THE SUPERFICIAL DEPOSITS OF YUTAOHO, SHANSI

BY

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Abstract. An account is given of the structural relations of a curious Pleistocene conglomerate and a calcareous tufa in Yutaoho valley the interpretation of which bears on the problem of the Pleistocene history of Shansi. Observations on the locality raise important questions as to tectonic development of the area.

The well-watered valley of the Yutaoho, with its clatter and thump of mill-wheels and its shady glades, has become a favourite summer resort for those who prefer the mountains of Shansi to the sea-coast settlements. The valley lies five miles north of Fenchow and the foot of it can be quickly reached by a side road which leaves the motor highway some two miles on the Taiyuan side of the city.

Dr. E. T. Nyström had noted a curious conglomerate below the point where the rocky mountain gorge opens abruptly onto the wider valley channeled in the soft sediments forming the margin of the plain.

To settle the problem of the origin of this conglomerate and its possible bearing on the history of the region, we paid a brief visit to the locality in January 1931 in company with Miss Meisen of Copenhagen University and Miss McClure of Fenchow. It was largely due to the latter's familiarity with the geography of the place that the short time available—less than two hours, with six miles to be covered—was so well utilized and yielded such satisfactory results.

These results include; (1) certain observations on the structure of the hard-rock formations of the locality, (2) what seems to be the first report both of the conglomerate and of calcareous tufa deposits which throw light on the Pleistocene history of the area, (3) new data on the springs to which the valley owes its prosperity and (4) precise confirmation of the recently established series of stages in the physiographic evolution of Shansi, and corroboration of conclusions put forward tentatively last year regarding the origin of the famous tufa of Niangtzekuan. In addition, (5) certain further problems remaining to be solved have been outlined and possible lines of attack indicated.

(1) The margin of the Taiyuan depression at this point is sharply defined by an upstanding fault-face of limestone forming the mountain front. On the 1/1,000,000 geological map (Taiyuan-Yulin Sheet) the bed-rock of the locality is indicated as Cambro-Ordovician. The map shows a boomerang-shaped strip of Archaean crossing the gorge at Hsiangyang 10 Km. west of Yutaoho village, well within the boundary of the mountain area; but east of this point the entire terrain is coloured as undifferentiated Lower Palæozoic right to the contact with the Tertiary and Quaternary deposits which occupy all the zone between it and the alluvium of the plain. Following the *thalweg* however we found hard-rock inliers below the superficial deposits. These outcrops present a less simple structure than one might have suspected and are shown in Fig. 1.

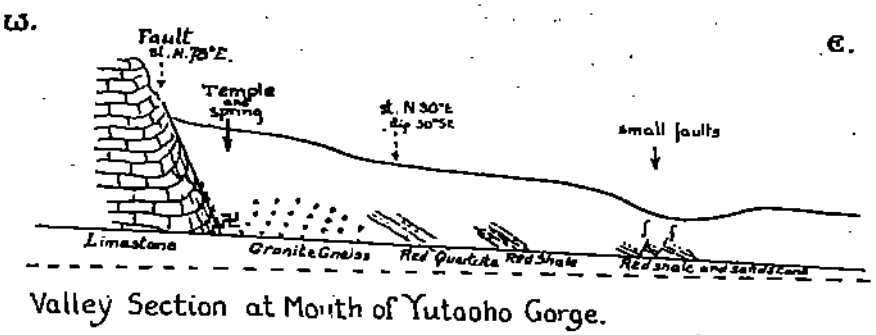

Fig. 1.

Going downstream, the bedding of the limestone north-west of the fault is dragged sharply up in the opposite direction from that which would be made by a normal graben-boundary fault with downthrow to the south-east. This interpretation is confirmed by outcrops of badly weathered granite gneiss abutting the fault, which is therefore seen to have a downthrow to the north-west, i. e. towards the mountains. The limestone hill-face is therefore *not* a *fault scarp*, but a *fault-line scarp due to subsequent differential erosion of the weaker mass on the upthrow side of the fault.*

Overlying the pre-Cambrian is a platey quartzite or quartzose sandstone, dipping away from the fault at an angle of 30° with a strike of N 30° E. A short distance downstream there are exposures of red shale closely resembling the Mant'ou. Several hundred yards further, the bed-rock is a firm sandstone

with shaley partings. The dip in each case is downstream towards the centre of the graben, but several small faults of a foot or two's throw hade to the north-west, and were possibly produced at the same time as the main fault at the gorge-mouth.

The identity of the strata was left unsettled. The sandstone with shale encountered going up the valley was first taken for Triassic, the shale outcrops in the middle were indistinguishable from one facies of the typical Mant'ou, while the red quartzose sandstone might be Hut'o. No fossils were found. In this region the Cambrian frequently lies concordantly on the Sinian which is at times represented only by a very thin band of quartzite. The outcrops are not continuous, but separated by considerable stretches of cover, so that disconformities or faults may be concealed. The general structure however suggests a pre-Ordovician age for all three facies, so that the shales are probably Cambrian and the lowest beds either basal Cambrian or Sinian.

If this reading of the structural relationships is correct, the fault is not connected with Wang's Yangchu pivotal fault but belongs to an older period than the rifting which produced the graben. For it means that the fault is old enough for erosion to have reversed the topographic relation, making the present surface of the downthrow block stand higher than that of the upthrow. The simplest way in which this reversal could have been achieved is in the

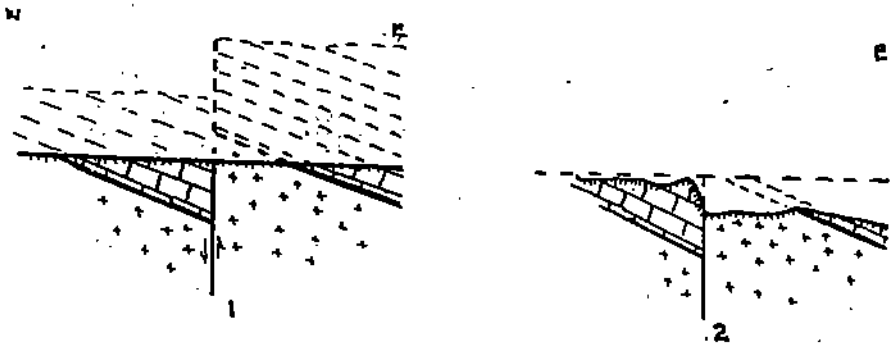

Fig. 2. Diagram illustrating reversal of escarpment due to erosion in two stages subsequent to faulting.

manner suggested in Fig. 2. (1) The stripping off from the up-throw side of the limestone block which capped it at the time of faulting was followed by (2) vigorous erosion which, under the conditions of weathering and erosion

prevalent in Tertiary times, attacked and reduced the granite faster than the limestone.

On this understanding, the fault ante-dates the Tanghsien erosion cycle and is at least as old as Middle Tertiary. In the Explanation to the Taiyuan-Yulin Map*, Wang refers to *folding* as the characteristic process at that epoch (Oligocene), but the Yutaoho section suggests that *faulting* also occurred, though in this instance it may be just the snapped limb of an anticline rather than a fault due to regional tensile tresses. The locality calls for careful study with these points in mind.

(2) The whole zone along the mountain front is veneered with loess, beneath which lies the red loamy deposit that Teilhard and Young have termed "reddish clay"** to distinguish it from the older "red clay" of early Pliocene age. But in the Yutaoho valley this simple relationship is complicated by the presence, at various levels above the valley bottom, both of tufa and of the coarse conglomerate which was our first objective. The left half of Fig. 3

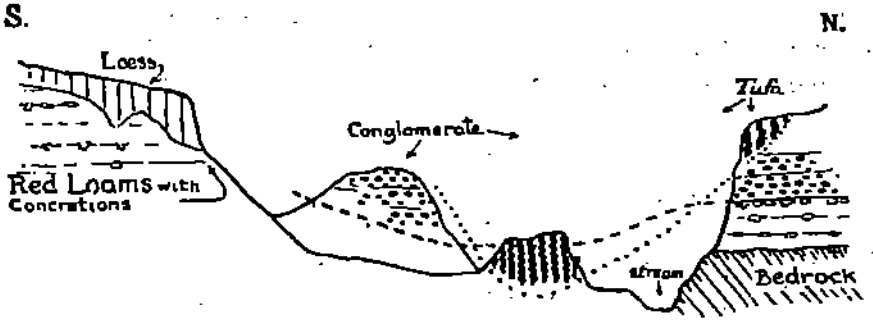

Fig. 3. Structure section across Yutaoho Valley

shows the kind of confusing situation encountered, rather suggesting that the tufa is the oldest formation, in contact with bed-rock and overlaid in turn by the conglomerate, the red loams and the loess. On the opposite (north) side of the valley, however, the relationships seem reversed, the conglomerate lying concordantly on the loams. The clue to the real structure was found in one

*Geological Map of China, G. S. C. 1926 Sheet NJ—10.

**Mem. Geol. Surv. China, A8, 1930.

small exposure where, in an area ten feet high, all the essential contact-relations are preserved.

These have been embodied in the structure section (Fig. 3) as if exposed more obviously than is actually the case. The tufa lies on the eroded surface of the conglomerate and its position in the valley bottom merely means that the stream at that time had cut to bed-rock—as it has again today. The pre-tufa topography is suggested by a dotted line. Similarly, the conglomerate occupies erosion depressions in the red-beds. Evidently it not only filled up the bottom of the old stream channel but spread out over the lateral slopes. It will be noted also that the red loams carry concretions roughly arranged in layers with the bedding of the deposit. But in places, immediately below the conglomerate contact there is an accumulation of these concretions showing clearly that they have been reworked and concentrated by running water. The stream whose cross-section is shown as a broken line first channeled the loams and then, becoming overloaded with gravel and boulders from upstream, buried them under this torrential material.

It is important to note that the loess occupies the same position relative to the red loams at slightly higher levels as do the conglomerates in the bottoms of the old depression. On lithological grounds it seems safe to assign the red loams to the Upper Sanmenian epoch, when the climate favoured the widespread development of such surface deposits in Shansi. Except in places where the complications of tectonic movement are added, the next stage throughout the province is the Chingshui erosion epoch, and this is followed in turn by the Malan stage of loess accumulation under somewhat colder and more arid conditions. Under these influences, the streams gradually failed, a fact attested by the frequent presence of gravel or sand beds at the base of the formation. It seems that the gravels at Yutaoho either occupy this position or are a somewhat older independent unit, due to tectonic readjustment at the close of the Sanmenian or early in the Chingshui.

The tufa lies on a dissected surface of conglomerate. Its distribution is clearly related to the springs. But it seems unlikely that the water issued with enough force to cut a deep chasm in the conglomerate floor, although, once above the ground level, the same water could acquire considerable erosive energy with the gradient. Hence, as the tufa itself is not just a

calcareous hardpan made by cementing and grouting the gravel, but a relatively unadulterated chemical precipitate with only a few pockets of sand deposited in a channel, it is necessary to infer an interval of erosion between the time of gravel deposition and that of tufa formation.

The tufa might belong either to the Panchiao rejuvenation or to an earlier stage. The absence of gravel from the body of the tufa negates the Panchiac, while the structure calls for a date later than the erosion which trenching the Sanmenian loams. Hence I regard the tufa as formed during the days of the loess when evaporation of lime-charged spring-water took place quickly in the dry air and when the run off was insignificant. This Malan age is identical with that inferred for the Niangtzekuan tufa.*

(3) The location of the springs shows the close relation to a line of tectonic weakness that is so frequent in Shansi. The famous Chintzu springs rise beside the Chiaocheng fault — the same is true of the Shentou spring and the Taiku fault, while a similar origin is commonly put forward for the springs at Niangtzekuan and Chinghsing.

At Yutaoho two points of interest are to be noted. The temple precincts at the gorge mouth were built to enclose the spring. But during the last few years the bulk of the supply that used to rise there has transferred itself to a new spring that developed on the other side of the river bed. Within a short period the temple will have to get all its water by bucket from the unprotected rival institution which nature has started on the opposite side.

It is also commonly said that the spring supply as a whole is failing. No certain evidence of this was found. The work of summer freshets effectively masks any change in the perennial erosive power of the flow from the springs. It seems quite likely that some diminution in flow results from an increasing proportion of the water finding its way through channels developed in the stream-bed gravels, thus joining the surface run-off indirectly instead of all welling up in the springs themselves.

(4) The succession of stages of erosion and deposit displayed in the Yutaoho sections fits in precisely with the order of Pleistocene physiographic epochs as determined in general for North China, and in particular for the Upper

* Bull. Geol. Soc. China, vol. 9, p. 213-222, 1930.

Fenho basin at Taiku and east of Yutze, for the Taihang anticline in the Shouyang basin and at other points along the Chengtai Railway, including Niangtzekuan and Chinghsing. The succession need not be repeated again here as it has been considered in connection with the problems of the superficial deposits already discussed; certain special aspects are indicated in the remaining section of the paper.

(5) In addition to the tectonic problem outlined in section (1) above, certain related problems call for further study.

(a) *The definite establishment by fossil evidence of the Sanmen age of the red loams.* In this paper I have assumed the identity on what seems to me the adequate evidence of the similar lithological character, structural and stratigraphic position and land-form relationship of other deposits in the same basin whose age is fixed beyond question on palaeontological grounds. Confirmation however is desirable.

(b) *The relationship of the red loams to the fault-face.* It is important to determine whether the red loams abut the mountain face with normal or abnormal contact.

(c) *The tectonic history of the locality.* Although the main fault took place in the manner inferred above, the possibility of later movement along the same plane cannot be ruled out. In the brief time available no attempt was made to study the walls of the gorge-mouth for minor structures that would indicate any later readjustment in the reverse sense from the first movement—i.e. revival of movement along the same, or an intersecting plane, but on a much smaller scale the first, and with upthrow this time to the north-west—an unusual occurrence, but not impossible in view of the long interval between disturbances. Further, if this fault is not the prolongation of Wang's Yangchu pivotal fault (which is clearly indicated as having up-throw to the north-west) —as seems to be the case—the actual prolongation of that fault must either have swung back into the mountain hinterland or be buried under the margin of the plain. In the latter case some topographic expression of the fact should occur. None could be detected. Moreover the Yangchu-Chiaocheng fault has begun to swing westwards north of the latter city, so that it seems certain that the actual line of the fault crosses the valley some distance above Yutaoho, possibly where the Archaean "boomerang" is shown on the map. It is to be

noted that this would fit in precisely with the tectonic explanation of the conglomerate—for such movement, with downthrow to the southeast, taking place upstream would increase the gradient and account for the deposition of gravel just outside the gorge mouth. Moreover its age as thus indicated by the conglomerate would accord precisely with that of the Taiku fault as recently demonstrated,* which lies between that of the basal Pleistocene red loams and the Middle Pleistocene loess.

In any study of the tectonic problem it would be important to compare with care the relative state of preservation and youthful character of the fault-facets at Taiku, Chiaocheng and Yutaoho. This I failed to do, as shortage of time confined our observations to the base of the valley. On the assumption that only one movement took place along the Yutaoho fault, the scarp face is exposed entirely as the result of erosion and should appear less fresh than as well as distinctly older than the other two. On the other hand, if all three present equally sharp surfaces a secondary movement along the old line might need to be postulated. In either case it seems necessary to revise the date of the faulting which up till now has been considered to be of late Pleistocene age.

*Grabau Anniversary Volume, 1931 (in press), Geol. Soc. China.