THE ORIGIN OF THE NIANGTZEKUAN TUFA

By

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For centuries the tufa of Niangtzekuan has possessed a peculiar fascination. It is to be seen decorating rock-gardens and fish-ponds all over North China, and is sold in curio-markets for use in flower-bowls, and as ornaments. It is commonly said that one has only to keep a block of the tufa well watered for it to begin to sprout again.

In his book 'Lapidarium Sinicum', the founder of the survey, Mr. H. T. Chang, devotes a section to this interesting geological curiosity, illustrating it with a beautiful reproduction of a typical specimen (Plate 9). In this instance

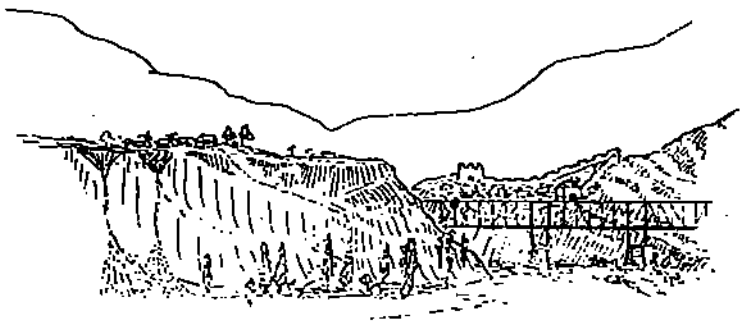

Fig. 1 Entrance to Niangtzekuan gorge looking downstream towards village and fort perched in the high platform overlooking the railway-bridge.

the precipitation agent was *Chara* sp. Other types including incrustations, round leaves and plant-stems, as well as irregular-shaped porous masses, are commonly seen.

Since it seemed possible that closer study of the general structural relationships of the deposit might throw further light on the conditions obtaining during some of the younger stages in the evolutionary history of the present landsurface, Père Teilhard de Chardin and I took advantage of the hospitality of M. Martin, Director of the Chengtai Railway, and spent a night in

the company's rest-house at Niangtzekuan. My companion's familiarity with the region proved a great asset in making the best use of the brief time available. I wish I could have submitted this paper to him for endorsement before publication, because the field relationships of the deposit are peculiar enough to introduce an element of uncertainty especially on one critical question which we failed to solve on the basis of local evidence, and which I have had in consequence to interpret in terms of known physiographic stages determined elsewhere.

Niangtzekuan in Pingtinghsien lies 40 miles from the Peking-Hankow Railway, at the point where the Chengtai branch line intersects the wall separating Shansi and Hopei (Chihli) Province, about a third of the distance from Shihchiachuang to Taiyuan. Immediately after leaving Niangtzekuan station eastward bound, the track crosses to the left bank of the stream by a bridge spanning the gorge (Fig. 1). From this point for a distance of over a mile down stream an excellent view of the opposite wall of the canyon is to be had all the way to below Weitzekuan.

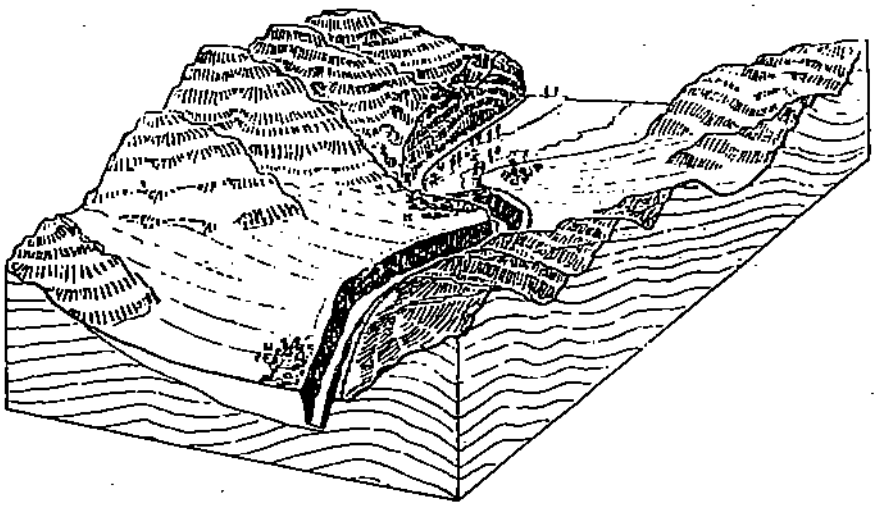

Fig. 2 Simplified Block-diagram of Niangtzekuan Gorge looking upstream, showing Weitzekuan (W), Niangtzekuan (N), position of observer in Fig. 1 (X) and general structure and topography of the locality.

The spot is one of considerable grandeur and natural beauty. The valley is dominated by massive ramparts and turrets of limestone. Even in

the driest seasons, the springs in the valley-floor ensure a copious supply of water, enough to keep several dozen water-mills at work, besides being extensively used for irrigation. It is significant that the springs, the water-wheels and the famous tufa all begin to occur together at a point just above the railway bridge and are conspicuously absent farther up stream.

The block-diagram (Fig. 2) shows in generalized form the essential features. The observer, a Hopei man, is supposed to be looking west up-stream into Shansi with his back towards his own province and the great delta-plain. The winding valley cut in hard rock is considerably wider than the actual entrenched gorge in which the stream is confined, having been filled by river sediments and material washed from the lateral mountain slopes, and then partially re-excavated during a subsequent epoch of erosion. The result is the prominent 80-foot terrace which extends back laterally from the lip of the canyon, sloping gently up to the point where it meets the steeper outcrops of bedrock. The upper surface or 'tread' of the terrace also has a general down-stream slope, well-graded, and in keeping with the gradient of the thalweg.

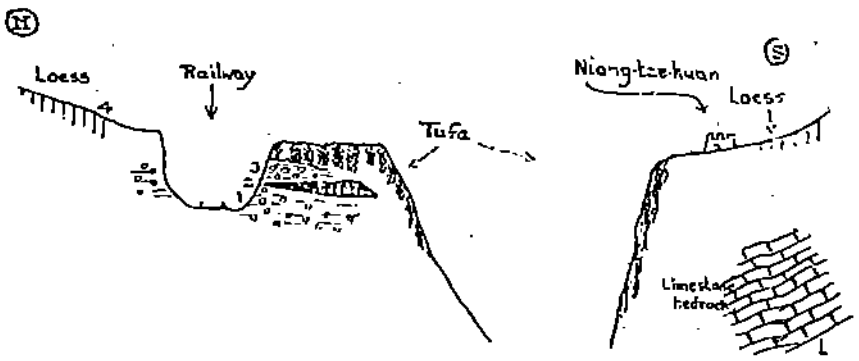

Fig. 3 Composite section to show structure across railway-cutting on left bank of gorge opposite Niangtzekuan. (Not drawn to Scale).

The tufa makes its appearance abruptly at the bridge—the northern abutments are actually built on the first outcrops—and from this point down stream seems to build the front face of the terrace. At first sight, this gives the impression that the terrace is actually cut in a tufa deposit that once filled the entire width of the bedrock valley. But study of the railway-cutting on the left bank —of which a section is given in Fig. 3—shows that the tufa is only a veneer, capping a heavy deposit of river gravel and sand which

must itself have filled the valley to a depth of over fifty feet. Fig. 1 shows the view looking down-stream from the point X on the block-diagram (Fig. 2) towards the village and fort perched on the dismembered terrace. The exposed face of the platform on the left is entirely of sands and gravels; beyond the bridge, both walls of the canyon are faced with tufa, but on the left bank (right of block-diagram) it only extends a short distance, because opposite the fort the stream swings to that side and has stripped the wall clean to solid limestone bedrock.

From the railway-cutting section (Fig. 3), as well as from similar exposures in the bottom of the canyon, it is clear that the tufa is younger than the stage of aggradation to which the gravels belong, and *a fortiori* younger than the cutting of the original valley in bedrock. The latter is of the type associated with the Fenho Stage of dissection a fact attested by the presence of the dissected remnants of a terrace, rockshelves and shoulders preserved from the older Tanghsien erosion (here standing at about 250 feet above the present stream level, and similarly in evidence at other points up and down stream).

To reconstruct the conditions under which the tufa deposit formed, the reader must recall the following succession of recognized physiographic stages in North China (the epochs of aggradation being indented to the right):

1 Tanghsien Stage of erosion—broad mature valleys
2 Paote Stage of Accumulation—red-clays etc.
3 Fenho Stage of dissection
4 Sanmen Stage of lake and river aggradation
5 Chingshui Stage of trenching
6 Malan Stage of loess accumulation with basal gravels.
7 Panchiao Stage of erosion
8 River gravels and Alluvium.

Erosion has removed all traces of the *Paote* clays (Stage 2) and they do not appear prominently till 20 miles further up stream.

The sub-tufa gravels at Niangtzekuan, being younger than the *Fenho* valley (Stage 3) they occupy must belong to Stages 4 or 6. Hence the tufa resting on them and lining the gorge cannot be older than stage 5 which cut the gorge or at least than the closing phase of stage 4. Now the

Chingshui Stage (Stage 5) was one of down-cutting and vigorous stream activity, more prone to erode than to favour the growth of tufa. In fact the contact between the tufa and underlying gravel indicates a canyon *in* gravel, irregularly faced with tufa. This canyon must have been of Chingshui or later, date.

The argument against *Panchiao* date (Stage 7) is that the latter likewise one of renewed vigorous down-cutting, alternating with deposition of torrential gravel in quantity,—both equally inimical to the formation of such delicate structures as those shown by the tufa. Moreover the Panchiao Stage came after the days of the Loess (Malan Stage), which should therefore underlie the tufa. Now in this connection there is the one point upon which the evidence is not conclusive. No place could be discovered where the exact structural relationship between the tufa and the Loess was exposed. In the railway cutting section (Fig. 3) a layer of reddish clay (2) separates the lower, presumably Sanmen, gravels (1) which are locally fairly firmly cemented, from a somewhat less consolidated layer (3) which may be of early Malan age, and thus represent the basal gravel of the Loess. If that is so, then the tufa might be post-Loess and formed during the Panchiao period of entrenching. This would also imply a *downward* growth of the deposit keeping pace with the deepening of the gorge. This hypothesis seems extremely unlikely, and as apart from this equivocal point, there is nothing to support a Panchiao date, it may be dismissed, at least until stronger evidence is forthcoming.

This leaves only the *Malan Stage* itself (Stage 6) unaccounted for. And on examination it seems that this offers the conditions most obviously favourable to tufa growth. The time was one of cold, semi-aridity and dust-storms. Evaporation encouraged the precipitation of matter in solution in spring waters. The gathering loess-deposits still further reduced the flow of surface water by absorbing most of the rain as it fell. But the springs continued to rise, their waters heavily charged with lime in solution, much of which was soon precipitated on exposure to the dry air.

It is clear that the tufa was deposited round a series of springs or pools rather than in a lake, both on account of its distribution and because the terrace of which it forms the facade has a down-stream gradient even greater than the present thalweg—at Niangtzekuan the terrace stands 80 feet above stream level while two kilometers down-stream it has fallen to 30 feet. in both

cases presenting a well-graded upper surface., Hence the idea of a single horizontal lake-surface formed by a dam of Malan gravels is untenable.

Even after the bottom of the gorge became clogged by the drifting loess the flow was still strong enough to keep the wells open. Doubtless the pools were not always the clear limpid streams they are today for loess dust was everywhere. Much of it clung to precipitating lime and was incorporated in the tufa forming on the bottom and round the sides of the pools. The only types of gastropods noted were *Succinea* and *Helix*. The presence of algae and plant life in abundance is attested by the varied forms of the incrustations. But the palaeontological evidence is neither delicate nor conclusive enough to supply the exact time-criteria needed to confirm the identity of the physiographic stages with which the whole story is intimately bound up. Until such data are forthcoming, the arguments have to be based on the physiographic reading of the problem here presented, backed by our knowledge of the climatic conditions which obtained in the Pleistocene Period in North China.

NOTE ON THE COMPOSITION OF THE NIANGTZEKUAN TUFA

By Chu Wen-ssu

In connection with a study recently made of the famous tufa from Niangtzekuan, Dr. Barbour asked me to determine by analysis the relative amounts of soluble and insoluble matter so as to find out what proportion of the deposit is due to direct precipitation of mineral matter in solution and what amount is clastic material incorporated in the growing deposit.

On treating the powdered tufa with hydrochloric acid the analysis shows

Soluble matter	93. 1
Insoluble matter	6. 9
	100. 0

During the heating of the sample after treatment with acid, a considerable amount of dark material appeared showing the presence of organic matter. Owing to the fine state of the organic matter, there appeared to be no simple means of determining just in what form it is present; it is presumably of recent date, as the tufa is extremely porous and capable of harbouring considerable quantities of living organic matter.

The analysis itself seems entirely consistent with the explanation offerred by Dr. Barbour for the origin of the tufa.

For comparison with Miss Chu's note on the percentage of soluble and insoluble matter it may be noted that according to Allen, the lithoid tufa of Lake Lahontan has only about 1.7 per cent of insoluble matter (Russell, U.S. G.S.Mon.II (1885) p.203). The tufa of Redding Spring in the desert of Great Salt Lake, however, shows 8.4 per cent of SiO_2 and 1.3 per cent of Al_2O_3 (see Woodward, Rept. U.S. Geol. Exped. 40th Par., vol.I (1878) p.502). In his Handbook of Rocks, Kemp quotes Whitfield's analysis of travertine from Yellowstone Park, showing 0.08 SiO_2, 0.15 Fe_2O_3 and 95.43 per cent of lime and magnesium carbonates. Clarke in the Data of Geochemistry (p.198) quotes Gooch's analysis of another Yellowstone sample with over 98 per cent of carbonate, and refers to other similar analyses given by Whitfield in the U.S.G.S. Bull. 228 (1908).

All these types are essentially highly porous. The ability of the Niangtzekuan tufa to absorb water so readily is the result of its fine grain spongy character. The variety due to *Chara* shows minute tubes of capillary dimensions forming the axis of the branching rods which build the network-structure of the deposit. When a lump of this tufa is stood in a basin of water, the tubelets deliver a capillary supply several inches above the free water surface. Hence its use as a base for growing mosses and other moisture-loving plants.

Since this paper was presented, I have found an interesting note on the Niangtzekuan Springs in a paper on "Some Shansi Waters Chemically Examined" by Dr. E. T. Nyström, published in the China Journal of Science and Arts (Vol. 2, 1924). In view of its bearing on the question of the composition of tufaceous material precipitated from the water as well as on the whole structural situation, the relevant section may be quoted in full:

"(Water No. 20—Niangtzekuan Springs). Proceeding now along the line right to the Eastern border of Shansi, we arrive at the station Niangtzekuan at an altitude above sea-level of 375.11 metres. This is an exceedingly picturesque place, and just where the line leaves Shansi it crosses over a deep canyon, where a swirling torrent of beautiful green water rushes down and forms waterfalls and rapids. This water originates in strong springs some distance to the west. The province derives only a small benefit from this stream, as it leaves Shansi almost at once and the canyon is too narrow for

extensive agriculture and irrigation. The stream is mainly used here to drive a number of flour mills (interesting objects for travellers, showing the application of vertically shafted turbine wheels).

"The water seems to originate in the thick Cambro-Ordovician limestone, which forms here the country rock, but it comes probably a long way underground, as the analysis shows a large content of gypsum, probably from the overlying Carboniferous.

"If one should take a guess at the quantity of water supply it might be in the neighbourhood of 3 cubic metres, or 660 gallons, per second.

"Appearance ; perfectly limpid and colourless.

Analysis;	*Total Solids*, mgr. per litre or parts per million	635
	Chlorine, mgr. per litre	44
	Total Hardness, mgr. $CaCO_3$ per litre	245
	Temporary Hardness,	33
	Permanent Hardness,	212

"This water gave an immediate and very strong precipitate with barium chloride showing a great tenure of gypsum, which is also confirmed by observing the excessive temporary hardness shown above."

Explanation of Plate

Fig. 1 Niangtzekuan tufa made by *Chara* sp. (Type specimen in Museum of Geological Survey of China).

Fig. 2 Niangtzekuan tufa made by incrustation round plant leaves and stems (Specimen in Museum, Department of Geology, Yenching University).

Note. If the plate is held with the top pointing towards the light, the true relief will be obtained.

The scale is indicated in each case by a 5-inch ruler.

I am glad of an opportunity to express my appreciation of the expert work of Mr. K. H. Hsu of the Geological Survey Staff, by whom these excellent photographs were taken.

G. B. B.