OROGENIC MOVEMENTS.

CALEDONIAN MOVEMENT:—In the Tsinlingshan the Devonian Kutaoling Limestone begins with a basal conglomerate consisting of granite and gneiss pebbles. This probably represents a profound disconformity between the Devonian and the Silurian. In northern Szechuan quartzites and limestones carrying Middle Devonian fossils lie unconformably on the Sintan Shale. The unconformity has been clearly observed near Ch'aot'ienchên, Kuangyüanhsien. It seems probable that northern Szechuan has been visited by the Caledonian disturbance though it was not so profound as to affect the Tapashan and the Tsinlingshan regions.

HERCYNIAN MOVEMENT:—Up to the present geologists generally believe that the Tsinlingshan came into existence as the result of a post-Carboniferous but pre-Triassic movement. The supposed evidence is furnished by the geological section along the Chialing river near Kuangyüanhsien given by Richthofen.[1] There the Triassic limestone, according to this eminent explorer, lies unconformably upon Silurian strata. The same section has been carefully studied by Y. T. Chao and the writer. It has been found that the shaly strata (the Feisienkuan Series), which Richthofen considered as Silurian, contain pelecypods of Triassic age and are perfectly conformable with the overlying Triassic limestone (the Chialing Limestone). The existence of this pre-Mesozoic unconformity being disproved the occurrence of Hercynian disturbance in the Tsinling region is questionable. Indeed nowhere did we find in the southern Tsinlingshan or in the Tapashan angular discordance between the Carboniferous and Permian or between the Permian and Triassic formations though parallel discordance or disconformity does occur below the Permian.

1. Richthofen, China, Vol. II, p. 602.

There is only one locality in which we obtained evidence for a Hercynian disturbance. At Ts'aoliangi near Funghsien a coal-bearing formation of conglomerate and sandstone with plant remains overlies the chlorite schist of the Tsinling System and the quartzite of the Heishui Series with a profound unconformity (see Fig. 3). The fossils include a species of *Neuropteris* probably of Permian age. Moreover, the lithological characters of the formation are quite similar to those of the Permian Shansi Series of northern China. On these grounds we think that the coal-bearing strata at Ts'aoliangi is of Permian rather than Carboniferous age. Since it is unlikely that orogenic disturbance occurred in northern Tsinlingshan in post-Sinian (Heishui Series) and pre-Carboniferous times, the unconformity below the Permian Tsaoliangi Series will be best considered as late Carboniferous.

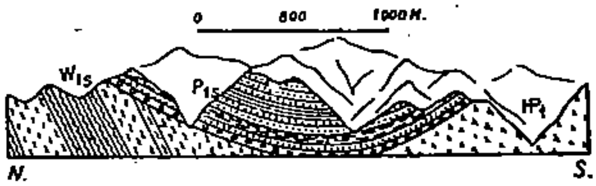


Fig. 3.—Section near Ts'aoliangi, Funghsien, showing the unconformity between the Permian coal-bearing beds (P_{ts}) and the underlying Pre-Cambrian schists (W_{ts}) and massive Sinian quartzite (HP_t).

We cannot take this unconformity as of local importance only. Evidently the northern Tsinlingshan was visited by an orogenic disturbance in pre-Permian time resulting in the folding of the Sinian as well as other early Palæozoic strata into mountain ranges. During Permian time these mountains were actively denuded and between them were formed intermontane basins in which the sediments of the Tsaoliangi Series were deposited.

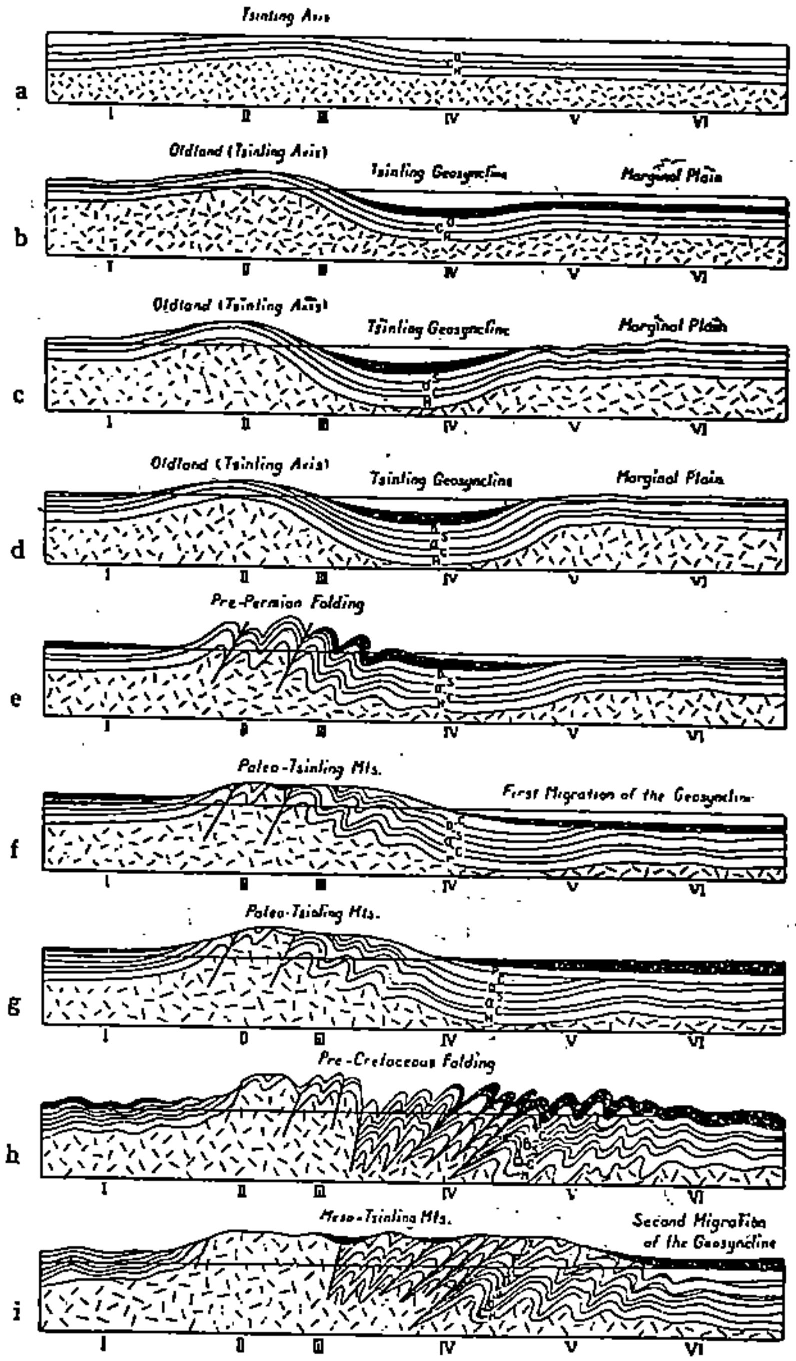
YENSHANIAN MOVEMENT.—That the southern Tsinlingshan and the Tapashan owe their existence to a late Mesozoic orogenic disturbance, the Yenshanian disturbance of Dr. Wong cannot be doubted.[1] Willis and Blackwelder have already pointed out that the intense metamorphism and folding of the strata in the Han Province were the result of a Mesozoic orogenic disturbance. Our investigations in the Tsinlingshan entirely confirm the view of these eminent geologists. North of Mienhsien in the southern Tsinlingshan the

1. W. H. Wong, Crustal Movements and Igneous Activities in Eastern China since Mesozoic Time. Bull. Geol. Soc. China, Vol. VI, No. I, 1927.

Fig. 4.—Section along the Peshui river above Chaohuahsien, N. Szechuan, showing the unconformity below the Cretaceous conglomerate. S_{st} — Sintan Series, D_1 — Devonian limestone with index fossils, P_y — Yanghsin Limestone, P_t —Tayeh Limestone, T_f —Triassic purple shale, T_o — Triassic limestone, J_h — Jurassic coal-bearing formation, K_t — Lower Cretaceous conglomerate and sandstone, K_k — Cretaceous red beds.

Mienhsien Series consisting of sandstones and conglomerates with early Jurassic plants is frequently metamorphosed into schist and quartzite. The strata are also strongly folded, often standing vertical. They lie upon the Peshui Series of Carboniferous and Permian age in apparent conformity. Thus it is certain that the folding of these strata occurred after early Jurassic time. Moreover, in the southern Tsinlingshan the Tishuipu Series of early Mesozoic age (equivalent to the Kueichou schists of Willis) is strongly folded together with the Carboniferous formations and metamorphosed to the same extent. In the Tapashan the Jurassic is everywhere in parallel relation with the Triassic which in turn lies conformably upon the Permian. These are all strongly disturbed and thrust one upon the other. We conclude therefore that the main period of orogenic movement both in the Tsinlingshan and in the Tapashan is post-Jurassic or at least post-early Jurassic.

It is to be noted that there are probably two periods of late Mesozoic disturbance. Near Shihkuantzu in Chaohuahsien, N. Szechuan, Cretaceous conglomerate lies unconformably on Triassic beds (see Fig. 4). Thus the unconformity must be pre-Cretaceous. In other places notably in central Szechuan however the Cretaceous is in parallel relation with the Jurassic. Y. T. Chao observed at T'anmupa just south of the Han river, that Cretaceous red beds lie conformably on the Jurassic coal-bearing strata. In these places the Cretaceous is folded with the Jurassic and the Triassic. Thus the period of folding cannot be earlier than early Cretaceous; yet it cannot be later than late Cretaceous because in many localities a red sandstone formation of suspected Eocene age (the Tunghu Sandstone) is only slightly tilted and lies unconformably on older



a
b
c
d
e
f
g
h
i
Tsinling Axis
Oldland (Tsinling Axis)
Tsinling Geosyncline
Marginal Plain
Pre-Permian Folding
Paleo-Tsinling Mts.
First Migration of the Geosyncline
Pre-Cretaceous Folding
Meso-Tsinling Mts.
Second Migration of the Geosyncline
I
II
III
IV
V
VI

Fig. 5.—Diagrams showing the development and migration of the Tsinling Geosyncline in geological times. In all the figures the upper straight line represents the level of the sea. Black indicates sediments formed in the geosyncline and its adjoining regions. Short rods represent ancient crystallines. The letters H, Є, O, S, D, C, P, T, tell the respective geological age of the strata.

The Roman letters are explained as follow:

I—Northern Shensi
II—Weiho River
III—Crestline of the Tsinlingshan
IV—Hanshui River
V—Tapashan
VI—Szechuan Red Basin.

a) The Tsinling region in Sinian, Cambrian, and Ordovician times. Note the gradually bulging up of the Tsinling Axis in late Ordovician.

b) The Tsinling geosyncline in Silurian time. Note the formation of the oldland in the north and of the marginal plain in the south.

c) The Tsinling geosyncline in Devonian time. Note the emergence of the marginal plain.

d) The Tsinling geosyncline in Carboniferous time.

e) The Tsinling geosyncline is affected by Hercynian disturbance. In this figure and in the following figures the shortening of strata by folding is not taken into account.

f) The Tsinling geosyncline in Permian time. The important events are the formation of the Palæo-Tsinling mountains and the southward migration or shifting of the geosyncline.

g) The Tsinling geosyncline in Triassic and Jurassic times. Note the emergence of the geosyncline.

h) The geosyncline is affected by the Yenshanian disturbance. All the strata except those in the southernmost part are folded and thrust faulting toward the south is a general feature.

i) The formation of the Meso-Tsinling mountains and the forward migration of the geosyncline into the Red Basin of Szechuan.

formations. Until further evidence is forthcoming we may reasonably conclude that the Yenshanian disturbance has two phases;[1] the first phase occurred in late Jurassic and the second in late Cretaceous. The first appears to be the most important in the Tsinlingshan and Tapashan.

IV. MIGRATION OF THE TSINLING GEOSYNCLINE.

Having briefly summarized the stratigraphical sequence and the orogenic periods of the Tsinlingshan we proceed to discuss the palæogeographical development of the Tsinling Geosyncline. It must be remembered that the Tsinlingshan, in its broadest sense, comprises all the mountainous regions of southern Kansu, southern Shensi, south-western Honan, and northern Hupeh. The writer, having personal knowledge only about the geology of southern Shensi, must restrict his theoretical deductions mainly on that part of the mountain system.

(1). *The Tsinling region in early Palæozoic time* (*see Fig. 6a*) :— In Sinian time sedimentation was active in the provinces both north and south of the Tsinling with the result that a thick series of mostly calcareous but frequently argillaceous strata was formed in these regions. These constitute the Nankou Limestone near Peking, the Huto Series in Shansi, and the Tõngying Limestone of the Yangtze valley.[2] If the Heishui Series of the Tsinling region really belongs to Sinian we cannot avoid the conclusion that this region was submerged under a widespread transgressing Sinian water body (be it marine or fresh water) which covered the entire area from the south-western provinces of China to Manchuria. In Cambrian time the sea probably covered large parts of China Proper including the Tsinling region. This was at least true for lower Cambrian time since we know that the peculiar *Redlichia* fauna of the Indo-Pacific Province occurs in Manchuria, in the northern provinces, in the Yangtze valley, in Kueichow and in Yunnan. Concerning the faunas of the middle and upper Cambrian periods our knowledge is quite meagre but owing to the fact that the Ichang Limestone of the Yangtze valley concordantly[3] succeeds the *Redlichia* shale it may be possible that the formation is partly of Cambrian age, being the equivalent of the Changhia Limestone, Kushan shale,

1 W. H. Wong, The Mesozoic orogenic movement in China, Bull. Geol. Soc. China, Vol. VIII, No. 1, p. 39, 1929.

2 Lee, op. cit.

3 There may be a disconformity. Prof. Grabau holds that the *Archaeocyathus* beds are lower Ordovician.

Chaomitien Limestone, and Tsinan Limestone of Shantung as defined by Willis and Blackwelder.[1] In early Ordovician time the same conditions seemed to have prevailed but toward late Ordovician the Tsinling region gradually emerged, cutting off marine communications between the north and the south. The fact that the faunas of the Neichia shale (which consists of graptolites, species of *Orthis*, the characteristic *Yangtzeella poloi* (Martelli), and other brachiopods) and of the Orthoceras Limestone of the Yangtze valley are markedly different from those of the Actinoceras Limestone of northern China can best be accounted for by the supposition that an east-west trending land barrier, the Tsinling Axis as it might be called, came into existence.

(2). *The first appearance of the Tsinling Geosyncline in Silurian time (see Fig. 6b)*:—Silurian strata, though well developed in all the provinces south of the Tsinling, are entirely wanting in the northern provinces, where Carboniferous rocks lie directly upon Ordovician limestone. This simply means that while marine deposition was going on in the south the northern Chinese basin was entirely emerged and became a land of erosion. It is to be noted that the marine sediments in the south, which constitute the Sintan Series of Willis, are chiefly green shales frequently intercalating with sandy beds, calcareous rocks being of rare occurrence; that is to say, that the Sintan Series was deposited in a comparatively shallow sea. In the Tsinling region on the other hand the Silurian Shihwengtzu Limestone consists almost exclusively of pure limestone with a thickness of 800 meters. It appears evident therefore that at the opening of Silurian time the Tsinling region was occupied by a sea of moderate depth while shallower water conditions prevailed to its south. This deeper sea formed the centre of the Tsinling Geosyncline whose marginal plain is supposed to have extended over the southern provinces. The great land-mass subject to erosion, which covered the northern provinces, is naturally to be taken as the oldland of the geosyncline. Thus the three essential features of a geosyncline, the oldland, the marginal plain, and the geosynclinal depression were foreshadowed at the beginning of the Silurian.

(3) *The Tsinling Geosyncline in Devonian time (see Fig. 5c)*:—As stated in a preceding paragraph marine Devonian strata are entirely wanting in the Tapashan region and in the Yangtze valley where the Permian Wushan

1 Willis, Research in China, Vol. I.

Limestone lies directly upon the Sintan Series. Thus we must postulate that the submerged marginal plain of the Tsinling Geosyncline was emerged and became a land of erosion in Devonian time. In the Tsinling proper, in the region north of the Han river and south of the present crestline of the Tsinlingshan, deeper sea conditions prevailed and it was in this sea that the Kutaoling Limestone was deposited. In the north the oldland persisted and continually supplied sediments for the geosyncline. It appears therefore that the Devonian Tsinling Geosyncline was much like its Silurian predecessor both in character and extent except that its marginal plain was brought above sea-level.

It is to be noticed that the Tsinling Geosyncline was not occupied by the sea without interruption from the beginning of Silurian to the end of Devonian time, but that the sea retreated in the late Silurian and returned only in the middle Devonian. As has already been stated the base of the Kutaoling Limestone is marked by a basal conglomerate of gneiss and granite pebbles. Insignificant as it appears to be, this conglomerate tells the long geological history that in late Silurian time the geosyncline was raised above the sea-level, that the pre-Palæozoic metamorphics north of the Tsinling suffered from active denudation resulting in the formation of shingles and gravel beds, and that the geosyncline was again submerged and became a region of marine deposition. In northern Szechuan which was a part of the marginal plain, not only was the submerged area uplifted in late Silurian time but it had suffered also from intense folding in consequence of Caledonian disturbance. Had this disturbance been so profound and prolonged that it caused the strata to fold into prominent mountain ranges one would naturally consider that the marginal plain was transformed into an oldland. As the folding is only local it is suggested that the Silurian marginal plain remained as such in the Devonian.

(4). *The Tsinling Geosyncline in Carboniferous time* (*see Fig. 5d*):—in Carboniferous time the geosyncline assumed the essential features of its Devonian predecessor. This is supported by stratigraphical evidence. As is true with the Devonian, Carboniferous is, as far as we know, wanting in the Tapashan and in the upper Yangtze valley. The Wushan Limestone formerly considered as Upper Carboniferous is now taken as Permian. It then becomes evident that these regions were above sea-level in the Carboniferous time. In the region north of the Han river and south of the crestline of the Tsinlingshan however marine deposition was actively going on resulting in the formation of the Lioyang Limestone in early Carboniferous and of the Chenan Series in later Carboniferous time. At first the sea water was deep enough so that calcareous sediments predominated but later on it gradually became shallower and terrigenous sediments replaced them. On a few occasions the bottom of the geosyncline appeared to have been laid bare, for otherwise the coal seams in the Chenan Series could not have been formed.

North of the geosyncline the oldland of Archæan complex still persisted as a high land of erosion and supplied most of the clastic sediments for the geosyncline. It is of course to be taken for granted that the theory of isostacy holds good in this case: The geosyncline gradually subsided under a burden of continually accumulating sediments while at the same time the oldland was uplifted.

North of the oldland continental as well as marine sediments were forming in the regions of Shansi, Shensi and Kansu, as is testified to by the occurrence of Carboniferous strata in these provinces. But these were deposited probably in a separate embayment which was not in communication with the Tsinling Geosyncline except in the far west where they might have joined.

(5) *The folding of the strata in the Tsinling Geosyncline and its first migration* (*see Fig. 5e*):—Toward the end of Carboniferous the strata in the northern part of the Tsinling Geosyncline as well as those in the oldland were folded into a series of anticlines and synclines in consequence of Hercynian disturbance. The result is that a folded mountain range, or a system of ranges striking essentially E-W came into existence in the regions of the present northern Tsinlingshan and the Weiho valley. We shall call these the Palæo-Tsinling Mountains. In the southern Tsinlingshan and in regions further south the orogenic force appeared to die out so that the strata in those regions were not folded though they might have been tilted. At the opening of Permian time the marginal plain, which remained a land of erosion in Devonian and Carboniferous times, was then submerged and became the centre of marine deposition (see Fig. 5f). This Permian sea, which unquestionally came from the south, transgressed as far as the Han river, since in the Liangshan near Hanchung Permian limestone with typical Chihsia faunas was discovered. Since no fossiliferous Permian beds occur north of the Han we are forced to conclude that the sea did not extend northward from the Han valley. It is possible however

that the upper part of the Peshui Series (metamorphic schists of late Palæozoic) belongs to the Permian. At any rate we may reasonably suggest that the central and northern Tsinlingshan were not visited by the Permian sea, even if it did gain a foothold in the southern part of that mountain system. This was of course a natural sequence of events: Hercynian movement gave rise to the Palæo-Tsinling Mountains which prevented the Permian sea from invading the north.

The most interesting point worthy of note is the shifting of the centre of marine deposition. As mentioned above deeper sea conditions prevailed in the region north of the Han river and south of the crestline of the Tsinling in Silurian, Devonian, and Carboniferous times. This is the proper position of the Tsinling Geosyncline in which were accumulated no less than 10,000 meters of sediments, mostly limestones. As the result of Hercynian disturbance however the greater part of the Tsinling Geosyncline became land while the smaller part of it was only submerged below a shallow sea. The deepest part of the Permian sea then was not in the north of the Han river but in the Tapashan region far south of it. It is clear therefore that the geosyncline in Permian time shifted from the Tsinling region southward to the Tapashan region. The oldland of this shifted geosyncline was naturally the Palæo-Tsinling Mountains amongst which continental sediments were forming in intermontane depressions. It will be noticed that there was no proper emerged marginal plain for this geosyncline. The Permian formations in Szechuan, in Kueichou and in other southern provinces are generally of the character of moderately deep sea sediments, similar to the Permian of the Tapashan.

(6) *The Tsinling Geosyncline in Triassic and Jurassic times* (*see Fig. 5g*):—The palæogeographical features in Triassic time were essentially the same as those in the Permian. Marine conditions prevailed in the region south of the Han river while the process of erosion was active in the oldland north of it. Toward the end of the Triassic, the sea gradually retreated toward the southwest so that the geosyncline appeared above sea-level during the Jurassic. But the process of deposition still went on in it resulting in the formation of the coal-bearing Hsiangchi Series. The total thickness of the sediments in the migrated Tsinling Geosyncline from the Permian to the Jurassic is not less than 2,400 meters.

(7) *The folding of the strata and the second migration of the geosyncline* (*see Fig. 5h*):—Toward the end of Jurassic an extensive and intensive orogenic disturbance took place. As the result of this all the sediments in the Tsinling Geosyncline including the Sinian, Cambro-Ordovician, Silurian, Devonian, Carboniferous, and later strata and the sediments in the Tapashan geosyncline (the shifted Tsinling geosyncline) including the Sinian, Cambro-Ordovician, Silurian, Permian, Triassic, and Jurassic were folded into anticlinoria and synclinoria which formed more or less parallel lofty ranges. The folding appeared most intense in that part of the country in which the sediments are thickest, *i. e.*, the region north of the Han river. In this not only were the strata strongly folded and overthrust but also metamorphosed and intruded by granitic batholiths. The region occupied by the Palæo-Tsinling Mountains seemed to have been disturbed for the second time, and the mountains, which in late Jurassic were nearly planed down, were rejuvenated. Thus it appears that after the Yenshanian movement the entire region from the Tsinlingshan to the Tapashan became a complex system of folded mountains which might be called the Meso-Tsinling Mountains in contra-distinction from the Palæo-Tsinling Mountains.

In Cretaceous time while the Meso-Tsinling Mountains were the region of active erosion the region lying immediately south of it, *i. e.*, the region of the Red Basin of Szechuan, became the centre of deposition (see Fig. 5i). There were developed consequent streams carrying the rock debris from the mountains into the Red Basin to form the 1500 meters of red beds. This basin which is only slightly smaller than the province of Szechuan may be considered as a typical supermarine geosyncline. Its oldland, the Meso-Tsinling Mountains, lay to the north while its marginal plain, the plateau of Kueichou, was situated in the south.

It will be seen that before the Yenshanian disturbance the shifted Tsinling geosyncline occupied the Tapashan region but after the movement the old geosyncline became uplifted and a new one came into existence on its south. In other words the geosyncline migrated for the Tapashan region southward to the Red Basin of Szechuan.

(8) *Post-Cretaceous palæogeography*:—Toward the end of the Cretaceous, continuous denudation seemed to have planed down the Meso-Tsinling Moun-

tains and at the same time sedimentation in the newly formed geosyncline (the Red Basin of Szechuan) practically ceased. Then another period of orogenic disturbance took place with the result that the Cretaceous sediments in the geosyncline were moderately folded while the Meso-Tsinling Mountains appeared to be rejuvenated. The folding, however, was not profound and might well be considered as a secondary manifestation of the main Yenshanian movement. The region south of the Red Basin, *i. e.*, the marginal plain of Kueichou was strongly disturbed, and lofty ranges were formed by Palæozoic as well as Triassic limestone.

In Eocene time river plains appeared in the region of the Red Basin and on them there accumulated red beds of considerable thickness. These however were generally isolated from one another and occurred on a small scale. They did not constitute a geosyncline as the Cretaceous basin did.

V. The Importance of the Forward Migration or "Shifting" of Geosynclines.

From the foregoing paragraphs we summarize that the Tsinling Geosyncline distinctly migrated twice in past geological periods; its first migration occurred in late Carboniferous while its second migration was in late Jurassic time. In both cases the migration is forward, *i. e.*, toward the marginal plain. Such a forward migration, it appears, is not a peculiar feature of the Tsinling Geosyncline but is characteristic of many other geosynclines. The descendants of the Himalayan geosyncline may be cited in this connection. In late Oligocene time the strata deposited in the Himalayan geosyncline since Cambrian time were folded into a complex system of lofty mountains which sufferred from active denudation. In Pliocene time south of these mountains continental sediments of more than 5,000 m. were forming in a geosynclinal depression called the Siwalik geosyncline by Grabau[1]. In latest Tertiary time these beds were again folded with the result that a series of ranges, the Siwalik Hills, appeared along the southern foot of the mighty Himalayas. South of these hills extends the wide alluvial plain of the Ganges, which in all respects can be considered a typical geosyncline. It is clear then that the Siwalik geosyncline migrated or as Grabau called it "shifted" southward to form the Indo-Gangetic

1. Grabau, op. cit., page 224.

geosyncline. Since the oldland, the Himalayas, is in the north we must consider this southward migration as a forward one.

Another example is furnished by the Tienshan. According to Keidel[1] the Tienshan region had been folded in late Devonian time into mountainous elevations south of which extend the Carboniferous geosyncline in which marine sediments were deposited. Then a second orogenic disturbance set in and the Carboniferous strata were folded along with the Devonian folds. As a result of this the geosyncline was shifted southward and in it were formed upper Carboniferous (possibly Permian) strata which overlapped the older beds unconformably. Thus we find a distinct forward migration in the development of the Tienshan geosyncline. Similar cases might be found, the writer believes, if the history of the geosynclines in past geological times were critically studied.

Concluding we may state that the migration of geosynclines may be accomplished in two different ways. In the one way the geosyncline migrates into the oldland while in the other it migrates toward the marginal plain. The former is considered as backward migration. The migration of the Appalachian geosyncline in North America and that of the Irkutzk Basin in Asia belong to this type. The latter is taken as forward migration and is exemplified by the migration of the Tsinling Geosyncline. This forward migration has been called a "Shifting" of the geosyncline by Prof. Grabau.

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1 Keidel, Geologische Untersuchungen in Süd-Tian-Schan, Neues Yahrbuch, 1906, Beilage-Band XXII.