A Re-excavated Cretaceous Valley on the Mongolian Border.

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The ancient caravan route across the Mongolian border of China divides for a short distance immediately north of the frontier-town of Kalgan. The Hanoor trail pierces the Great Wall, and enters a rugged gorge, which, for part of its way, follows the line of an old disinterred Cretaceous river-valley. This, after being filled and buried for half the Tertiary Era, was reopened by erosion and used again by rivers in three distinct geological periods, the channel thus becoming a watercourse successively in Mesozoic, Tertiary, Quaternary, and Recent times, and being filled up again, partly or wholly, during each of the intervening epochs. Moreover, the peculiar conditions of preservation of the valley-deposits have made possible the mapping, with considerable certainty, of the early Cretaceous land-surface and the comparison of its configuration with that of the present day.

Examples of buried erosion-surfaces are known in many regions from the basal contacts of continental deposits, as far back as the Torridonian of Scotland. Striking cases have been cited by Watts from Charnwood Forest,\(^1\) by Johnson from the Cerrillos Hills of New Mexico,\(^2\) and by Haughton & Frommurate from the pre-Dwyka terrane of the Warmbad District of South Africa.\(^3\) In the Kalgan area, however, the clear evidence of the repetition of erosion and deposition at geologically distinct epochs, with the combination of factors which permit the reconstruction of minor details in the original topography, must be almost without parallel, and appears sufficiently unusual to warrant an account of the main features of the occurrence.

The locality lies in the mountain-district immediately below the edge of the Mongolian Plateau, 85 miles north-west of Peking. The general aspect of this area is represented in the block-diagram (fig. 1, p. 720).

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1. W. W. Watts, 'Charnwood Forest, a Buried Triassic Landscape' Geogr. Journ. vol. xxi (1903) pp. 623-36. When mapping the Hanoor Gorge (PL LI) I was unaware of this somewhat analogous occurrence in Leicestershire. In Prof. Watts's very striking reconstruction of the ancient topography, the comparison of the Triassic and present surfaces is achieved by contoured maps placed side by side, instead of being superposed.


The two branches of the famous Peking-Urga-Kiachtata trail divide at Kalgan. The one used to-day for motor traffic runs eastwards for 7 miles to Wanchuan, and then turns northwards up a long rise to the rim of the plateau. The northern trail follows the stream-bed up the Hanoor Gorge, but ends in a steep ascent which calls for double teams for all carts, and is impassable in wet weather. In the rainy season the roadway becomes a torrent within 10 minutes. The Nantienmen area shown on the large-scale map (Pl. LV) is near the lower end of the pass, Shih-chiang-yao being within 2 miles of Kalgan. The Great Wall itself follows the crest of the east-and-west ridge that here separates the two passes.

Many interesting references to the Kiachta trail occur in early travellers' records from the 17th century onwards, but no geological observations of importance were made previous to Pumpelly's reconnaissance in 1864. In 1871 Ferdinand von Richthofen passed through Kalgan. Obruchev made a sketch-map of the main trail in 1892, with elaborate lithological descriptions of the various rock-types encountered. Anderson's 'Essays on the Cenozoic of North China' summarized the results of a visit to the area in 1919. More recently the geologists of the Central Asiatic Expedition have used Kalgan as a railhead for their various reconnaissance parties entering Mongolia, and it was Dr. C. P. Berkey, Chief Geologist of that expedition, who first drew my attention to the locality as one calling for study. In 1923 a preliminary report was prepared on the stratigraphy of the region, which has since been made the subject of more extended research, the result of

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which will shortly appear as a Memoir of the Geological Survey of China.

The various stages in the earlier tectonic history may be inferred from the diagrammatic geological column (fig. 2, p. 721).

Very early in Cretaceous times the Kalgan Series of acidic lavas and tuffs were heaped up on an eroded floor of pre-Cambrian rocks. The earth-movements with which these eruptions had begun during the previous period, reaching a climax in Upper Jurassic times with a vigorous folding of the outer elements of the basement, and the new mountain-ranges had been considerably reduced before the volcanic outbursts took place. That crustal adjustment was not even then entirely complete is shown by the fact that the Kalgan Series itself is thrown into gentle folds.

With a final spasm of the disturbance the district immediately on the north-east was uplifted. Erosion at once took place, and trenches the new rock-surface, cutting gorges which at some points reached depths of 600 feet below the ridges on either side. At the moment when this relief reached a maximum, conditions changed, erosion giving place to rapid deposition, and the bottoms of the channels became choked with heavy layers of flood-boulders and torrential deposits which attained formidable proportions. Gravels and sands filled the lower valleys up to the brim, burying the spurs on either side and spilling out upon the plain in a vast apron of alluvial material, which now forms 'badlands' for 20 miles to the west, and formerly must have covered an area not far short of 500 square miles. This deposit may be designated the Nanmen Formation (4); it is practically monogenic in origin, over 95 per cent. of the material being derived exclusively from the porphyry series, and attained a thickness exceeding 2000 feet. Plant-remains typical of the Wealden strata of Europe found in several localities, supported by general diastrophic evidence, make it possible to date the formation as early Cretaceous.

During the later Cretaceous and early Tertiary erosion, the overburden of gravel was planed off and the surface reduced almost to a peneplain (unconformity D). At the close of the Oligocene Period or very early in the Miocene this surface was coated with a heavy layer of basalt—the Hanoor Formation (5)—part of the vast outpouring which covered thousands of square miles of Northern China and South-Eastern Mongolia with lava-flows comparable to the plateau-basalts of the Deccan and the Western States of North America. This effectually wiped out the pre-existing drainage controls, and buried the older rock-structures, so that all trace of what lay beneath was lost. Erosion in turn attacked the new surface which had been still further broken up by the folding of Miocene disturbances. By the end of the Pliocene Period this protective basalt overlayer had been stripped back, uncovering the older formations below the recently-buried early Tertiary peneplain-surface. During this erosion a down-cutting stream uncovered part of the axis of the former valley and, working down between the porphyry flanks, let itself be guided for 2 miles along the line of least resistance before striking off over bed-rock towards the Great Gate at Kalgan. The stream-bed was slowly let down upon the western section of the old Cretaceous gorge, erosion continuing until at some points all the old gravel was stripped off, while at others a thin layer still remained adhering to the valley-walls as a veneer, through 'windows' in which the bed-rock beneath could be seen.

During the Middle Pleistocene stages of glaciation in Europe and America, China was free from ice. Instead, the cold dry north-westerly winds from the interior of Mongolia brought immense volumes of fine dust, which settled in the depressions and was wafted up the slopes, finally consolidating as less deposits. In the Kalgan area the Less Formation (7) never exceeds 100 feet in vertical thickness. The presence of eroded patches of such less in the Hanoor Valley (as shown in the map, Pl. LV), at various elevations above the present stream-bed, is evidence that the preceding erosion had uncovered the old channel before the onset of the less conditions, and had opened it up down to within a few feet above the present thalweg.

The close of the Pleistocene Period was marked by a return of moister conditions, with an alternation of torrential rains and severe winds. This led to the splitting into gullies of the recently formed less, followed by the deposition of a veneer of mixed gravel and 'redeposited less', which can be distinguished from the true primary alluvial less by the presence of occasional gravel layers. Where basalt is present in these younger deposits, they are equally diagnostic, and indicate a distinctly later date for the formation.

As this Redeposited Less Formation (8) is found at the very bottom of the Hanoor Valley, it is clear that, for the third time, stream-action scoured out a channel, and then once again partly refilled it. The present stream is in a graded condition, its floor being buried under a layer of gravel. It has reached an early mature stage of development, the actual valley-floor being considerably wider where the stream is flowing along the re-excavated course than where it is running through solid porphyry. The contrast is seen in the two views (Pl. LL, figs. 1 & 2) which were taken within half a mile one of the other, the narrow gorge being farther down-stream beyond the point where the valley narrows on entering the porphyry terrain.

The actual relationship will be clear from the map (Pl. LV). Let us consider the stages mentioned above in reverse order:

(1) The present land-surface is represented by contours printed in green.
(2) The Redeposited Less Formation is not mapped, as it is practically confined to the immediate margins of the present stream-beds.
(3) The few outliers of the Pliocene Less which have escaped erosion are shown with coarse vertical striations in green.
(4) The surface upon which the Less rests is the erosion-surface produced by Pliocene and early Pleistocene dissection.
(5) The outcrops of the Nanmen Cretaceous Conglomerates are coloured pink.
ascending any one of a number of steep lateral gullies, one walks on a floor alternately of igneous and of sedimentary rock, whereas the entire sides of the gully are of conglomerate. The map shows several of these lanceolate *windowed gullies* on the north side of the gorge between Naftienmén and Tsaihsih. A cross-section drawn immediately west of Naftienmén village corroborates the accuracy of the interpretation (see fig. 3, p. 724).

Among other minor points of interest, it may be noted how the distribution of the patches of loss has determined the human settlements in these mountain-regions. All the villages shown on the maps are built on, or near, such isolated remnants of the formation, which furnishes alike a ready building-material, a fertile soil, and a porous reservoir for water in an otherwise rocky terrain.

The evolution of the present land-surface as here described may be linked directly with the physiographic stages recognizable in North-Eastern China. Briefly, the pre-loss erosion includes both the Tunghsien and the Fenbo Stages, which are not clearly separable within the small area mapped. I have considered elsewhere the time-relationship between these stages and the intervening Sanmen Stage of accumulation, not here represented. The deposition of primary loss falls within the Malan Stage, while the erosion that followed, and the subsequent infilling of the bottom of the gorge with `redeposited loss', belong to the Panchiao Stage, which bridged the close of the Pleistocene Period.

It lies outside the scope of this paper to discuss the further correlation of the physiographic stages here represented with those observed elsewhere in China and in Mongolia. As pointed out in another paper, although there is a strikingly close parallel between the North and Central China stages and those established by Deprat and Coggin Brown in the extreme south, the data in hand are still inadequate to admit of the exact time-relationships being known, so that direct correlation is not yet warranted.

**EXPLANATION OF PLATES LIII-LV.**

**PLATE LIII.**

Fig. 1. Hancour Pass above Naftienmén village, showing the flood-plain (150 yards wide) and the sloping walls where the valley has developed in Cretaceous sediments.

Fig. 2. View looking towards the same peak as that shown in fig. 1 from a point 400 yards down-stream, where the gorge is cut through the Kalgan Porphyry Series.

PLATE LIV.

Fig. 1. Coarse basal conglomerate in the Nantienmen Series.

PLATE LV.

Map comparing the present relief with the erosion-surface upon which the Nantienmen Beds were deposited.

DISCUSSION.

The President (Prof. J. W. Gregory) congratulated the Author on his clear exposition of this remarkable case of the repeated recurrence of geological action on the same line, which also throws light on the correlation of earth-movements in Eastern Asia. Prof. Bailey Willis, in the Yangtse Valley, described a great Cretaceous peneplain, the Pei-tai, which was followed by three stages, those of deep valley-erosion, the deposition of loose, and, in the present period, great faulting and uplift. The French geologists in South-Western China and Indo-China have described a great post-Himalayan peneplain which they identified as Pei-tai, but assigned to an epoch later than the Middle Miocene; it was followed by the same three stages as those of Willis. The present paper, therefore, supports Willis as to the Cretaceous age of the Pei-tai peneplain. The 'Third Asiatic Expedition' under Dr. R. C. Andrews, at Iren Daban, about 250 miles north-west of the Author's area, described four erosion-surfaces with the first immediately before the Cretaceous Period; in one case, the beds above and below were separated by a disconformity which seems to prove the long-continued geographical stability indicated also by the Author's evidence.

Prof. W. W. Watts called the attention of the Author to the Trias-filled valleys in the Archaean rocks of Charnwood Forest which showed many features like those described by him, such as the re-excavated Blackbrook valley, and others which showed un-excavated Trias clinging to their sides. In these valleys the superposed drainage was guided by the softness of the infilling into the lines of the old valleys; but, where the superposed streams had 'lost their way' owing to thickness of cover, valleys had been left only in part excavated, in consequence of the check to erosion due to the crossing of the old, buried, ridges.

Mr. S. I. Tomkiewicz said that he had seen a somewhat similar occurrence in Russian Central Asia, not far from the Mongolian border. In the chain of Ala Tau (the northern chain of the

Tian Shan system) north of the lake Issyk Kul, a deep depression in rocks of granite and gneissic composition is completely filled up with a very thick accumulation of less. The depression, which may be a buried pre-Tertiary valley, or a graben, runs almost parallel with the ridge, and extends for about 18 to 20 miles. The recent river-valley is cut through it approximately at right angles.

The Author said, in reply, that ancient 'fossil' valleys were doubtless of more frequent occurrence than was usually recognized, especially in association with coarse continental deposits. The unusual features of the occurrence described from the Kalgan area are (1) the repeated alternation of erosion and deposit along the same course at geologically distinct intervals, which can be dated with considerable accuracy; and (2) the preservation of the Cretaceous valley-surface in such a manner that it can be mapped and contoured.
Fig. 1.—Broad flood-plain in the Hanoor Pass, above Nantienmen Village.

Fig. 2.—Gorge cut in loess, looking towards the same peak as in fig. 1.
Fig. 1.—Coarse basal conglomerate in the Nantienmen Series.

Fig. 2.—Detail of cross-bedding in the Nantienmen Series.