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FOSSIL CONGELIFLUCTION COVERS IN THE NORTHERN PART OF THE LUSHAN (CENTRAL CHINA)

Abstract

Two fossil slope covers of different age were found to occur in the northern part of the Lushan (Central China). On the basis of their structure and texture, these covers are attributed to congelifluction. The older cover which is characterized by a high degree of lateratization is believed to have been deposited during the Taku (Mindel) glaciation and the younger one, during the Lushan (Riss) glaciation.

INTRODUCTION

The Lushan are a small mountain range extending between the Yangtze river and the Poyang lake, over ten km south of the town Kiukang (Kiangsi province). Their maximum length measured along the axis oriented NE—SW is of about 25 km, and in the middle part their width is about 10 km. The geographic situation of the mountains is 29°30′40″ φ N and 116° λ E. The culminating points of the Lushan are: in the southern part of the range the summit of the Hanyangfeng (1480 m above sea level) and in its northern part the somewhat lower crest of the Tayueshan.

In the third decade of the present century, the well-known Chinese geologist J. S. Lee who postulated the presence of Pleistocene glaciations in the mountains of north and central China, became interested in the Lushan range. J. S. Lee was the first, who in both his articles published in 1934 visualized the possibility of Pleistocene glaciations in the mountains of the region of the Lower Yangtze river, especially in the Lushan and supported his assumption by a whole number of geologic and geomorphic arguments. However, vigorous objections against these articles were raised by the English geologist G. B. Barbour (1934) who decidedly rejected the theory of Pleistocene glaciations in the Lushan. At first, the concept was also questioned by H. v. Wissmann who later was to agree with J. S. Lee's views and to make the first attempt towards including the mountains of Central China into the system of Pleistocene glaciations (H. v. Wissmann 1937).

Probably under the influence of G. B. Barbour's (1934) criticisms,

J. S. Lee and his co-workers undertook detailed investigations in the region of the Lushan. As a result of these studies conducted during several years J. S. Lee published in 1947 the highly interesting monograph: ,,Quaternary glaciations in the Lushan area, Central China". His views are here not only confirmed by new facts but also widely amplified, since as many as three glaciations are believed to have taken place in the Lushan range. Most severe were the two oldest glaciations: Poyang (Günz) and Taku (Mindel). Glaciers descending during these periods from the mountain summits onto the lowland caused glaciations of the piedmont type. During the third glaciation, which J. S. Lee termed Lushan glaciation (Riss), the glaciers did not advance beyond the main mountain ridge.

This uncommon phenomenon of Pleistocene glaciations in relatively low mountains lying at scarcely 29°30′40″ φ N latitude, appeared so intriguing, that the present writer decided to visit the Lushan during his travel to China[1]. While he conducted investigations in these mountains and studied glacial landforms and deposits, his attention was attracted by some well-exposed slope covers occurring in fresh roadcuts made in the vast area surrounding the village Kuling. Three of the exposures studied by the writer were already known to the geomorphologists from the Nanking University: Yang Huai-jen and Yang Sun-yuen, who were the first to interprete the structures and deposits occurring in these exposures (Yang Huai-jen, Yang Sun-yuen 1958). The interpretation given by those two workers and published in 1958 will be discussed in the next section of the present article.

On account of the specific character of these covers, their relationship to the bedrock, their structure and texture, the present writer decided to investigate them in greater detail. The observational results obtained are presented below.

GEOLOGIC COMPOSITION OF THE LUSHAN

According to J. S. Lee's (1947) estimate and to the information contained in the geologic map (scale 1 : 75 000) elaborated by J. S. Lee and T. Y. Yü the Lushan represent a certain type of block mountains with large side faults extending in two directions. The rocks of which this relatively small mountain range is built are folded into one anticline and two synclines the axes of which are oriented roughly NE—SW.

[1] During his visit to the Lushan, the writer was accompanied by Mr. Chen Bin-shen, assistant professor of Geomorphology at the University of Nanking, to whom he once more expresses his sincere gratitude for his help in the field and for his suggestions.

J. S. Lee (1947) holds that the south part of the mountains developed principally in mica-garnetite and hornblende schists including quartz--porphyry intrusions. These metamorphic layers are underlain by gneisses and granites, and overlain by fissile sandstones, phyllites and phyllite schists showing a constant dip of 20—30° NW-ward. All these rocks, except the intrusions probably belong to the Wutai system.

The north part of the Lushan is composed of Wulaofeng grit, 800 m in thickness. The Wulaofeng series is overlain by the Kuniuling series whose lower part consists of porous, easily weathered sandstone with greenish quartzite sandstone, whereas its upper part is predominantly composed of schists sandstone and non-typical schists. The summit part of the ridges is generally built of Nuercheng sandstone.

Wulaofeng grit and the Kuniuling series are the only components of the south part of the Lushan.

DESCRIPTION OF EXPOSURES

THE LULING BASIN

Exposure south of the Luling bridge. Some tens of meters south of the Luling bridge, in the roadcut of the new highway from Luling to the Institute of Botany of the Academia Sinica there is an exposure, about 50 m in length showing the subsurficial structure of the western side of the Luling basin. The wall of the exposure, undercutting the slope vertically to the direction of slope is quite fresh and thereby facilitates the study of the component sediments. The wall has about 6 m in height. Bedrock consisting of Kuniuling sandstone is exposed in the downward part of the wall. The surface of the sandstone is cut by numerous erosional V-shaped grooves, separated by well-marked ridges (fig. 1). The series

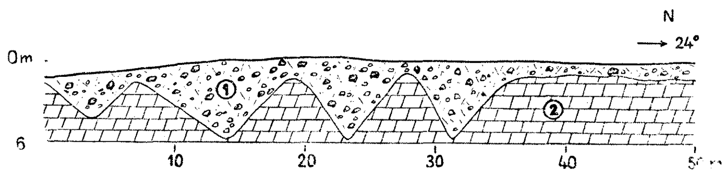

Fig. 1. Luling Bassin. Schematic drawing of the exposure with brick colored congelifluction covers south of the Luling bridge

1. congelifluction cover; 2. Kuniuling sandstone series

of Kuniuling sandstone is overlain by a tightly packed formation of clayey debris the brick-red color of which indicates a high degree of lateratization. The formation has a thickness varying from 0,5 to 6,0 m and completely fills the grooves mentioned above, coalescing above the divides into a uniform cover. Abundant debris materials embedded in the clayey mass are derived from weathered sandstone of the Kuniuling series of which the slope is built not only below the cover but also above.

The contact between cover and bedrock is unusually clear-cut (pl. 2). There is no trace of such a gradual passage from the rock-surface loosened by mechanical weathering to the strongly comminuted covering formations, as in the case of debris covers *in situ*. Here, the cover directly overlies the unweathered rock surface. The fact proves that the material composing the cover was transported downslope. Further evidence to that effect is provided by the arrangement of the debris material of which the cover is partly composed, a predominant majority (about 70%) of rock fragments which average 3—10 cm in diameter, being oriented with their longer axis in the direction of slope. The debris is poorly rounded and analysis according to A. Cailleux' method (1947) showed that roundness indexes range from 0 to 100 (fig. 2).

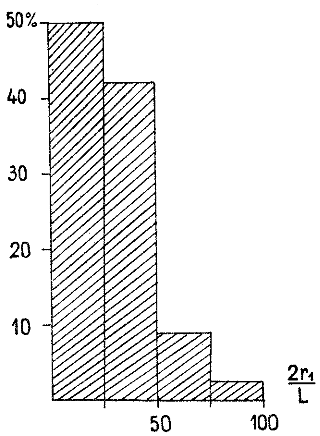

Fig. 2. Diagram of roundness indexes of debris material included in the brick-colored congelifluction cover occurring in exposure south of the Luling bridge

In the top portion of the cover which is yellowish to a depth of about 0,3—0,5 m from the surface the color visibly changes. This portion also contains a lesser percentage of debris and a higher percentage of clayey material. An important detail is that in three places the cover is clearly cut by small, temporarily dry valleys, a few meters in depth.

The exposure described was already known to the geomorphologists Yang Huai-jen and Yang Sun-yuen (1958) who attempted to interprete the formations occurring here and to determine their relative age. According to these writers, the characteristic cuts dissecting the surface of the Kuniuling sandstone are nothing but ice-wedges which, on melting of the ice-body became filled with clay and debris of various age. In the infilling of the wedges, the Chinese authors recognized three different series. The lowest, which is composed of reddish clay mixed with gravel and has a thickness of about 4,5—5,0 cm, they attribute to the Taku glaciation. This series is overlain by a 1 m thick layer of yellow clay including boulders, which is regarded as corresponding to the Lushan glaciation. A thin veneer of so-called Shiashu clay that completes the profile is considered to be a counterpart of the Malan loess of north-west China.

Several objections may be raised against the interpretation of this exposure by Yang Huai-jen and Yang Sun-yuen, especially regarding the origin of the fissures dissecting the Kuniuling sandstone and the stratification of their infilling. Even if a whole number of circumstances were not taken into account such as e. g. the orientation of the longer stone axes in the direction of slope, depth (5 m) and width (up to 8 m at the top) of these cuts, there still remains one basic evidence arguing against their being ice-wedges. Ice-wedges are generally associated with polygonar soils (E. A. FitzPatrick 1958; A. Jahn 1951; H. Poser 1948; S. Z. Różycki 1957) and therefore occur predominantly in either flat or slightly sloping surfaces, whereas the mean gradient of the eastern slope of the Luling basin is 25°. This proves that the cuts are not ice-wedges but simply small erosional forms that became overstrewn with slope material.

As mentioned above, the division of the cover into three series also appears questionable. On the basis of his own observations, the present writer finds that no more than two horizons slightly differing in color and texture may be distinguished here, i.e. the tightly packed, brick-colored clay-debris forming the lower horizon and the one developed in its top and characterized by finer material and a yellowish color, forming the upper horizon. The intermediate series mentioned by Yang Huai-jen and Yang Sun-yuen does not appear in this exposure. Another question is whether the origin of these two horizons can be attributed to two different periods. The assumption seems somewhat fallacious since: 1° the limit between these horizons is not a linear, but a zonal one. The change of color from brick-red to yellow is a gradual and very mild one; 2° likewise, the different fraction of the material shows a successive gradation from one into the other, not a clear-cut line separating two distinctly different formations. In view of these facts, the present writer reached the conclusion that the exposure exhibits only one formation composing the slope cover. As a result of weathering, both chemical and mechanical, the top portion of the formation underwent certain slight modifications in color and texture. However, this is not a sufficient reason for regarding it as an element differing in age from the rest of the cover.

Exposure north of the Luling bridge. In the same roadcut, north of the Luling bridge there is another exposure in which the subsurficial structure of the western slope of the Luling basin has been laid bare. The exposure has a length of about 20 m and its wall is 6 m high. From the base to the top it exhibits the following pattern. In the downward part of the wall the bedrock is exposed. It consists of Kuniuling sandstone. At the center of the exposure, the top of the sandstone protrudes about 1,5 m from the surface while in the north and the south side it merges gradually below the underlying formations until it disappears at its crossing point with the base level of the exposure (fig. 3). The sandstone is overlain by a brick-colored cover of clay and debris. The limit between cover and bedrock is a very sharp one. Like in the exposure previously described the cover can by no means be interpreted as an ordinary waste cover. Its thickness ranges from 1,5 to 5,0 m. Thinnest in the central part of the exposure, it increases in thickness both south- and westward. Apart from

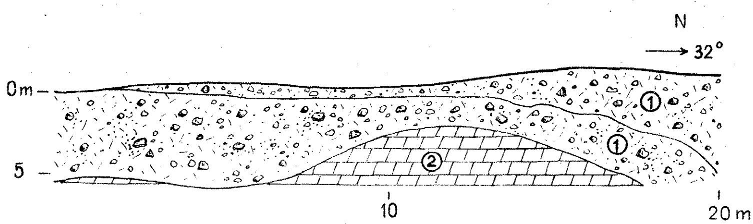

Fig. 3. Luling Basin. Schematic drawing of exposure with congelifluction covers north of the Luling bridge

1. yellow-colored congelifluction cover; 2. brick-colored congelifluction cover; 3. Kuniuling sandstone series

other circumstances, the fact is chiefly due to the surface shape of the underlying sandstone.

The brick-colored cover is overlain by a series of yellowish, clayey debris. The thickness of this series is 1 m at the center and the 4 m in the northern part. The limit between both covers is undulating and well-marked. These covers differ not only in color but also in degree of cementation, the brick-colored cover being more compact that the yellow one. However, both covers exhibit the same texture i.e. a clayey mass with embedded fragments of the Kuniuling sandstone, of which the slope is built, both below and above their place of occurrence. Stones are lying with their longer axes oriented predominantly in the direction of slope. The debris is poorly rounded, the sharp edges only showing some traces of erosion. A note-worthy fact is the occurrence in these covers of striae, due to greater accumulation of either debris or clayey material within certain zones.

The exposure described above was also known to Yang Huai-jen and Yang Sun-yuen (1958). According to these writers, the gentle depressions in this sandstone surface (see fig. 3) are the result of frost-processes and represent ice wedge-like structures. The objections enumerated above in connection with the views of these authors regarding the former exposure need not be repeated in order to prove that in the present case their interpretation is also unacceptable, as it is obviously a mistake to regard as ice-wedges such depressions as are formed in the surface of sandstone underlying slope covers.

Exposure between the Luling basin and Sanyihsiang. The third exposure investigated by the writer is situated in the pass between the Luling basin and Sanyihsiang, in the fresh roadcut near-by the gate of the Institute of Botany of the Academia Sinica. The road leading from the Luling Basin up to the Institute of Botany traverses a small valley. At the point where the valley-head abuts against the pass it shows a narrowing, into which the road is cut. The cut, 40 m in length and about 5 m in height was made scarcely a few years ago and the profile here exposed has not yet been studied. The wall, still quite fresh exhibits the following pattern, from the base to the top. Sandstone of the Kuniuling series appears at the base. In the northern wall it occurs only at base level, while in the southern one it attains almost 2 m in height. The sandstone surface is truncated and unweathered. A series of clay and debris overlies the sandstone. In the north wall it is about 5 m in thickness and in the south wall, 1—3 m. The series shows the same yellow color as the cover occurring in the exposure north of the Luling bridge. In the top of the cover, a sandy-clayey horizon including some debris extends to a depth of 0,5 m.

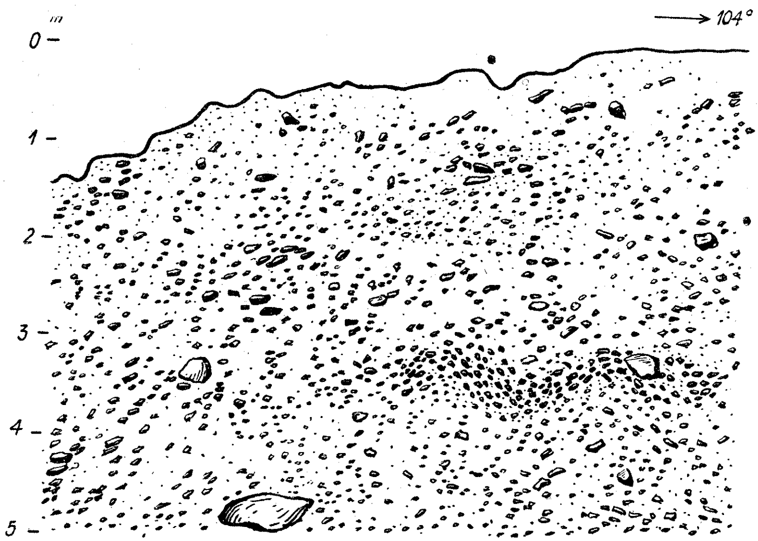

Fig. 4. Pass between Luling Basin and Sanyihsiang. Part of exposure in yellow-colored congelifluction cover

The interrupted line marks the morphologic axis of the declivity into which the cover is inset

A clear-cut limit separates the whole cover from the subjacent sandstone. Like in the case of the exposures previously described the fact seems to indicate that the component material of the cover was transported downslope. Also the texture of the cover argues in favour of this assumption.

As mentioned above, the cover is composed of clayey-debris derived from weathered Kuniuling sandstone. The rock-fragments are poorly rounded, roundness indexes calculated according to A. Cailleux' (1947) method average 0—100. Even a casual observation of the exposure shows that the longer stone axes are oriented in the direction of the morphologic axis of the declivity which merges from the pass into the valley into which the cover is inset. The measurements made by the writer, of the azimuths of the longer axes of a hundred pebbles also tend to confirm this assumption. The results of measurements are presented colletively in the diagram (fig. 5) Such distinct orientation of the longer stone-axes parallel to the morphologic axis of slope affords another reliable proof of the movement to which these deposits must have been subjected. The conclusion is further supported by several other facts, such as the frequent occurrence in the northern wall of the cut of alternate zones exhibiting a predominance of either clay or debris and slight foldings of the material that are indicative of a fluidal texture (fig. 4).

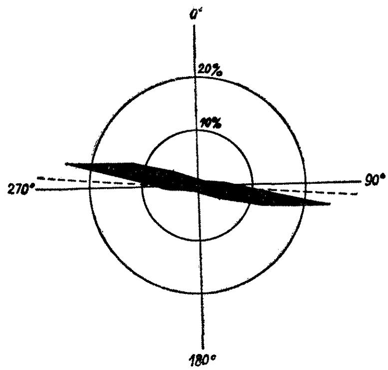

Fig. 5. Congelifluction cover in the pass between the Luling Basin and Sanyihsiang. Orientation of longer axes of debris material

As results from the above characteristics, the cover in question is not an ordinary waste cover *in situ*. Nor can the component material be attributed to fluvial transportation as: 1° neither structure nor texture of the cover suggest such transportation, 2° the cover overlies the pass and slopes down as well into the valley oriented westward in the direction of the Luling basin as eastward into the valley where the buildings of the Institute of Botany are situated.

WEST VALLEY

In the West Valley, by the road to the Devil's Cave in the outskirts of the village of Kuling there is an exposure that had been previously investigated by Yang Huai-jen & Yang Sun-yuen (1958). Along a stretch of 10 m the wall of the exposure undercuts the valley side facing north-west. Here also, like in the previous exposures, Kuniuling sandstone is exposed in the lower part of the profile (fig. 6). It is overlain by and

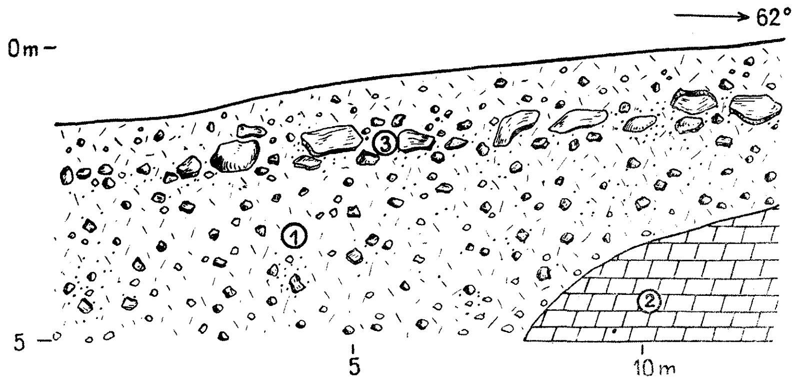

Fig. 6. West Valley. Schematic drawing of exposure with brick-colored congelifluction cover

1. congelifluction cover; 2. boulder horizon; 3. Kuniuling sandstone series

sharply separated from a brick-colored clay and debris-cover. In the top of the cover, the total thickness of which is up to 5 m maximum, the color changes, visibly passing into yellow, which is no doubt a result of weathe-ring. The debris is angular and the longer axes generally oriented in the direction of slope. In addition to clayey mass and rock fragments (3—20 cm in diameter) the cover exhibits a horizon of boulders. It appears at a depth of about 1,0—1,5 m from the surface. The boulders, 0,5 to 1,0 m across, are derived like the rubble from the Kuniuling sandstone series. All the component materials of this cover show a high degree of cementation. Although some boulders are projecting out of the wall beyond their own center of gravity the compactness of the clayey-debris in which they are firmly fixed prevents them from dropping down. In gerenal, the brick--colored covers are as a rule much better cemented that the yellow ones.

Yang Huai-jen & Yang Sun-yuen (1958) have attributed the formations occurring in this exposure to deposition by congelifluction. These authors have also attempted to determine the age of this cover which they ascribe to the Taku (Mindel) glaciation. Unfortunately, the criteria upon which this determination of the relative age of the cover is based, are unknown to the present writer.

VALLEY BETWEEN THE LULING BASIN AND THE DEVIL'S CAVE

On the way from the Devil's Cave to the Luling basin, the new high--road enters a nameless valley through which, according to J. S. Lee (1947) during the Taku glaciation an ice-lobe slided down into the north-western foreground of the Lushan. The south-west facing valley side is undercut by the road over a stretch of about 60 m. The wall, 3—6 m high is quite fresh and sandstone of the Kuniuling series is exposed in its lower part. The surface of the sandstone is vigorously truncated and its line throughout the wall is slightly undulatory. The sandstone is overlain by brick-colored clayey debris.

At the point of convergence of side- and main valley the cover is dissected and can be observed only on the ridges of watersheds. The cover has a varying thickness ranging from 1 to 3 m. The debris material included is angular, only the sharp angels of rock fragments are slightly abraded. Here also the majority of stones shows a preferred downslope orientation of their longer axis. Apart from particles ranging from 3 to 20 cm in diameter, which constitute the essential component, the cover includes also larger rock fragments, 20 to 50 cm across. The wall exhibits several zones characterized by predominance of either debris or clay. Since the cover exposed in only one intersection vertical to the angle of slope, no further details regarding its structure could be ascertained.

Anyhow, the cover in question shows all the structural characteristics of the brick-colored covers occurring in the localities previously described.

Finally, it should be pointed out that all these covers have still another feature in common which is that they occur at an altitude of 900 to 1000 m above sea level.

All the facts presented above i.e. dissection of the covers by temporarily dry valleys, appreciable thickness of the covers as well as several other properties, both structural and textural, testify to the fossil character of these covers. Their genesis cannot possibly be attributed to climatic conditions similar to those prevailing at present in the area of the Lushan. Slope covers of contemporary origin hardly ever attain a thickness exceeding some tens of cm, the weathering material they contain is generally quite loose and shows a well-marked relationship to the weathered surface of the bedrock. Also in color does the debris resemble the parent rock. The only factors likely to be responsible for the formation of such thick, either brick- or yellow-colored covers are: intense mechanical weathering and the gravitative downslope creep of its water-saturated products. Most favourable to the cooperation of these two factors are the conditions offered by a cold and humid climate. Therefore, the only reasonable explanation of the genesis of these covers would be to attribute it to the cold, subnival climatic conditions that prevailed at these altitudes of the Lushan during the Pleistocene glaciations, whose existence has been demontrated by J. S. Lee (1947).

As recognized by the majority of investigators, debris material included in congelifluction covers is as a rule poorly rounded (e. g. Hövermann 1954; Richter 1958) and the fragments are oriented with their longer axis in the direction of slope (Hövermann 1953; Lundqvist 1949; Poser 1954; Richter 1951; Suchel 1954; Weinberger 1954). Thus, considering the fact that slight degree of roundness and orientation of longer axis in the direction of slope constitute the essential characteristics of the debris material of which these covers are built, the writer does not see any valid reason that might argue against their being due to congelifluction.

TENTATIVE DETERMINATION OF THE AGE OF THE CONGELIFLUCTION COVERS

The evidence available, seems to argue in favour of the hypothesis that the congelifluction covers occurring in the northern Lushan originated during two different glaciations. According to the writer such evidence is offered by the following facts: 1° higher degree of lateratization and consequently of cementation in the brick-colored than in the yellow--colored cover (the difference in color and degree of lateratization must be due to a difference in the lenght of time during which the covers underwent chemical weathering, since the material consists of weathering products derived from the same rock i.e. from Kuniuling sandstone); 2° the yellow cover that was found to overlie the brick-colored one in the exposure north of the Luling bridge. Both these facts are sufficient evidence to support the view that the brick-colored cover is older than the yellow one.

A further problem is that of the glaciaitions during which these covers were formed. H. v. Wissmann (1937) has established on the basis of climatic data, that during the last (Tali) glaciation that invaded the Chinese mountains, the snow-line in the Lower Yangtze area could not have extended at a lesser altitude than 2600 m above sea level. Since the mountains of the Lower Yangtze region, among which also the Lushan, are much lower, H. v. Wissmann (1937), followed by J. S. Lee (1947) holds that they could not have been subjected to glaciation.

According to this statement of H. v. Wissmann (1937), the Lushan area was deprived during the last glaciation of the conditions required for the formation of congelifluction covers. Hence, the youthful (yellow) congelifluction cover can not have developed prior to the Lushan (Riss) glaciation and the brick-colored one until the Taku (Mindel) glaciation. There is still another argument that tends to confirm this dating. J. S. Lee

(1947) who applied the criterion of degree of lateratization in the dating of glacial covers, concluded on the basis of a large number of comparative data that brick-colored morainic clay corresponds to the Taku (Mindel) glaciation. The color of that clay is identical with that of the older congelifluction cover.

A comparison of the results obtained by the writer with those of Yang Huai-jen & Yang Sun-yuen (1958) shows that the latter authors correctly ascribed the congelifluction cover occurring in the West Valley to the Taku glaciation.

Finally, in order to complete these considerations regarding the age of the congelifluction covers it might be appropriate to discuss briefly the problem of the snowline in the Lushan during the maximum glaciation. H. v. Wissmann (1937) basing his estimate on the results obtained by J. S. Lee (1947) assumes that during the maximum glaciation (Taku glaciation, according to J. S. Lee) the snowline could not have extended at a higher altitude than 900 m above sea level. H. v. Wissmann claims that such an altitude of snowline is the pre-requisite condition of such piedmont glaciations, as those occurring in the Lushan and other mountains of Central China.

However, the results obtained by the present writer seem to contradict this assertion. It is well-known (Troll 1947, 1948) that the snowline is at the same time the upper limit of congelifluction. In view of the fact that brick-colored congelifluction covers were found in the Lushan at an altitude of 1000 m above sea level, the limit of perpetual snow should be, as it seems raised at least another 100 m.

Translation by T. Dmochowska

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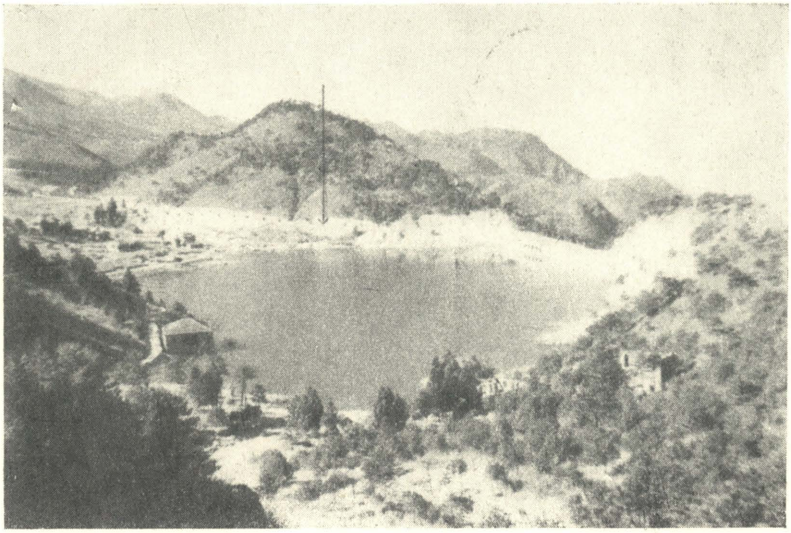


phot. by the author, 1958

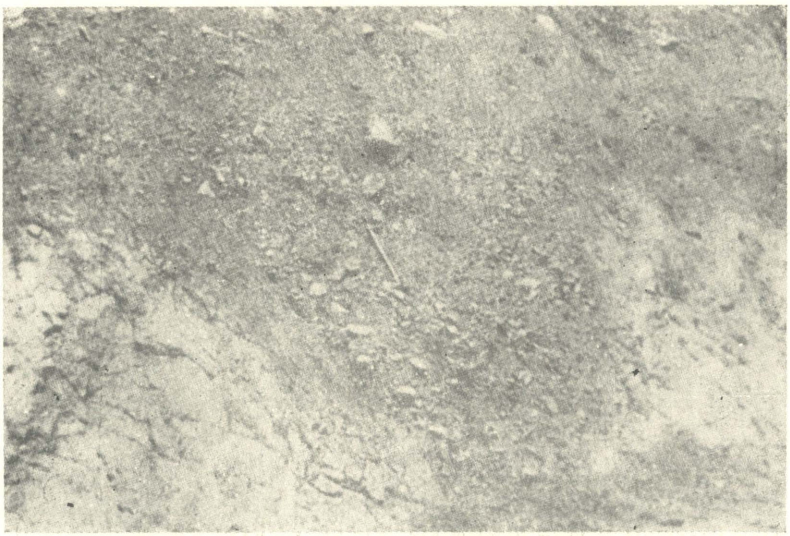
Pl. 1. General view of Luling Basin. The arrow indicates the place of occurrence of the exposure with brick-colored congelifluction cover (south of the Luling bridge)

phot. by the author, 1958

Pl. 2. Luling-Basin. Part of exposure showing brick-colored cover (south of the Luling bridge). Black line marks the contact between cover and Kuniuling sandstone series

phot. by the author, 1958

Pl. 3. Luling Basin. Top portion of brick-colored congelifluction cover (central part of exposure south of the Luling bridge)



from Yang Huai-jen & Yang Sun-yuen

Pl. 4. Luling Basin. Exposure south of Luling bridge. Erosional groove cut in the surface of sandstone and filled with brick-colored congelifluction cover. Yang Huai-jen and Yang Sun-yuen considered it to be an ice-wedge