THE PLEISTOCENE VOLCANOES OF THE SANGKANHO.

By George B. Barbour and M. N. Pien.
Department of Geology, Yenching University

Introduction

Looking east across the Yüho from the higher ground around Tatungfu, the eye is caught by a dome-shaped hill on the horizon some twenty miles away. The existence of volcanoes in that direction had already been brought to the notice of P. Teilhard de Chardin by P. De Vleeschouwer of the Mission du Scheut and a passing reference is made to them in the former's memoir on

Fig. 1

the Sanmenian formations of Shansi.* The same publication reproduces two photographs of the eruptives. But beyond the three brief lines in that volume I have failed to find any reference in print to these interesting examples of recent vulcanicity.

In March 1931, we had an opportunity to confirm and extend the previous observations, though under the unfavourable circumstances of a dust-storm and limited time. Before setting out from Tatungfu we had the benefit of P. De Vleeschouwer's familiarity with the district in deciding what were likely to be the critical localities.

General Geological Structure.

The chief points in the general geology of the area can be condensed into a paragraph with the help of a generalized block-diagram (see Fig. 2).

*Teilhard and Young, Mem. Geol. Surv. China, A 8, 1930 p. 10 and Plate I.

The Tatung basin is a structural depression bounded on the south-east by an imposing fault-scarp roughly parallel with the right bank of the Sangkanho. Judging by the distribution of the present outcrops of charc*ter-

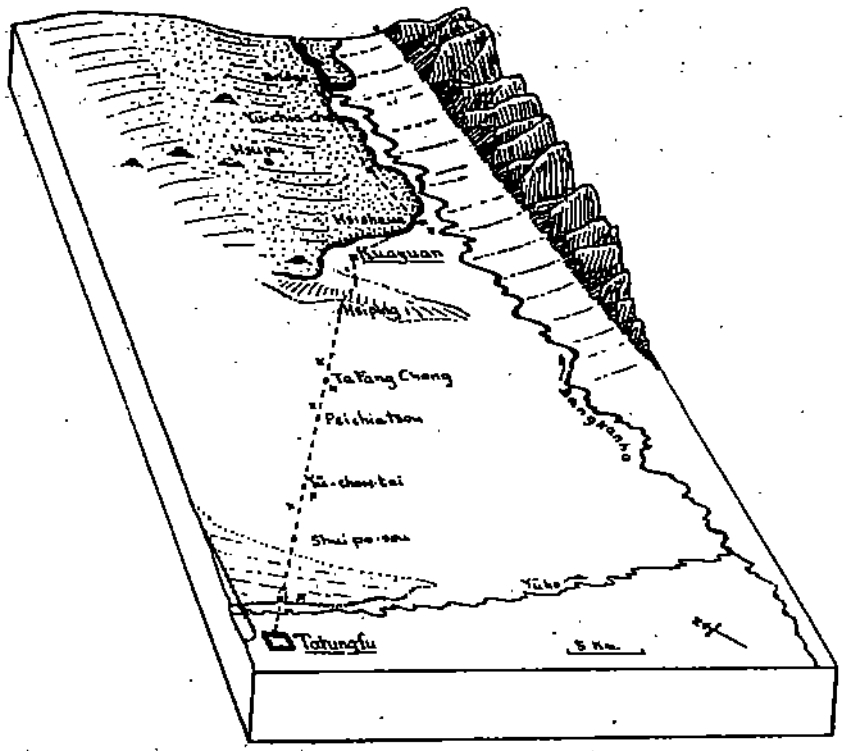

Fig. 2

istic fossiliferous marls and sands—marked by crosses on the sketch-map—the low-lying parts of the basin are occupied by Sanmenian deposits of the Nihowan type.* East of Hsiping the road breasts a buried spur of an older

*Barbour, Licent and Teilhard, Bull. Geol. Soc. China, vol. 5, 1926, p. 263.

Note. The Sanmenian in the Tatungfu area is identified as such on the ground of its lithological character, its freshwater molluscan association and its structural relationship to other deposits and to physiographic surfaces of known age or type, in all of which respects it exactly repeats the features of the Nihowan deposits which have provided a rich mammalian fauna. Fossils are reported from west of Hsishawa and a silicified bone-fragment was shown to us, but the locality was not visited.

formation. Otherwise Sanmenian material, veneered with loess, blown sand and alluvium, forms the entire terrain from Tatungfu to Kuayuan. Immediately east of Kuayuan an abrupt change occurs, soft sediments give place to basalt and the whole scenery becomes one of utter desolation. The western limits of the lava-field are roughly indicated on the map. The Sangkanho keeps to Sanmenian terrain, skirting the southern edge of the basalt-flows as long as it can avoid them and then, when the lava-field stretches right across its path, enters a narrow gorge cut in the igneous rock. During seasons of low water the river is forded below Yü-chia-chai but when it is deep a suspension bridge is thrown across the canyon cut in the basalt. Four chains are anchored a foot apart on one side of the river, the other ends being then ferried across to the further bank, and passed over a windlass which is then turned until they are stretched taut across the chasm. The bridge is completed by laying sticks at right angles across the chains and making them fast to prevent slipping. The bridge has no hand-rail, and as it hangs in a catenary curve on account of the weight of the chains, and rises and falls as well as sways ominously when anyone walks across, crossing unaided needs a steady head (see Plate 1, Fig. 1). An inhabitant of the district remarked—it seemed to me, rather casually!—"usually not more than two or three animals, and perhaps as many men, fall overboard each season"—a reassuring thought when about half way across I realized that somebody was trying to come over in the opposite direction!

THE BASALTS

The basalts exert such a dominating influence on the topography, and hence on life in the area concerned that they deserve to be made the subject of more detailed study.

Two facies of the effusives can be clearly distinguished; (a) the volcanic cones and (b) the lava-flows.

(a) The eruptions took place at so geologically recent a date that weathering and erosion have done little to destroy the original shapes of the volcanoes. We only visited one, but six others lying to the east and north-east were sighted from a distance, P. Teilhard noted two more, while yet others are reported from further afield. Fig. 1 shows the appearance of the cone on the ridge just behind Tungping. It is the one visible from Tatungfu and lies a mile and a quarter off the main road due north of Kuayuan. It is appropriately named

Horse-shoe Hill (Matiehshan) and is breached crater with incipient radial drainage. The ground around the base of the cone is strewn with volcanic bombs of all sizes, and a great variety of fantastically shaped fluted or ropy fragments (see Fig. 3). The lava itself is ashy and vesicular.

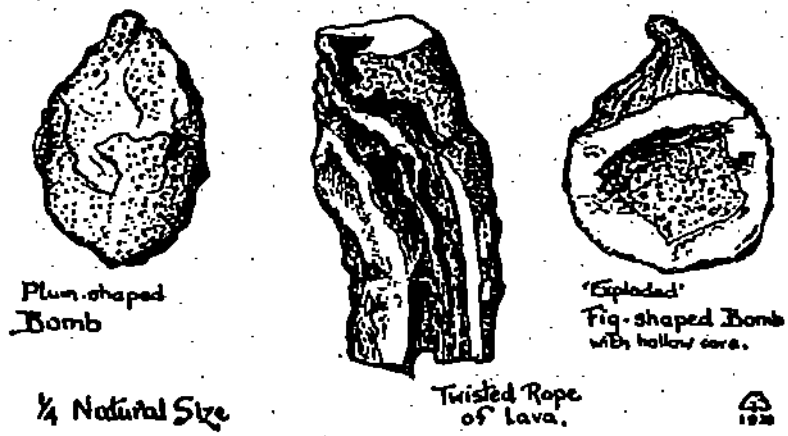

Fig. 3

(b) The basalt flows pave the entire surface of the rock desert that lies east of Kuayuan (see Fig. 2). The surface unevennesses due to the irregular overlap of successive flows remains much as they were immediately after the eruptions except that blown sand had drifted into the depressions and given rise to an almost barren soil which only adds to the general desolation of the landscape. Human settlements are set far apart and are confined to the banks of the river or the high-road along the base of the ridge to the north, thus leaving an uninhabited patch in the middle. We crossed a dozen miles or so of such terrain and were told that it extended considerably more than as far again.

The thickness of individual flows observed ranges from less than 3 to more than 20 feet. The exposed lava is coarsely vesicular, but without much amygdular filling, although locally joints and cavities are lined with a white calcareous fur which is entirely soluble in hydrochloric acid. The original ropy surface of the lava is often perfectly preserved (See Plate 1, Fig. 2).

Beneath the spongy outer layers the basalt is of a dense felsitic texture practically free from phenocrysts. It is being made the subject of an independent petrographic study. A specimen from near Hsūpu has been studied by Dr. A Lacroix who describes it simply as "basalte dolèritique"

The rock is used for miles around as a structural and ornamental stone. Over ninety-five per cent of the memorial tablets, boundary stones, pedestals, curb-stones, etc. in the Tatung district are of the material.

Age and Structural Relationships of the Basalts.

The lavas are clearly younger than beds of Sanmenian age because at Yū-chia-chai a four-foot flow overlies and bakes marls and sands from which freshwater molluscs were collected within 18 inches of the contact. Similar relationships were observed in four other localities. In addition it may be noted that at no point anywhere in the district do beds of Sanmenian type yield detrital basalt material.

One the other hand, though concretion-bearing red loams of the type now recognized as Upper Sanmenian do underlie the basalts on the higher slopes, no loess or other younger formation occurs in this position.

In point of fact, most of the loess in this locality is so sandy as hardly to deserve the name of true loess, so that the precise relationship of the basalts to the Malan Stage of loess accumulation seemed open to question until clear proof was found in two unexpectedly fortunate discoveries. One was the finding of a fragment of *Struthiolithus* in a patch of otherwise equivocal sandy loess resting directly on the basalt of the lower slopes of Ma-tieh-shan itself. The other was the establishment of a clear connection between the eruptions and the stage of erosion which immediately preceded the loess epoch.

This Chingshui rejuvenation stage, which elsewhere in Shansi has been shown to be related to crustal movement rather than climatic change,* incised the flat or gently sloping surface of the Sanmen basin sediments, producing a dissected surface similar to that of much of the North China loess terrain today. Had the basalts poured out late in the Sanmen epoch, the lavas would have spread in a more or less even layer over the gently concave surface of

*Barbour, The Taiku Formation, Grabau Anniversary Volume (in press) Geol. Soc. China.

the basin-bottom much like a glaze on the inside of a shallow bowl. Only on the site of volcanic vents where the magma moved vertically would the igneous rock extend to any depth, while everywhere else its basal contact would be the even surface of the basin sediments.

If however the Chingshui erosion was already well under way before the lavas broke out, the Sanmenian surface must have been channelled and gullied, and some of the lava streams would have flowed into the depressions. Moreover, if any such channel was of considerable width and depth, the lava might well fail to fill the trough level with the high ground on each bank. In such a case the ponded water upstream, after its level had risen to form a lake by being thus dammed, could still find an escape by overflow through this natural spillway across the surface of the lava along the line of the old stream course.

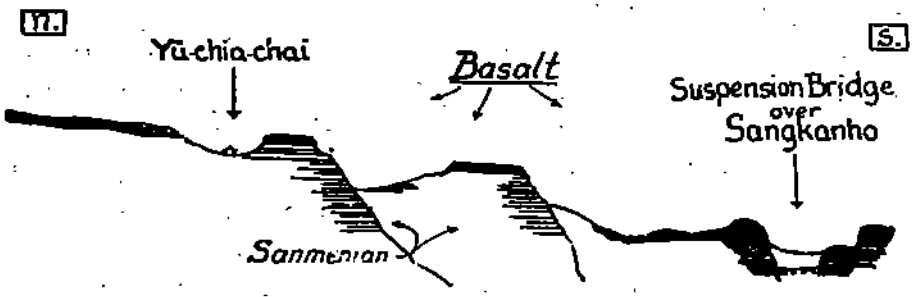

Fig 4 Composite Structure-Section at Yüchiachai and Tiehshengchiao.

This is exactly what seems to have happened, as will be realized by considering the composite structure-section made by superposing the section at Yüchiachai and the bluff below T'ant'ou upon that at the "chain bridge" (Tiehshengchiao) a few hundred yards down stream (see Fig. 4).

As measured by aneroid, the difference of level between the lowest exposure of basalt in the gorge and the basal contact of the flow at Yüchiachai was 200 feet, but as a violent duststorm was just breaking, the readings are not reliable. A safely conservative estimate would be 80 to 100 feet. The walls of the gorge show irregularly superposed layers of basalt with an aggregate thickness of 40 to 60 feet in flows ten or more feet deep. In the neighbourhood of the bridge the flows are horizontal or only moderately inclined,

thus showing that the greater depth of igneous rock in the gorge is not that of a volcanic vent. There is no evidence of faulting. Moreover, even if there were, it would only explain the difference of elevation of the basal contact of the lavas, and would not account for the great discrepancy in thickness. Hence the latter can safely be attributed to the uneven surface upon which the lava came to rest. Further, probability is given to this interpretation by the facts (1) that the Sanmen Stage is known to have been followed by a period of dissection, and (2) that the point where the greatest thickness of basalt occurs lies on the axis of the Sanmenian basin, and hence of the line necessarily followed by the trunk stream of the Chingshui stage.

Summary of Geological History.

Reconstructing the picture of the area towards the close of the Pliocene, we see the trough made by the collapse of the ground along the front of the fault-scarp gradually filling with sediment. It is very possible that at first the water found no outlet and only left the basin by evaporation or by sinking beneath the surface. But by the time she projecting rock masses round the basin had been worn down to a surface of subdued relief, the basin had silted up and running water flowed sluggishly down the median depression flanked on each side by wide strips of gently sloping loam-land.

Slight upwarping of the earth's crust, which locally caused further yielding along fault-lines, increased the gradient of the streams so that the youthful Sangkanho cut down into the Sanmenian basin-sediments. Then came the basaltic outbursts from the vents and fissures on the north bank, which poured their lava streams down the slopes and into the canyon cut in the soft deposits, forcing the river over towards its southern bank and finally damming its entire channel. But the water rose against the obstructing barrier and soon found the lowest point of overflow across its surface, so that the hold-up was brief and erosion went on as before, but this time in solid rock.

Just how long the eruptions actually continued we do not know Probably after the main streams of lava had exuded from fissures and hardened like a crust over the ground, explosive bursts of lava still occasionally sputtered forth and heaped up cones of volcanic debris round their vents. But geologically speaking the whole episode was very brief.

Then came the days of the loess, with dryness and dust, but here the winds were so fierce and had at hand so ample a supply of loose sand from the old

Sanmen beds that the loess was coarse and gritty—poor stuff at best. And then the moister times came back and streams became active again, though never again with the vigour they had had before, and erosion continued to the present day.

Neolithic Culture.

On the Sanmanian terrace overlooking t ıe Sangkanho at Hsi-sha-wo, just outside the western limits of the lava field, four flakes of characteristic Neolithic type were picked up on the field. They are of a dove-grey chalcedony not found among the pebbles of the locality. Fragments of *Struthiolithus* were found in the same field.

Problems for Further Study.

It has been already suggested that a detailed study of the whole basalt area is desirable. Two further points call for special attention as being directly connected with the history of the district.

(1) The first of these may furnish important confirmation of the interpretation put forward in this paper. On the farther (south) back of the Sangkanho, just upstream from the gorge-mouth there is a platform of stratified yellow-brown sand, which from across the river appears unlike the Sanmenian exposed in similar relatiye positions farther upstream. On account of this lithological difference, the concordance of the top of the platform with the top of original basalt surface at the point of outflow and their position immediately upstream from the basalt dam, we interpret these as sediments collected in the temporary lake made when the lavas ponded the stream. If we had had another hour of daylight we could have reached the spot and verified the truth of this supposition. Should it prove correct, this must be one of the few North China localities where the Chingshui Stage is represented by freshwater sediments; if mollusca are present, they should show derivation from Sanmenian types and as such any variations of species are important. If by good fortune mammalian remains are recovered they must belong to a faunal group which existed between the Nihowan and Malan (loess) association, and in that case the relationship to the Choukoutien types would be significant. Even if no fossils are found or the beds prove to be simply a facies of the Sanmenian, the spot still calls for study to discover whether or not the freshwater beds are capped bv loess, and, if so, to learn the nature of the

contact. If the molluscan fauna is indistinguishable from that of the Sanmenian formation, the presence of basalt material in the sediment would of itself be enough to establish the later date of the beds.

(2) Reference was made near the beginning of the paper to a small exposure of an older formation composing the core of a ridge some two miles west of Kuayuan. This is a poorly consolidated series of highly inclined layers of red, grey and greenish decayed rock material of varied texture resembling badly weathered volcanic ash dipping north-west at angles of 30°-50°. The lumps of more consolidated material are either concretions or weathered rock fragments so badly decomposed that their original character can only be guessed at, though they are probably igneous. The tilted beds are overlaid unconformably by a small patch of horizontally bedded red laminated sandy clays.

The whole appearance and structure suggest a volcanic cone deposit of andesitic or more acid character. The core of the ridge itself is clearly older than the Sanmenian deposits which cover its flanks. The crest-line of the ridge itself evidently belongs to an earlier cycle of erosion, which must be at least as old as the Tanghsien Stage. If the present dip of the beds is entirely an original feature due to the steepness of the sides of the cone, the age may well be Middle Tertiary. If the dip is due to movement other than drag by local normal faulting, the formation must be distinctly older. It is evidently considerably younger than the Jurassic rocks west of Tatungfu which are all thoroughly indurated, but rocks of Cretaceous age in the Kalgan area are as poorly cemented as these at Hsiping. Meanwhile probably the best provisional date is early Tertiary. Confirmation is to be sought by examining the extent and general character of the formation at other points on the ridge, noting specially the constancy or variability of the structures, especially the dip of the bedding. The small exposure of red-beds overlying is not of a typical Sanmenian appearance and may be a remnant of a distinctly older formation,—i.e., probably of Paote age,—so that other outcrops of the same facies should be sought and studied.

Another perplexing exposure lies right in the roadway on a rise a mile and a half west of Hsiping. Here there are several curious small outcrops of what looks like part of an old artificial dump but it might be connected with

a volcanic vent. The material is a kind of irregular bedded granular calcareous hardpan with layers of pea-size gravel, mostly of basalt but with badly weathered granite or gneiss. We assumed the first outcrop was artificial in origin, but when it was repeated some hundred yards further on as if part of the same structure and without any surface indication of ancient settlements, the dimensions of the "formation" suggested that it might be connected with the bed rock of the 'rise' as a whole and be of natural origin. Dusk and dust prevented any attempt to solve the puzzle.

Conclusion.

There is no conclusion,—except that 20 miles east of Tatungfu there is the first of a series of volcanic cones connected with a basalt lava field extending for a number of miles beyond, which is young enough to preserve its pristine features with surprising perfection. The eruption took place during the erosion which followed the deposition of the Sanmenian freshwater beds and before the Malan. Stage of Loess formation. Lava dammed the Sangkanho, thus ponding its waters. But they cut a channel through the rock, and so again found an outlet for the drainage of the entire basin.

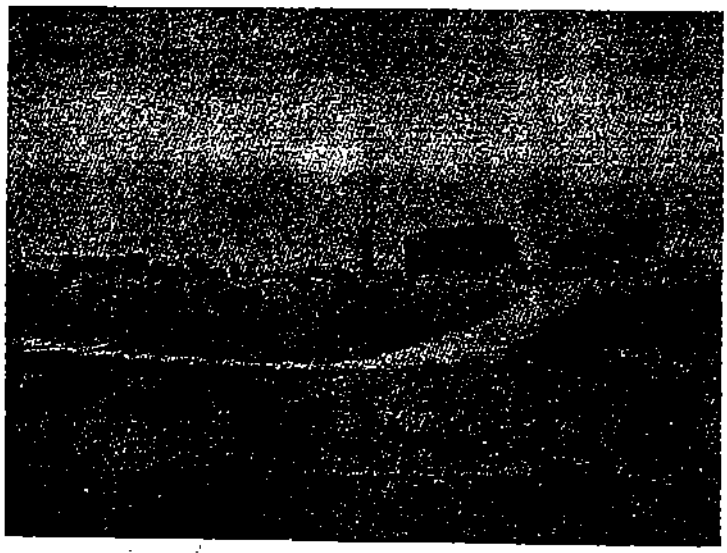

Fig. 1. Suspension bridge across gorge cut in jointed basalt flows at Tiehshengchiao.

Fig. 2. Wrinkled and ropy surface of Pleistocene lava-flow near Tungshawa at western margin of basalt desert.