Geomorphology of Taiwan

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I. Introduction

About two-thirds of the area of Taiwan is occupied by high rugged mountainous districts. The highest peak, Yushan rises 3,997 m above sea level. The peaks around this mountain in the same chain are more than 3,000 m above sea level and form a great barrier (Fig. 1).

In contrast to these high peaks, an abyssal submarine trough 5,000 m deep lies within a distance of several tens of km off the east coast of the island. It has been said that the ruggedness of the topography of Taiwan is believed to be unequalled in any part of the earth's crust. The island belongs to a young orogenic zone which was formed in the Tertiary along the Circum-Pacific geosyncline, and the rugged topography and the complicated geologic structures are due to severe crustal movements, as folding, thrusting and faulting. This complicated structure is reflected in the relief of the land, and very rugged topographic expressions can be found in many places throughout the island. Such a rugged topography is thought to have resulted from the rejuvenation of down-cutting of rivers accompanying the recent uplift. The down-cutting of river bottoms has become more and more intensified and the mountains have become higher and higher, so that the fluvial erosion topography accompanying the land uplift represent practically all the types of topographic expression. Moreover, each topographic form is preserved very clearly so that for any one who wishes to study geomorphology, Taiwan is thought to be the best for field work.

The fluvial erosion topography accompanying the land uplift can be classified into "old" and "young." It remains to be decided whether the old and young topographies were formed during continuous uplift or whether the two are divided by a period of pause. In some cases, consideration must be given to other influencing factors in the activity of river cutting during the time of land uplift. The differences of hardness of rocks also must be considered. It is not always an easy matter to explain the order of development of the topographic groups which have been formed up to the present even though each retains its characteristic form. Besides uplifted topographic types, in various places some land forms remain which had existed before the land was uplifted. These topographic forms, combined with the

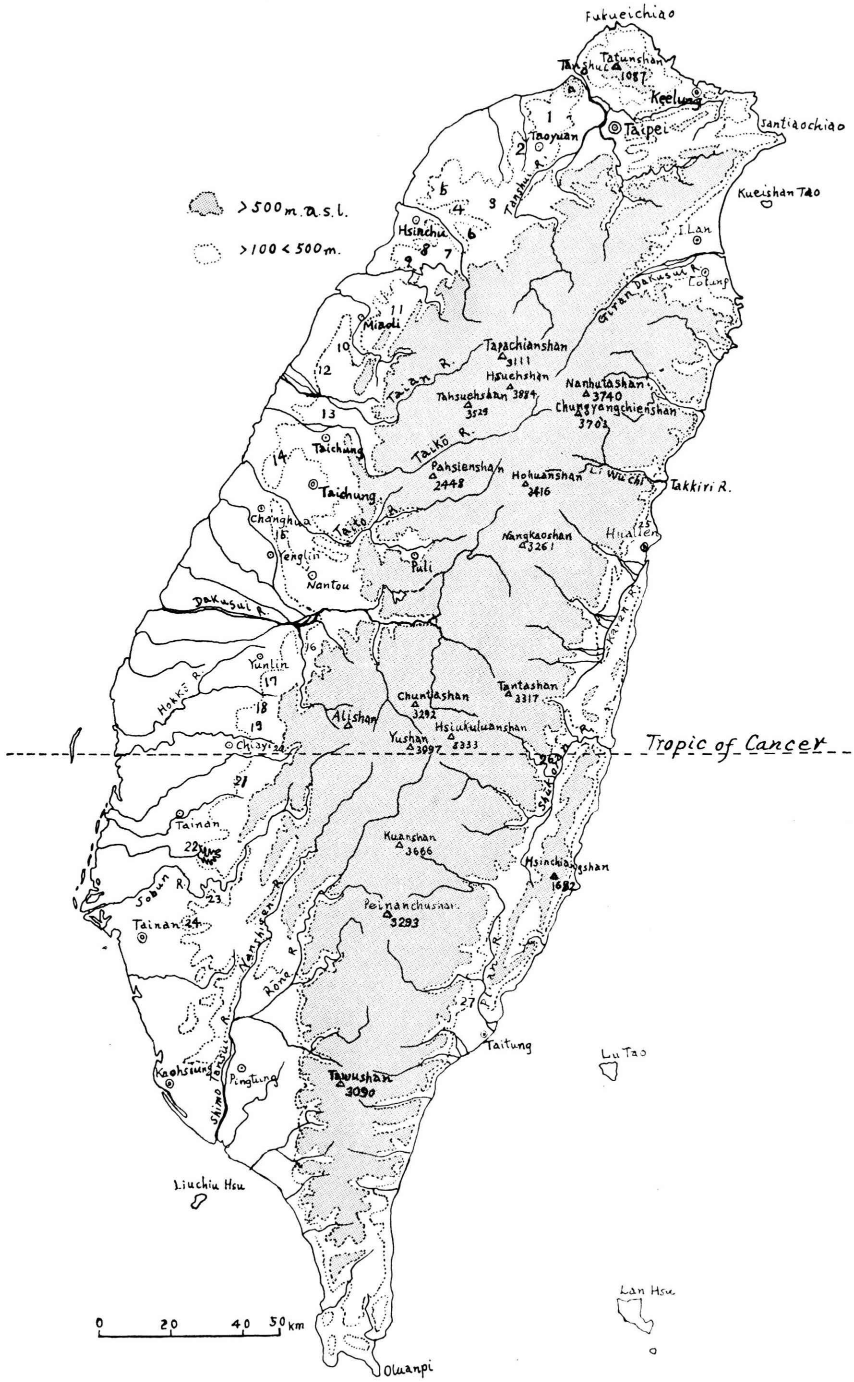

Fig. 1. Relief Map of Taiwan.

development of the submarine topography in the nearby Sea of Taiwan, are to be taken into account for a startling episode in the history of physiographic development.

Herein, I intend to discuss the geomorphology on the bases of data furnished by the actual land forms in their limited sense. In a broad sense the geology should be considered before the topography, and the original topography should be discussed by tracing past geologic time, starting with the deposition of formations and their later denudation. These discussions, however, belong to the sphere of historical geology rather than the sphere of physiography so that in their place I intend to discuss the very recent history of physiographic development in a rather narrow sense.

II. Kinds of Fluvial Erosion Topography and their Correlation

Among various fluvial erosion topographic groups, one of the most noticeable features in lowland districts is the steep slopes. But as mountainous areas consist mostly of slopes, the noticeable feature is, conversely, flat surfaces or gentle slopes. If the study is pursued along the line of how and in what order these surfaces and gentle slopes were developed, and if the study is linked with other developments of topographic forms, then the sequence of topographic development of the whole mountain zone can be elucidated. The flat surfaces and gentle slopes are particularly important, because these land forms are not only prominent in the mountain topography, but at the same time they serve to correlate one form with another.

In the mountain zone of Taiwan, the flat and gently sloping surfaces that are situated in the lower position consist of river terraces or alluvial fans, but those located in high places consist of mountain spurs and shoulder-shaped plane surfaces or ledges developed on the mountain spurs, or gently sloping surfaces as are developed on the mountain sides. At the same time, a flat plane on the crest of a high mountain is thought to be a remnant of a flat-topped peak. The mechanics of the formation of flat and gently sloping surfaces are varied, but confusion must be avoided at the time of correlation so that first the classifications of land forms must be made clear in each case (Tomita, 1939, 1941).

A. Fluvial Terraces

The topographic surface that is the most typical as well as the most common feature is the fluvial or river terrace. Moreover, the fluvial terraces often occur as several step-like forms at one place and their formational sequence is shown clearly, and is important study material for the standardized classification of topographic forms.

The fluvial terraces observable in Taiwan can be classified broadly into two types on the basis of topographic forms, namely "higher and lower terraces." The classification of these two types of terrace surfaces is based first on the relative height from the river bottom; second, by the grade of dissection of the terrace surfaces is based first on the relative height from the river bottom; second, by the grade of dissection of the terrace surface, third, by the kinds of rock and soil which compose the terrace surfaces. First, as to the relative height, the kind of terrace can be determined roughly if one draws a longitudinal section of each river bottom then projects it to the terrace (see Fig. 2). However, the relative height formulated by this method occasionally may be almost worthless for correlation. The first reason for this may be due to the knickpoint (Wendepunkt). The second reason is more common: a narrow canyon is often dammed by a landslide, and a lake is formed in which material is deposited. If this lacustrine deposit subsequently became land the terraces may have been formed by the progressive dissective activity of rivers on this older lacustrine deposit.

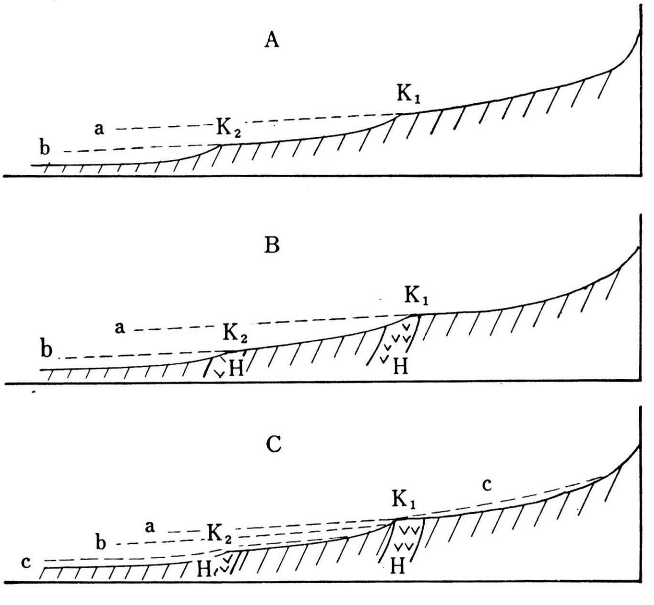

Fig. 2. Hypothetical Longitudinal Profile of a River Bottom.
K Knickpoint H Hard rocks a,b,c Terraces

As the knickpoint can be drawn on the longitudinal profile, it indicates the steep slope at a certain point on the river bottom. That indicates (1) a lowering of the base level of the river or, conversely, uplift of the land; or (2) an increase of flow in the river, the increase being due to an increase in precipitation because of climatic change or enlargement of the drainage area by capture or by joining of tributaries; (3) the existence of rocks that have a higher resistance against erosion. These varying factors play independently or in combination.

In Fig. 2–A, the location of the knickpoint is determined only by the seocnd uplift so the point moves gradually upstream and the portion below the knickpoint forms two step terraces, "a and b," representing a part of the river bottom before uplift B was started. Then the position of the knickpoint was determined by the presence of hard rock formation. But the appearance of a and b terraces formed by the second uplift is the same as in A. In each case, the uplift, or in other words, the lowering of the river base level, is achieved, so that upstream from the knickpoint a nondissective equilibrium drainage channel is created. In C, equilibrium is not achieved in the upper drainage channel, so cutting of the river bottom continues, as is often visible in Taiwan. In this case terrace surface a below the knickpoint K_1, as is shown in Fig. 2, originally formed the balanced drainage channel with the new low terrace plane c upstream from K_1. Therefore, this plane is considered as the same land surface. But on the basis of the time of formation of the land surface, terrace plane c was recently formed by advancement toward the upper stream channel through further down-cutting, crossing over the knickpoints $K_{1\text{-}2}$ after the formation of terrace planes a and b. A good example of this type of terrace is observable in the terraces on the bank of the Rōnō River (Fig. 3).

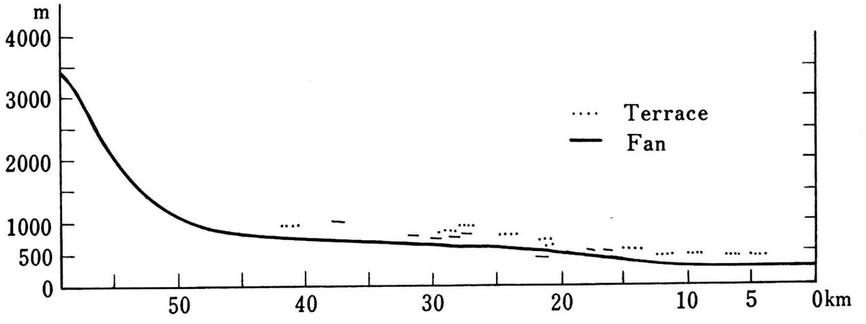

Fig. 3. Profile of the Rōnō River with Terraces and Fans.
A Convergence of knickpoint B Divergence of knickpoint

The relation between the times of formation of the young and old terrace levels on the one hand, and the differences in height of plane on the other may not be conformable in some cases. For example, in case the graded river channel as has been attained before the uplift of the terrace plane a at K, in Fig. 2–A, the river floor farther upstream must be looked upon as the same topographic plane. If, however, the river did not maintain a drainage channel at equilibrium, the down-cutting activity in the river channel above the knickpoint might have continued and the terrace forming process might have been continuous even after the uplift. If the uplift movement affected the entire drainage area and the land showed an increased tilting movement, the gradient increased throughout the drainage area, and the terrace-forming process was much activated by the simultaneous down-cutting process of the river. As a result, the formation of terraces increased. The age of terraces and the topographic positions have no relation, so that in the terraces connected with river valleys, the degree of dissection and the topographic position are considered as different problems..

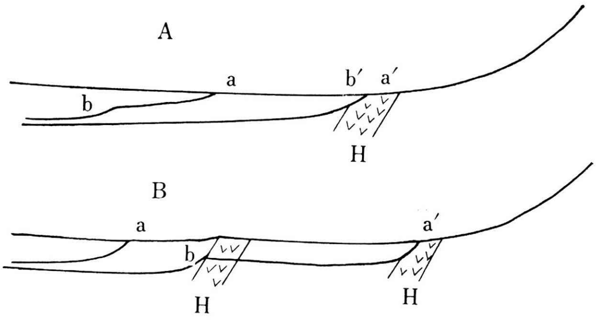

Fig. 4. Hypothetical Longitudinal Profile of a River Bottom Showing Convergent and Divergent Knickpoints.
H Hard rocks

The next case is that the knickpoint is located at a place where hard rock is exposed. The knickpoints are formed at the two points a and b by two successive elevations in case A, as shown in Fig. 4. The progressive dissective activity was retarded by the presence of hard rocks, and the knickpoints a′ and b′ have been combined into the knickpoints a″ and b″. Or as indicated in B, only one knickpoint was formed by a single uplift, but it has diverged into two knickpoints where hard rocks are exposed in two places just as if two upliftings had occurred.

The correlation of the terrace planes formed by the above-mentioned processes is very complicated and is difficult to explain plausibly. However, it is not always complicated nor strange, and its explanation may not be difficult. But precaution must be exercised in order to evade the major fallacies incurred by a simple judgement based on the relative height in the topographical map and the degree of river dissection.

In order to determine, on the basis of a profile of the river bed, how far the present river bed is from the profile of equilibrium, and where the point of change in gradient is located, as well as to compute the amount of uplift and the relative height of the terraces from the past equilibrium channel, an equilibrium curve should be drawn for each river (in its state of equilibrium). In the computation, it is considered very convenient to use the logarithmic curve formula proposed by J. F. N. Green (1936).

$$y = a - k \log (p - x)$$

p = Length of river channel
a = Height of headwaters
x = Distance of a given location of river floor from the mouth of river
y = Height of river bed at location x
k = Constant (see Fig. 5)

The surface of the fluvial terrace is regarded as a base plane of a river bed as compared to the topographic plane. All the river terraces, however, do not always represent the basal plane of drainage channel of equilibrium so that it is necessary

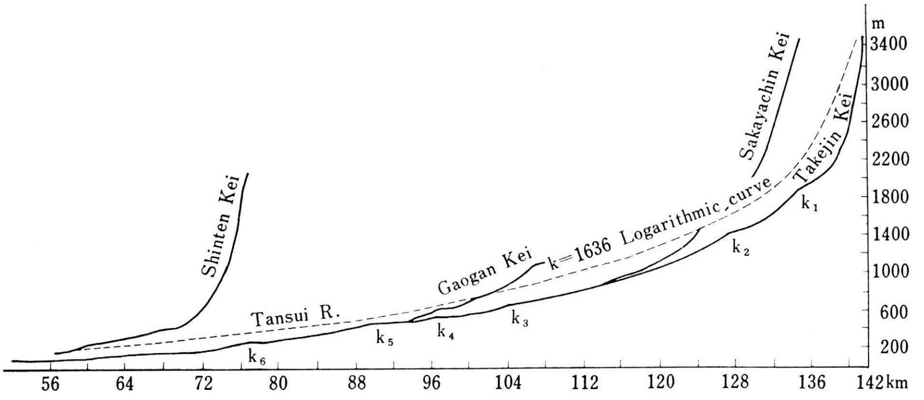

Fig. 5. Profile of Water Courses of Tansui River and the Approximate Logarithmic Curve.

to study what kind of river terraces one is dealing with. In order to select a suitable terrace plane for study, it is necessary to have some appropriate classification.

Bruno DIETRICH (1911) proposed to broadly classify terraces into "durchlaufend Terrasse" and "Lokal terrasse." The former are arranged continuously along the drainage channel, and its terrace plane is considered to indicate the "ruhe phase" of the previous river bed. The latter is only of local distribution so he contended that it has only a secondary significance in geomorphology.

De la MOTHE (1915) divided the terraces into "terrasses de régulieres ou du principales" (principal terraces), "terrasses de secondaires" (secondary terraces), and "fausses terrasses" (false terraces). The first two conform with the classification proposed by DIETRICH, but the third, "fausses térrasses", are those formed by the retrogressive dissection of the main river on a portion of the alluvial plain or fan (deposited by a tributary) at the point of confluence of the tributary with the main river bed. These terrace planes do not indicate a part of the main river bed. E. CHAPUT (1924) called the terraces developed on both the Seine and Garonne Rivers "terrasses polygeniques." These indicate a series of equilibrium phases (due to a series of uplifts), but in this case show a continuous sloping terrace plane resulting from several phases of equilibrium completed after a series of uplift movements. They correspond to the so-called slip-off slope (formed by incised meanders). This type of terrace is also the same as that of the "amphitheatre terrasses" proposed by H. MILLER.

J. HANSON-LOWE (1938) has proposed the following new classification:

Significant terraces	Principal erosion terrace Principal aggradational terrace
Relatively insignificant terrace	Secondary, or meander terrace False terrace (slip-off slope terrace)

I propose the following classification which is based on the idea that the terrace surface indicates a topographical plane formed at the base level of the river as a standard.

Standard terraces...............	Perfect / Partial	Standard depositional terrace / Standard erosional terrace
Subordinate or Supplementary terraces	Meander terrace Slip-off slope terrace Fan terrace False terrace Polygenic terrace	

A terrace used in topographic correlation must be, at least, a standard (key) terrace. Of course, it is rather rare to find a terrace that can be traced completely along the major part of a river channel of equilibrium. Thus, in most cases we have to select certain standardized terraces of a partial nature.

Subordinate terraces developed along the river channel of equilibrium may be correlated with those mentioned above by using the curve of equilibrium as an accessory medium. The meander terraces often retain the value of partial standard terraces. In the slip-off slope terrace, each surface is more or less flat, as is observable along the middle portion of the Tansui River. In the vicinity of the entrance of the Kappan-san Canyon or Rahau, each surface appears roughly level so it can be said to have the quality of a partial standard terrace as long as it is bounded clearly by a terrace scarp (see Fig. 6).

A fan terrace is formed by the interaction of a tributary with the depositional processes of the main river. Its surface extends downstream along the main river bank from the point of confluence, so that it looks extraordinarily prolonged. It might be said that the fan had been converted into a terrace.

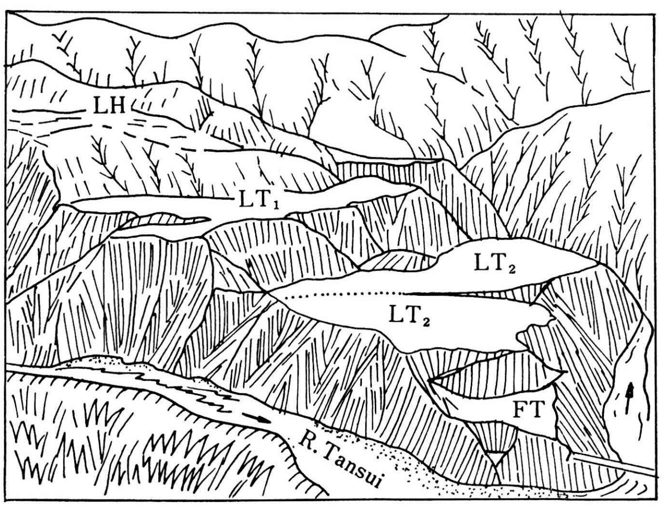

Fig. 6. Keikōdai Terraces Opposite Kappanzan.

A fan may even become an accessory to a standard terrace formed at the point of confluence of each tributary, as is the case of the upper part of the Girandakusui River. Herein is a very good example that the relative height of each terrace does not always indicate relative age. In Takkiri River on the east coast of Taiwan, there is a terrace called Burowan terrace on which an aborigine village of the same name is situated. The Burowan terrace is situated on the southern foot of Sangetsu-kyō (bridge) at the bottom of the famous Taroko canyon near Batakan. The terrace is situated 400 m above sea level and the present river bed stands at about 200 m, thus, the relative height is 200 m. On the basis of relative height, it belongs to the highest terrace group in Taiwan. Thus, it definitely can be called a higher terrace. However, when we glance over the terrace surface, there is practically no residual weathered soil; it is composed wholly of those gravels constituting the flood plain near the present river bottom. Moreover, the terrace surface is divided into two horizons by a well-defined terrace slope 5 m high. When one climbs over the slope, it crumbles easily and does not show any difference in composition from the slope formed in the terrace near the present river bottom. The terrace gravel is composed of roughly uniform pieces of crystalline schist and sub-angular flat slate smaller than a human fist. Below the Burowan terrace there is a narrow terrace having a relative height of only 20 m. The gravel composing this terrace is limestone (crystalline) and the gravels are cemented with matrix so that the terrace looks somewhat old.

Thus, in the observations based on the depositional nature, there is an inconsistency in that the higher terrace has a much younger aspect in comparison with the lower terrace. In this case, my interpretation is that a landslide occurred some place in the lower part of the canyon below the Burowan terrace and the river was dammed and formed a lake. As the bottom accumulation proceeded, redissection commenced and the majority of the dry lake surface eroded away. Only a small part remains as the present Burowan terrace.

The formation of terraces due to damming of the streams by landslides are common phenomena, especially in places where rejuvenation of erosion is very active and deep canyons are formed. It is not difficult to conceive that such slides or dislocations very frequently occur on both the river banks as dissection advances. The best example of this is [lake] Sorei-tan or Seisui-tan which was formed by a landslide on the right bank in the upper stream of Seisui River, a tributary of the Dakusui River, as the result of a strong earthquake which occurred in December 1941. This dammed lake had an area of 6.6 sq. km, so that it was wider than the Jitsugetsu-tan (4.4 sq. km) the largest intermontane lake in the island. Such a lake was called a "seismogenetic lake" by HAYASAKA (1947), and when this natural lake formed by a landslide is stabilized, the water can be utilized for generation of electricity. Under the Japanese regime, a survey was made to determine whether it would stand permanently or not. In May 18, 1951, this natural dam was destroyed by an enormous increase of water brought by heavy and long rains. This catastrophe resulted in 150 deaths. Great property damage was inflicted by the inundation of paddy land in that area. It is thought that since the destruction of the dam a new lake shore terrace might have been formed. It was reported that a strong earthquake which occurred on October 22, 1951, in Karenko resulted in the formation of a seismogenetic lake as a result of a landslide on the Takkiri River. Detailed information as to the location and extent of damages has not been confirmed.

In the correlation of terrace surfaces, chief consideration must be given to the nature of the material composing the terrace planes, the relative height, and the degree of dissection. Of course on all gravel terraces and even rock terraces, the erosion surface of terrace is usually covered with a thin gravel bed. When a terrace is old, the gravel of the terrace surface is decomposed and the upper surface is usually covered by residual soil. By the degree of weathering of a terrace surface, it may be possible to judge the relative ages of the terraces. On both the higher and lower terraces which have been classified in Taiwan, the gravel in the lower terrace is identical with that of the flood plain because it has not been weathered and is not cemented with matrix or coated with limonite. The surface terrace gravel is only slightly covered by thin transported sand and mud. In higher terraces, on the other hand, the gravels are somewhat weathered and usually impregnated with limonite without having been consolidated. Of course, the surface is covered by lateritic soil but the boundary between the gravel bed and lateritic soil is clearly marked. It has been suggested by HILGARD (1911) that the lateritic soil is a subsoil formed through the permeation of colloidal clay by rain water, under the prevailing climatic conditions of high temperature and humidity; and that it becomes soil through the process of lateritization. The lateritic soil widely distributed along the terraces of Taiwan has a higher silica content than the laterite of tropical districts. The name lateritic soil was proposed by Kisaburō SHIBUYA (1922) in Taiwan, but Eitarō SEKI called it a red loam. The process of lateritization has a tendency to decrease the silica content but it is said that the loam-forming process has a tendency to gradually increase the silica content. There are two theories for the formation of lateritic soil of Taiwan; one is that the laterite forms through the loam-forming process, and the other is that the loam is formed during the lateritization process.

Both the higher and lower terraces cannot always be distinguished clearly, for when a series of terraces are arranged in a step-like form, there is a terrace which may be assignable to an intermediate type. This type of terrace is found in the middle of Unrin Pref., south of Chikuzan district (Nantō Pref.) where a group of terraces are formed around hills by the Dakusui River and its tributary on the south, the Seisui River. The top plain of these hills form an undulating dissected tableland. The surface of the terrace is covered with a thick reddish-brown surface soil, below which lies a lateritic subsoil. In the terraces 2 to 3 steps below, the top soil becomes thinner and at the same time the reddish tint fades. The more recent soil grades from reddish brown to yellowish brown; on the lower terraces, a dark-brownish soil is formed, and no trace of weathering of the gravel bed is visible.

An intermediate terrace is recognizable in the middle part between the higher and lower terraces.

It is relatively rare to see terraces arranged in 5 to 6 steps at one place. Even in such a case, it is possible to determine by the degree of weathering of the gravel bed whether the terrace is assignable to a higher or lower terrace, so that it probably is not necessary to make an intermediate division.

What comes into question here is lateritic soil which constitutes the surface soil of the higher terraces LT. It is impossible to regard the lateritic soil as a residual soil resulting from weathering of the top layer of the underlying gravel bed. In the gentle slope of lateritic soil which is topographically situated above the higher terraces, as will be stated later, the lower part of the lateritic soil bed often contains lateritized gravel due to weathering, leaving only the outlines of gravel grains. So, the boundary between the gravel bed and the lateritic soil bed is indistinct. In the higher terraces, however, the boundary is distinct, as already mentioned, which shows that the lateritic soil is not a product of weathering in the underlying gravel bed. It cannot be considered, however, that the lateritic soil was washed down from the lateritic soil slope in a higher altitude and was redeposited. It would be appropriate to attribute the sedimentation of lateritic soil to permeation and diffusion, as HILGARD maintains.

As mentioned before, when we regard river terraces as criteria in the correlation of topographic surfaces, we must consider the existence in Taiwan of two terrace surfaces, the higher and lower. For the sake of convenience in correlation, the former is designated tentatively as the LT surface and the latter the FT surface.

B. GENTLE SLOPE SURFACE COVERED WITH LATERITIC SOIL

As mentioned before, the upper portion of the higher terrace in Chikuzan is shown by the hilly land of a dissected tableland and flat surfaces are retained locally. In a broad sense, an undulating land surface is formed. We glance over the nature of rock formations: gravel beds cover the erosion surface of the Shinchiku series of the Tertiary system and the upper part of the gravel bed is converted into the lateritic soil. In the lower part of the lateritic soil bed the gravels still retain their form but their composition is totally changed into lateritic soil or to yellowish clay. The gravel is composed mostly of slate, sandstone, and siliceous sandstone, but because of the effect of weathering the nature of the gravel is not recongnizable. The gravel grains are almost wholly cemented and the cementing material has also been laterized. The boundary between the lateritic soil and gravel bed is not clear. As mentioned before, there is a point of marked difference between the lateritic soil slope surface and the higher terrace surface. In this place this gentle slope surface of lateritic soil is used tentatively as the former topographic surface and is called the "LH surface." This gently sloping LH surface is not only widely distributed in the tableland on the west consisting of the lateritic soil bed thickness of 5 m or so, but such surfaces are widely distributed from the upper portions of the river valleys to the mountain slopes throughout the island.

Notably, those situated on the mountain slope are now the aborigine villages for the mountain people of the "Takasago tribe." These villages are distributed in places with heights ranging from 1,000 to 1,500 above sea level in the north and central parts of the island.

In the southern part, however, these zones of gentle slope gradually decrease in altitude and height, and they attain a height from 300 m to 500 m. As these places are in a purely tropical climatic environment, the amount of rainfall is more than in the plains of the lowland areas, and foggy days are numerous so that the areas become a humid zone. Under this climatic condition, the areas became a focal point for pharmaceutical enterprises, including the quinine plantation of the Hoshi Pharmaceutical Company and the tropical medicinal plantations managed by such pharmaceutical companies as Takeda, Meito, and Shionogi.

In the northern and western parts the sloping surface of lateritic soil become gradually lower and grade into the tableland covered by the lateritic gravel bed mentioned before; at the same time the height is also lowered. The Rinkō tableland surface in the north attains a height of 200 meters. The original surface of the Tōen tableland links with Nyūko-zan (389 m), extends to the Taito tableland, Hakkei tableland, Shokkō tableland, and to the dissected Nantō tableland through the hilly areas of dissected tablelands including the Chikutō, Chikunan, and Byōritsu tablelands.

In the vicinity of Kagi, the tops of low hills composed of lateritic gravel beds and encroaching onto the Kanan plain can be correlated with these tablelands, but these low hilly areas are postulated as being due to the land tilting. Farther toward the south where the area approaches the south bank of the Sobun River by way of the Kanden River a remnant of the original gravel tableland is clearly visible in the vicinity of Kiriga where it attains 160 m in height. This tableland, called the Shinka dissected tableland, is correlated with the tableland situated in the vicinity of Kizan. Farther toward the south, the Shinka dissected tableland can be correlated with the dissected limestone tableland of Hozan about 100 m in altitude and it terminates in the limestone tableland near Kontei on the Kōshun peninsula and the Byōritsu tableland surface. To the north, it is also possible that gentle slopes on the sides of both the north and south summits of Mt. Daibu can be correlated topographically. On the top of the summits grouped on the east slope, a series of flat surface still remain. The best example of these flat-topped hills is that of "Chyokakurai" which stands about 700 m above sea level. This place is the site which has been utilized as a medicinal plant farm land as mentioned before. A quinine plantation of the Hoshi Pharmaceutical Company is located on the gently sloping surface above the Chippon hot spring to the north. This sloping surfaces are dissected consequent rivers, but these surfaces are developed in a narrow and long belt in the area extending from between 300 to 500 m in altitude. During the war a nursery of quinine trees extending for several km was developed on these surfaces.

In the Taito rift valley on the east side of the island, the gravel tableland of

Pinan in the southern part, the gravel tableland of Mizuho, in the middle, and the gravel tableland of Beiron-san near Karenkō in the northern part are all topographic surfaces which may be correlated. As remnants of gravel-covered tableland are found near Tamasato, Taishō, Tōjimpo, and the area between Shinkaien, and Raikōka, Hinode, it is probable that the faulting in this rift valley occurred before the accumulation of the tableland gravel. Hence, these gravel beds are alluvial fan deposits formed after the faulting or they may have accumulated after the dis-

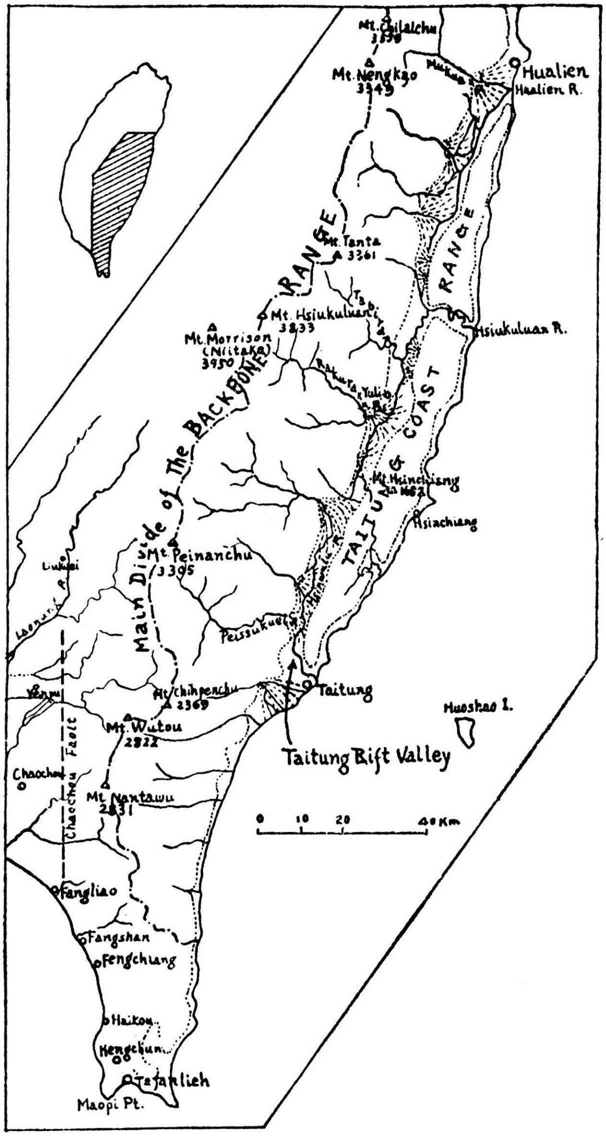

Fig. 7. Alluvial Fans in the Taitō Rift Valley.

section process was completed. The faulting was repeated and the alluvial fan-shaped land forms we now see were developed.

The physiographic development of the Taito rift valley is considerably complicated. It is probable that the graben structure was formed by the faulting in the beginning of the Pleistocene epoch, the fan-like accumulations were formed, and by subsequent dissection a subdued topography has developed on the gentle slopes of the lateritic soil. Following this episode, uplift at the end of the Pleistocene brought about deep dissection of the alluvial fans, and local remnants of the fans have been changed into the gravel-covered tablelands. On the other hand, it is considered that the faulting accompanying the land uplift caused the present land form resembling an alluvial fan (Fig. 7).

The Taito mountain range is a range of extreme dissection; it shows a topographic form recalling a skeleton mountain range composed of hard and compact rock such as limestone intercalated with the Tertiary system or agglomerates of basic andesite. The development on the mountain side of gentle slopes covered with lateritic soil is rare. However, on the west slope of the central area at Mt. Rokujukkoku, a flat surface of considerable width is covered with lateritic soil. Commonly, in the mountain systems of Taiwan, the latiritization process extends into a considerable depth and is weathered into the lateritic gravel bed, but in the Taitō mountain range such a feature is exceptional. These flat surfaces are lumbering locations and the exposures along the sides of the timber haulage roads expose the rock formations so that observation is facilitated.

Generally the lateritic gentle slope surface (LH), as is developed on the mountain side, can be interpreted as the penultimate form of the pre-subcycle of erosion and its form apparently similar to cirques due to ice erosion in the slope surface. Such shallow hollows are often recognizable in the topographic surface at the head of valley (Figs. 8 and 9). This kind of concave slope resembles a crate which is

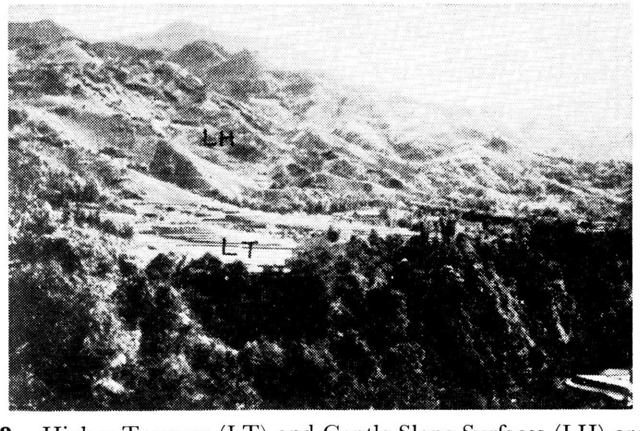

Fig. 8. Higher Terraces (LT) and Gentle Slope Surfaces (LH) around the Upper Stream Region of the Tansui River Viewed from Kara Village to the Southwest (Ibao River Side).

Fig. 9. A Concave Slope (LH) of Yōrō Village in the Upstream Region of the Tansui River (Sakayachin River).

commonly used for the transportation of soil or a farm implement a sort of bamboo basket known as "punki" in Taiwan, so that in the term applied to the geographical name Funkiko, ko means a basin plain. A station name "Funkiko" of the Arisan Railroad Line is derived from "Punkiko." In any case it indicates the topographic feature.

According to Walther PENCK (1920) in his essay on the developmental processes of concave slope surfaces, such a concave form of sloping surface is developed in the interval between the pause and the subsidence. Such a landform, then, can be correlated with the convex slope of a surface which was formed during the period of uplift. I observed the topographic surface which has developed in the piedmont area of Hainanto in South China and compared it with that of Taiwan (TOMITA, 1944). This concave sloping surface covered by lateritic soil is considered to have been formed during the period turning from the pause to a period of subsidence.

The topography of the original surface of the gravel tableland, as is developed in a broad area on the western part, also may be correlated with the above-mentioned gently sloping surface covered by the lateritic soil. A shallow and wide valley shows a trellis drainage system peculiar to river valleys dissecting cliff margins. Thus, the original surface of the tableland must have been undulating, but it is distinct that a valley rejuvenated due to the recent uplift has cut into the wide and shallow valley of old age until a valley-in-valley topography developed, as is clearly manifested in the Rinkō tableland on the north. (TOMITA and WATANABE, 1931; TOMITA, 1932)

Fig. 10. Ledge (L) on the Left Side Spur and Gentle Slope Surfaces (LH-plane) around the Upper Stream Region of the Tansui River (Sakayachin River).

C. Ledges on the Mountain Spurs

A prominent development of an ingrown meander is found from the middle to the upper portion of the drainage course in each river valley of Taiwan, especially along the Tansui River, Taikō River, Dakusui River, Sobun River, Nanshisen River, Rōnō River and Dakkō River (the last three rivers are tributaries of the Shimotansui River). Here, extensive slip-off slope terraces are formed, however, in the upper stream valleys, the mountain spurs are linked with the shoulder-like plane (ledge), as remnants of slip-off slope terrace can be seen. This ledge was originally termed a slip-off slope terrace, but as the downward dissection advanced the terrace surface narrowed, and at the same time the relative height increased. The result is that the summit of practically all remnants stand as a horizontal line which can be termed ledge surface (Tomita, 1937A, 1938A) on the mountain spur (Fig. 10). Most of ledge surfaces can be correlated with the high terrace surface, but in the upstream area of the Taikō River they can be correlated with the lateritic soil slope surface (LH-plane). It is true, however, that another terrace surface stands higher, but the nature of the higher terrace makes determining its position difficult.

D. Ecktreppe Topography

In the upstream area of the Taikō River, on Heigan-san and in the vicinity of Saramao there are 4 to 5 step terrace-like flat surfaces. These are found in the interfluvial areas at the point of confluence of the Taikō River and its tributary the Nanko River, and between Gōkan River which drains from the south and joins the Nanko River. These terrace-like flat surfaces on spurs were named Eckflur by J. Sölch and the eckflur arranged step-like on a spur was called ecktreppe (Sölch, 1918). On this spur of interfluvial district, narrow and long planes run in step-like extending from the northeast between the Taikō River and

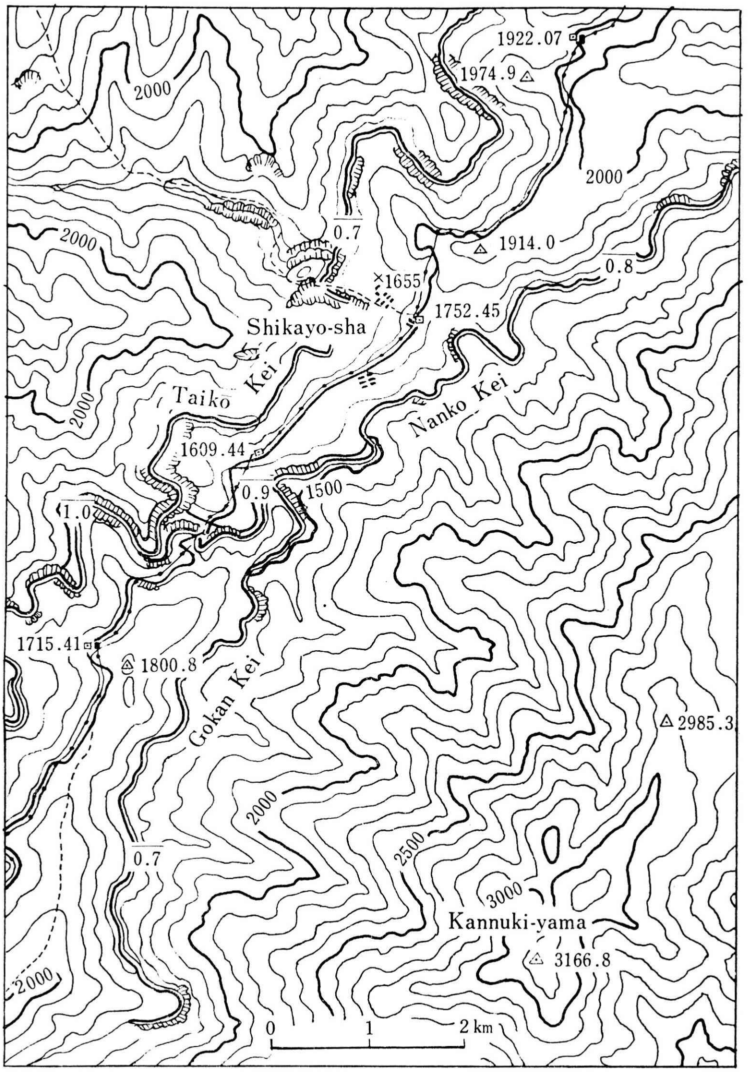

Fig. 11. Ecktreppe Topography along the Taikō River.

Nanko River called the Heigan-san spur, and one called the Taboku-oné or the Taboku spur extends from the southwest between the Taikō River and Gōkan River. On the Heigan-san spur there are five stepped flat surfaces at the following heights: 2,100–2,080, 2,000–1,900, 1,900–1,780, 1,780–1,600 and 1,580–1,540 m. These flat eckflure surfaces form an ecktreppe. On the Taboku spur there are four stairs as follows: 2,000–1,800, 1,780–1,760, 1,740–1,720 and 1,540–1,500 m (see Fig. 11). In each eckflur, the lateritic soil rests on the gravel bed. The gravel bed situated below the second stair has not been cemented so that they can be correlated with the surface of the higher terrace, but the first stair is considered to be correlated with the gentle slope covered by the lateritic soil. In the third stair of the Taboku Spur, the beds of sand and clay overlying the gravel bed indicate that the rivers of that time were sluggish.

Such ecktreppe is interpreted by J. Sölch (1918) as being formed due to the merger of river valleys. If that is the case, the process might have taken place in the

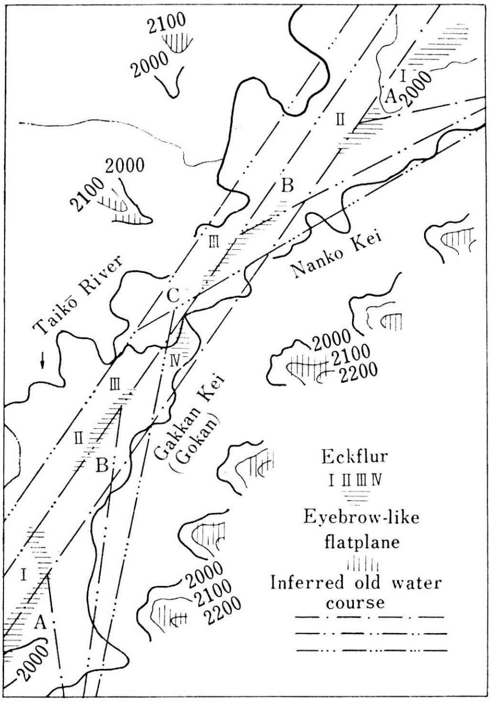

Fig. 12. Formation Process of the Ecktreppe of the Taikō River.

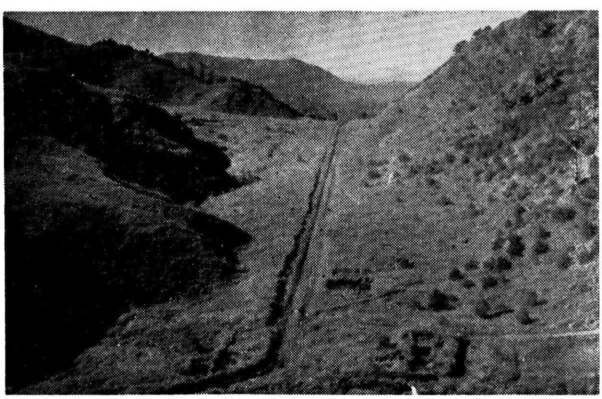

Fig. 13. Wind Gap of the Pianan Pass in the Taikō River Valley. Hills on Right Side are the Dissected River Terrace (LT-plane) Covered with River Gravel.

manner indicated in Fig. 12. It is considered to be reasonably explained by the mündungsmäander (confluent meander) proposed by I. MOSCHELES (1922). Examples of ecktreppe topography which has been formed through such a procedure

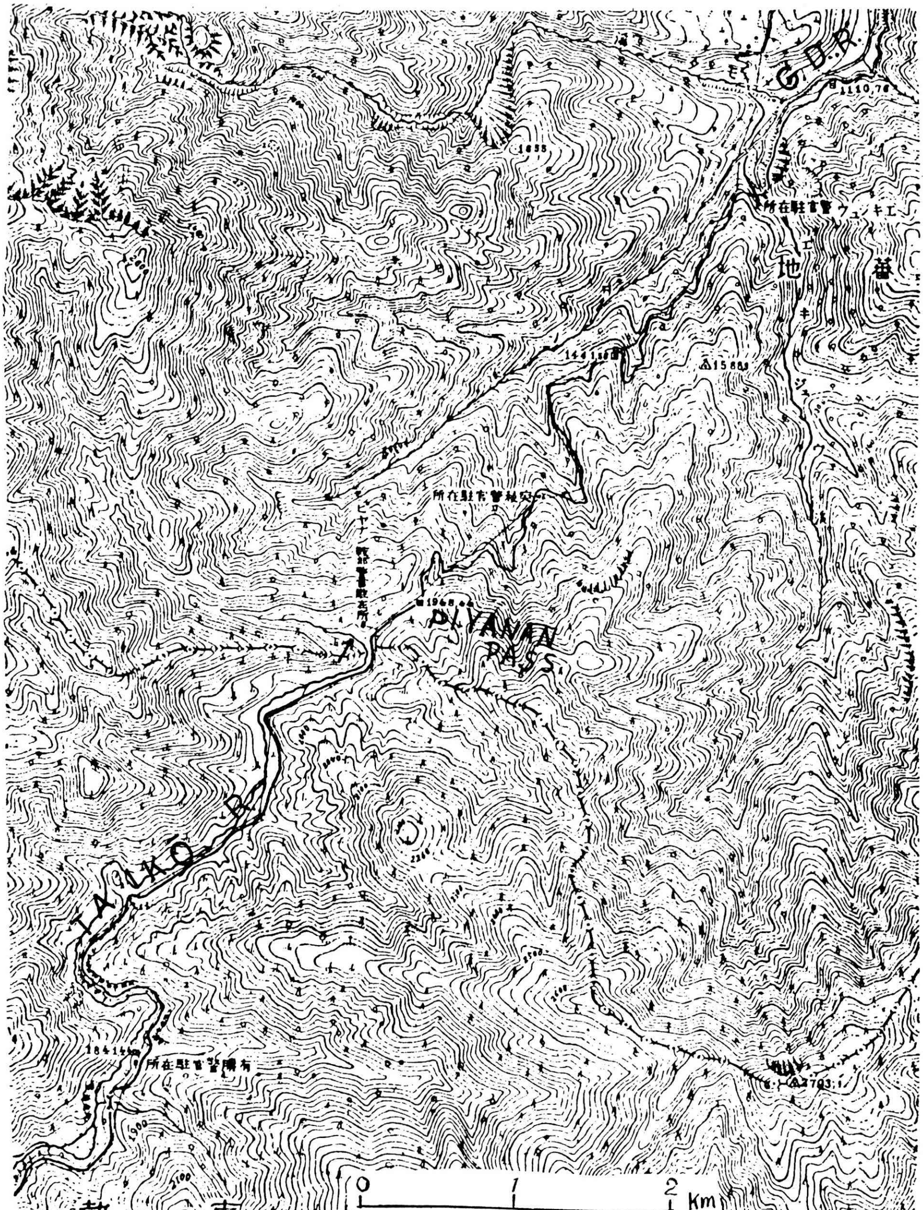

Fig. 14. Main Divide between the Taikō River (SW) and Girandakusui River (NE). Arrow in the Center of the Map Shows Wind Gap in Fig. 13.

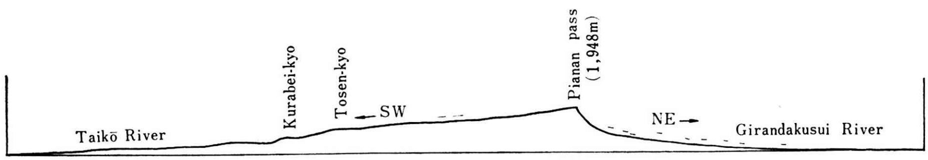

Fig. 15. Profile of the Taikō River and the Girandakusui River.

should be found in other river canyons in Taiwan, but so far as we are aware no such form has been found up to the present. At least, a type on such a large scale as that of the Taikō River may not be found on other rivers. The reason may be attributable to the fact that the river-valley topography developed on the Taikō River is different from other river valleys. That is, in the upstream canyon of the Taikō River, the valley remnant of the equilibrium channel of the pre-subcycle of erosion has prevailed for a much longer time than any other river. In addition, it shows a notable difference from the Girandakusui River which takes a NE direction from the divide (see Figs. 13, 14 and 15). A reasonable explanation is that in the middle part of the Taikō River there are two great canyons, Kurahei and Tosen-gorges which have sharp knick point so that down-cutting of the river bed has been prevented by these two turning points in spite of recent uplift.

Consequently the equilibrium channel in the upstream part of the Taikō River may represent an old topography. It is also verifiable on the basis of faunal distribution, as the habitat of the so-called "saramao" trout is exclusively confined to the equilibrium drainage channel after Wülm (4) (the name of this trout is derived from the aborigine village of the same name which is an important village situated near Heigan-san). In the present river bed, however, downcutting due to the recent uplift extends to just above the village of Saramao beyond the canyons of Kurahei and Tōsen-kyō, as is substantiated by the presence of a "umlaufberg" at Saramao where the old river bed is 40 to 50 m in relative height.

E. Denuded Planes in High Mountains

It has been known that flat or gently sloping surfaces are found in far higher places than the lateritic slope surface mentioned above. These flat surfaces are found locally on the divides of the high mountain range of Taiwan. Along the road crossing the backbone range from east to west, the gently sloping surfaces is visible near the divides where the road passes, and at the same time an old shallow river valley topography can be seen. The gently sloping surface is also visible between the backbone range and Nan-san south of Niitaka-yama (Yushan), and a relatively wide area of such surfaces is also recognizable where timbering is under way on Taihei-zan, Hassen-zan, and Ari-san. In all these areas, no lateritic soil is visible, but within the forest, a podzol is recognizable. On the northeast slope of Nankotai-san a wide plain surface 3,400–3,500 m is found that is assumed to be a remnant of glacial topography (Fig. 16). This area is considered to be one of the source areas of glaciation (Tanaka and Kano, 1934). Of course, some of these tableland sur-

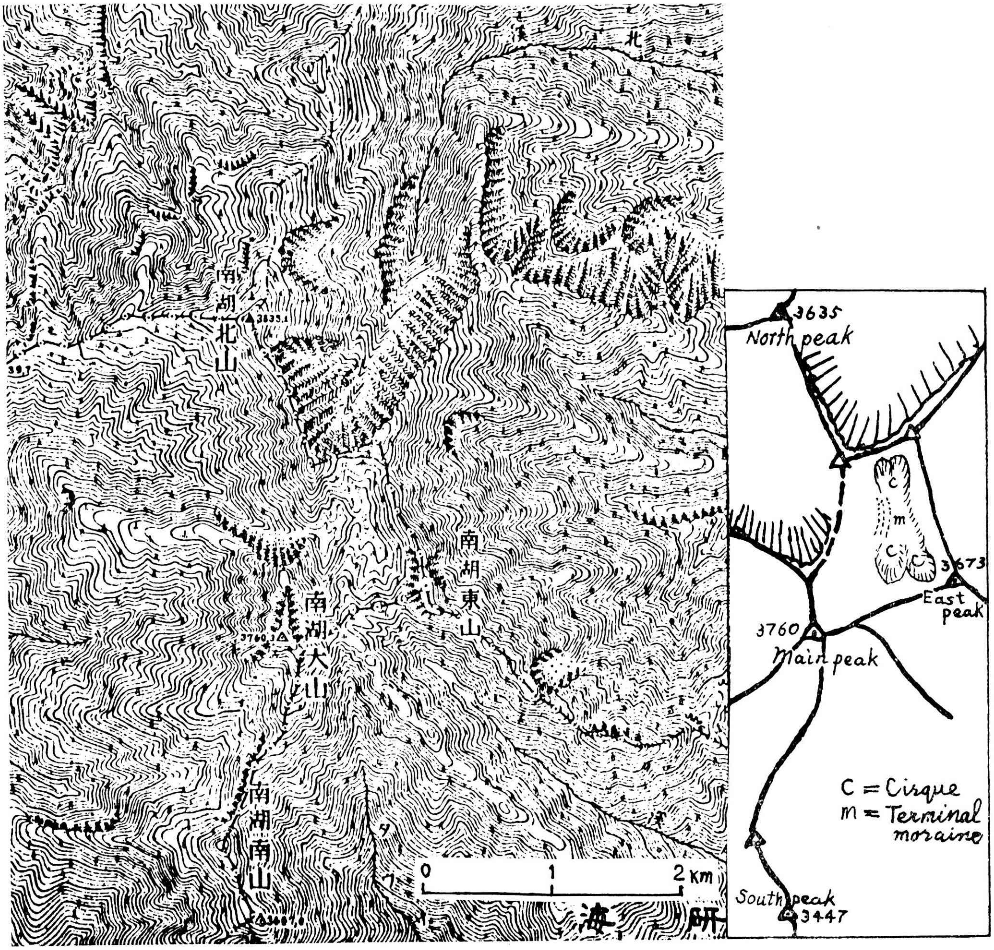

Fig. 16. Site of Cirque on Mt. Nankotaisan.

faces have been formed by differential erosion of hard rock formations, but usually it is thought that hard rock leads to the formation of undulating surfaces.

The absolute heights of high-mountain dissected tablelands are not uniform but they stand at a height of more than 2,000 m, and the gently sloping lateritic surface below is bounded by an erosional scarp so that it forms an independent topographic surface. Consequently this high-mountain dissected tableland, termed the HE surface, is considered to be the highest and oldest topographic surface of Taiwan.

A fan as a topographic form does not necessarily indicate a stage of equilibrium in river dissection of the alluvial topography. For example, one that formed at the base of a fault cliff is connected simply with the period of block movement. However, as many terraces are found in the areas where alluvial fans are developed, the fan surface is closely related to the alluvial terraces. As alluvial terraces can be classified into higher and lower terraces the fan surface can also be divided into higher and lower planes, according to their relative heights. The mode of weathering of fanglomerate on the fan surface is similar to that of terrace conglomerate. As the fan surface is rather gently sloping, like that of the terrace surface, some uncertainties may accompany topographic correlation, but it can be utilized as an accessory fact in determining the age of a topographic surface.

The fans of Taiwan are classified into four types according to the stage of development as follows: old, intermediate, young, and immature fans.

Old Fans

An old fan became a tableland by dissection after the land was uplifted; by further dissection it became a hilly land so that its original surface can be correlated with the gently sloping lateritic surface, that is, the LH plane. Although the topographic surface of the old fan is included in this chapter in which the broad outline of its distribution was described, it will be described again from the point of formational process.

An old fan topography can be found throughout the west piedmont zone in Taiwan in the northernmost part of it is the Tōen tableland (Fig. 1–2). As was described by ICHIKAWA (1929), a great fan area was formed at the base of the reverse or thrust-fault scarp of the Shinten fault which borders the western margin of the mountain area on the east. This old fan has been dissected by the Sekimon River the predecessor of the original Shinten and Tansui River. The aforementioned Rinkō tableland (Fig. 1–1), which stands west of the city of Taihoku, corresponds to the northern extension of this great old fan land. The Rinkō tableland was separated from the fault cliff due to subsidence of the Taihoku basin, and it as a remnant of the tableland can be found in that area. The fan surfaces in the central part of west Taiwan still retain the original surface which extends from the Tenshiko tableland (Fig. 1–3) through various tablelands including the Shimpo and Kokō tablelands (Fig. 1–4, 5). In the Tōen tableland district, according to HANAI (1931), an active fault scarp facing to W is running from ENE to WSW played a part in the formation of a series of fractures on the fan surfaces. The Kyūrin dissected tableland (Fig. 1–6) which borders the south edge of tbe Tōen tableland, and the Chikutō and the Shinchiku dissected tablelands (Fig. 1–7, 8) on its west all have a hilly aspect. Some remaining initial surfaces are composed of tableland gravels and still show some aspects of the great old tableland in spite of its subsequent dissection. The true nature of the topographic precursor of the Chikunan dissected tableland (Fig. 1–9) is difficult to determine because of the advanced stage of dissection.

Under close scrutiny, the Nanseikō tableland (Fig. 1–10), a part of the Byōritsu dissected tableland (Fig. 1–11) on the south reveals vast gravel tableland remnants of an original surface which shows the nature of an alluvial fan. Farther west, in the Hakushaton area and in the Tsūsho tableland (Fig. 1–12) south of this tableland, there are remnants of the gravel tableland surface. A part of this gravel tableland has become a terrace but most shows that it was deposited as alluvial fans. The Kōri tableland (Fig. 1–13) on the south, across the Taian River, is also considered a part of the same alluvial fan as the one which forms the Daito tableland (Fig. 1–14) on the south across the Taikō River. It is a great confluent fan area, but subsequently a part of the former fan surface was covered by intermediate and young fans. The latter (Daito tableland) was tilted gently toward the east, accompanied by subsequent depression of the Taichū basin, so that the fan surface also tilted toward the east.

The Hakkei hill (Fig. 1–15) which is situated south of the Daito tableland is also considered to have been deposited as an alluvial fan and it also is tilted toward the east. This tableland seems to link with the Heichōho tableland (Fig. 1–16) near the village of Takeyama across the Dakusui River. This tilting movement seems to have started at the eastern margin of the Taichū basin along a fault which shows displacement to the west, and the tilted surface shows downwarping.

The type locality of the Shokkō-zan gravel bed (HAYASAKA, 1931) which underlies the tableland gravel is situated in the area south of the Dakusui River between it the Seisui River. At this place the bed does not tilt as much as it does on the north, and on the eastern margin terraces are formed by the Seisui River. Here, the tableland gravel bed overlies the Shokkō-zan gravel beds. However, whether the tableland gravel has been formed by fan accumulation or not is impossible to judge on the basis of the present topography, but it can be inferred to form the south flank of the huge old alluvial fan formed together with the gravel tablelands developed on the north of the Dakusui River. On the south dissected tablelands such as Kokō (Fig. 1–17) and Koume (Fig. 1–18) run continuously to Takezaki (Fig. 1–19).

Farther southward the hills, as developed in Banro (Fig. 1–20), Shirakawa (Fig. 1–21), and Rokkō (Fig. 1–22), are similarly dissected tablelands, but all the traces of the original tableland surfaces have disappeared and a cliff-margin erosion pattern has been formed. The gravel bed remnants in the crest of the valley system are assumed to have existed as already mentioned. The existence of such gravel beds are affirmed by the fact that a remnant gravel bed is found at a height of 160 m in the Kiriga tableland (Fig. 1–23), a part of the Shinka tableland (Fig. 1–24) south of the Sōbun River, showing that it formerly was a gravel tableland. Further inference can be made that these were once alluvial fan deposits.

Turning to the eastern area of Taiwan, in the Taitō rift valley district there are gravel tablelands of old alluvial fan deposits besides the younger alluvial deposits already mentioned in Chapter B, namely in the north the Beiron tableland north of Karenkō, in middle the Mizuho tableland and in the south, the Pinan tableland (Fig. 1–25, 26 and 27).

The name intermediate alluvial fan designates the fan surface which has been dissected after uplift and which now remains as a tableland. The upper part of it can be correlated in topographically with the LT plane of the higher terrace surface.

When we observe the distribution of the old and intermediate alluvial fans, the old fans are typically developed north of the boundary formed by the Dakusui

River; of course, some doubtful old fans are also found in the southern part, but the typical forms are rather few compared with those of the northern part. On the contrary, fans of intermediate age are abundant in the southern districts. There is a remnant of an intermediate fan on the gentle slope at Daisuikutsu, Shikatani-shō, east of Takeyama near the south bank of the Dakusui River, even though it is suspected to have been built on solid rock. The surface is covered by a thin gravel bed which is covered by the lateritic soil. The elevation of the highest point attains 800 m, with a relative height of 420 m, and the length is 2.6 km. Between Kokō and Koume east of Toroku are found the Kantōseki, Sanchokutsu, Tairin and Chinsekiryō alluvial fans. All these places are located at an elevation ranging from 160 to 200 m and with a relative height ranging from 40–90 m. They have been dissected by consequent rivers but they still retain wide remnants of the fan surface.

On the right bank of the Hasshō River, east of the city of Kagi is a fan called the Banro alluvial fan (Fig. 17). It is a narrow, long remnant of a fan surface having a maximum height of 400 m, a relative height of 160 m, and a length of 8 km. South of Kagi to the Heitō plain intermediate alluvial fans are not developed, but the hills of the dissected tableland gradually lower westward and grade into the lowland plain. At the base of the aforementioned Chōshū fault scarps, on the northern half of the eastern margin of the Heitō plain, the development of an intermediate alluvial fan is prominent (Fig. 18). They extend from the bank of the Dakkō River to the mouth of the Rōnō River, on north to the Chingpuwei tableland, the Chialapu dissected fan and the Ailiao dissected fan consisting of the Santeimon and the Pinglungshan tableland.

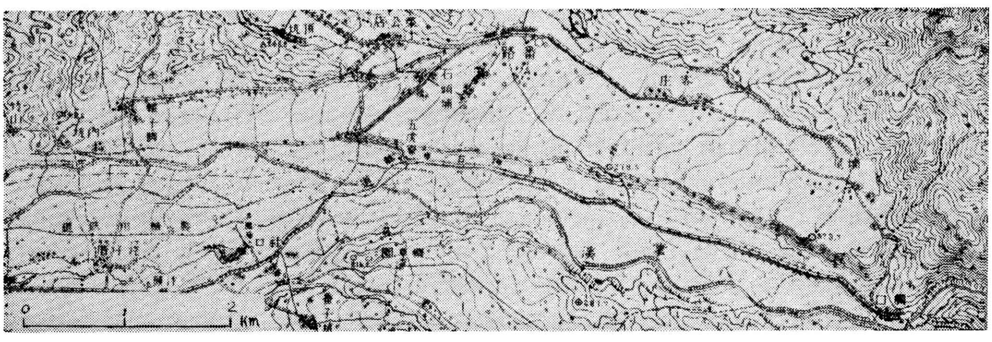

Fig. 17. The Banro Dissected Fan (Intermediate) along the North Side of the Hasshō River, East of Chia-l (Kagi) City.

Toward the south are gravel-covered hills which have been formed by river dissection of the old alluvial fans. Intermediate alluvial fans cannot be detected.

Many intermediate fans are found in the river valleys of Taiwan (Tomita, 1938). In most cases they are found in the longitudinal valleys and these longitudinal valleys are structural valleys which differ from the transverse valleys. Starting from the north, the Girandakusui River is shown clearly as an eroded

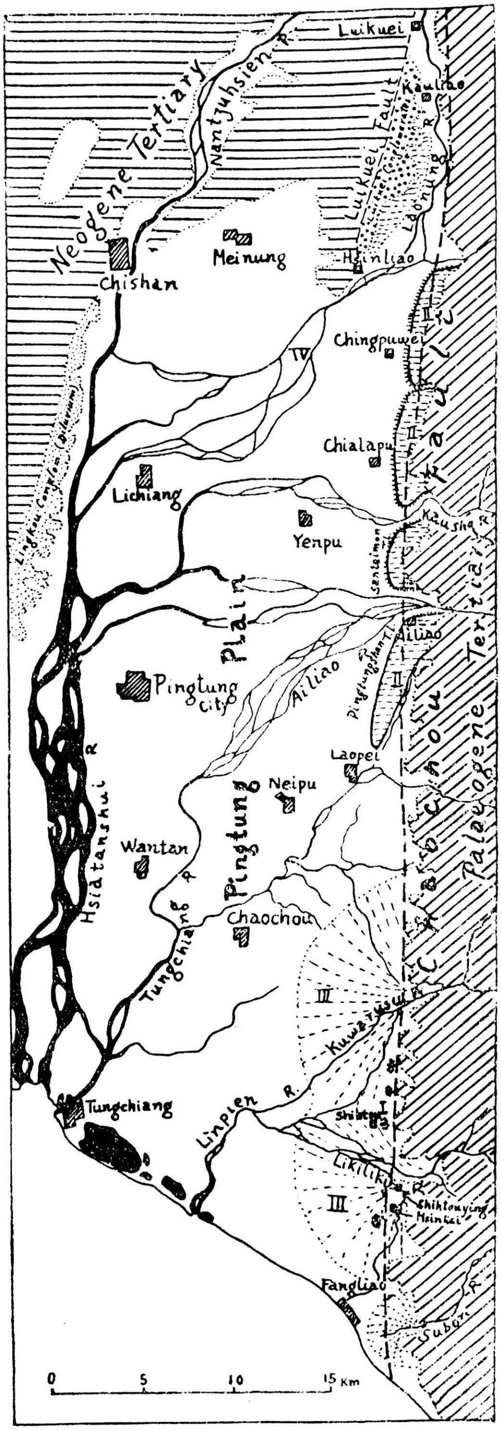

Fig. 18. The Pingtung Plain and the Chaochou Fault. II Shows Tableland Dissected Intermediate Fans.

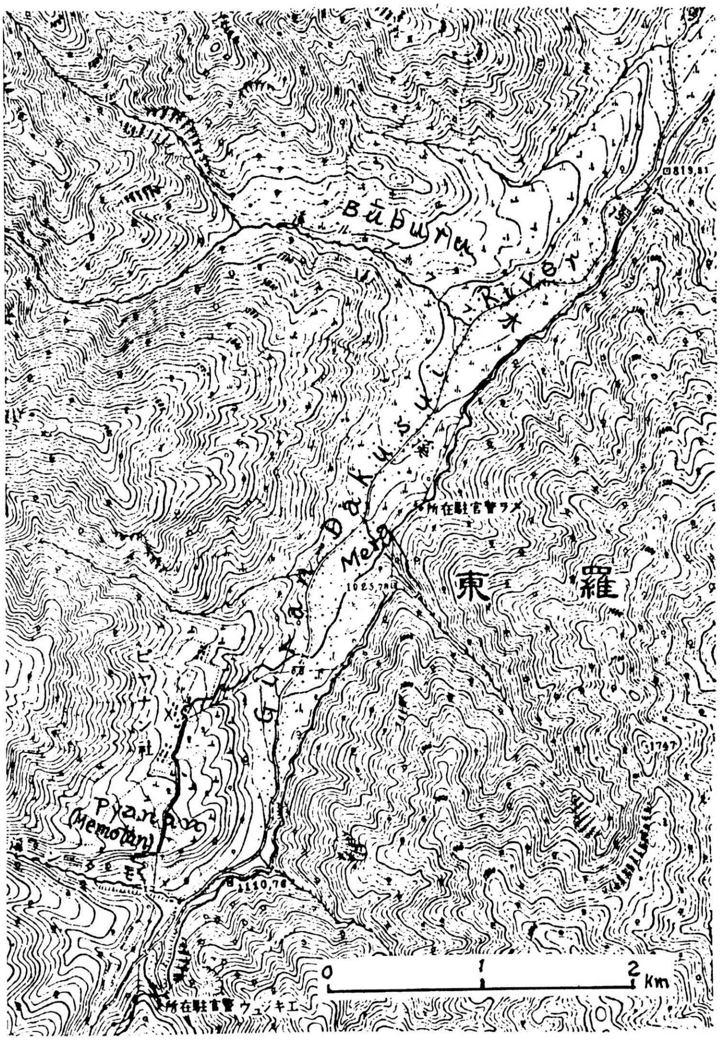

Fig. 19. Composite Fans in the Valley of the Giran-Dakusui River.

fault valley. In this river are four alluvial fans, namely: Pyanan (or Memotan), Mera and Būburu fans, in order, from the upper to the lower reaches (Fig. 19). Their relative heights as well as the heights above sea level gradually decrease and all alluvial fans except the Mera occur on the left side. The Būburu and Memotan fans are composite fans similar to a triple fan (Drew, 1873; Cotton, 1926). These fan surfaces are correlated with the LT plane, but a young fan surface in the lower part belongs to the FT plane.

The so-called Kayō fan terrace (Tomita, 1937C) is located on the right side in the headwaters of the Taikō River. This fan has been dissected to form a four-stepped terrace below the fan surface (Fig. 20). The fan surface and the first step

Fig. 20. The Kayō Fan, a Dissected Rock Fan in the Taiko River Valley.

are correlated with the LT plane, and the second, third, and fourth steps are correlated with the FT plane.

Along a longitudinal tributary valley at the middle part of the Dakusui River called the Chinyūran River, the Namakaban fan and Aripton fan are composed the largest confluent fan in Taiwan and the remnant of the fan surface is still widely retained indicating that it belongs to the LT plane (Fig. 21). The Bōkyō fan occurs adjacent to, and upstream from this fan. Tompo and Rakuraku fans are located farther upstream.

The Magatsun fan (Fig. 22) is situated on the left bank of the Nanshisen River,

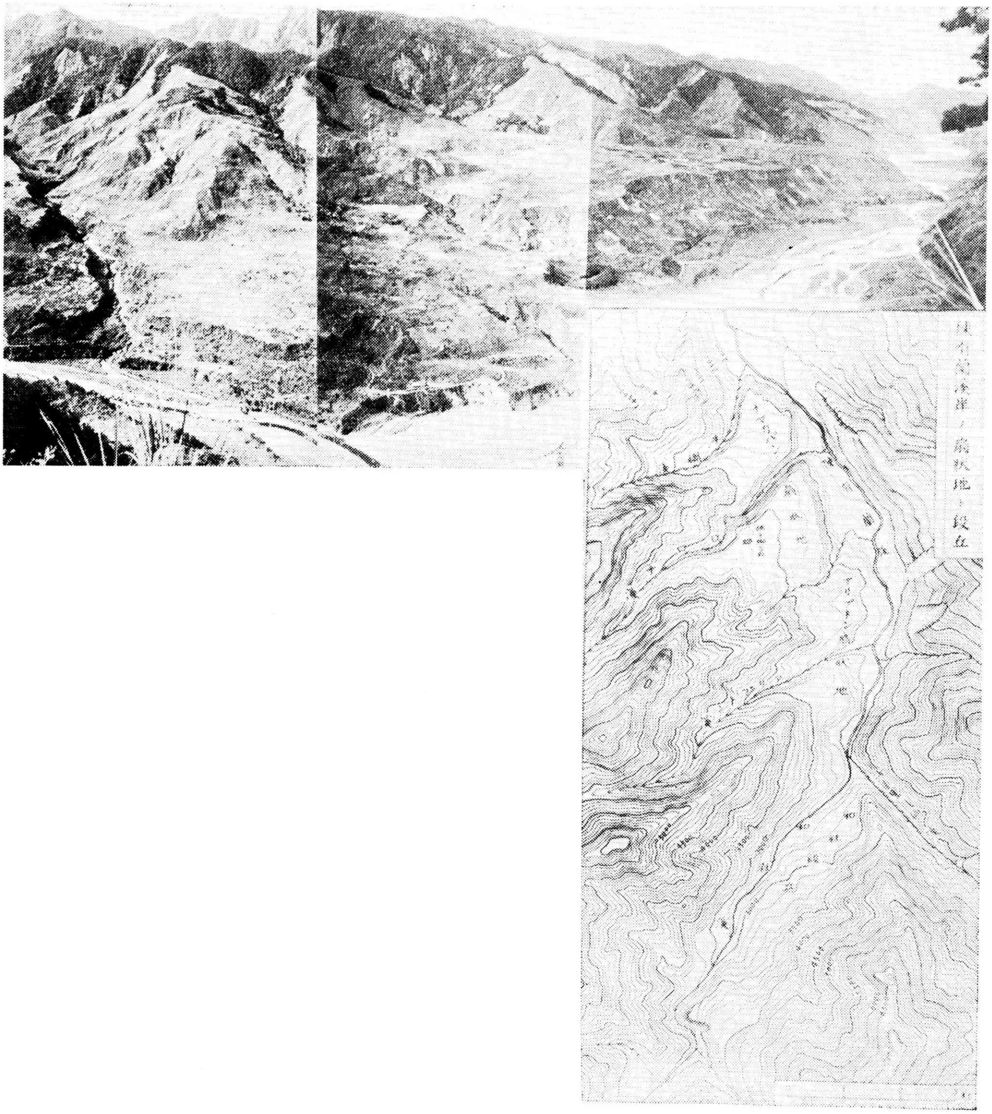

Fig. 21. The Namakaban Fan (North) and the Aripton Fan (South) along the Western Valleyside of the Chinyūran River in Central Taiwan.

a longitudinal valley in the upstream of the Shimotansui River in the south, and the shape of the fan is the most typical example of an uplifted fan. The surface of the fan is the LT plane, but the surface is used as a farm land and contains much humus so that the laterized soil has changed to a chocolate color. The fan on the right side of the upstream valley is narrower than the fan of the left side and the inclination is much steeper. The valley fan is different from the plain fan and it is clear that its development is restricted by the size of allowable ground.

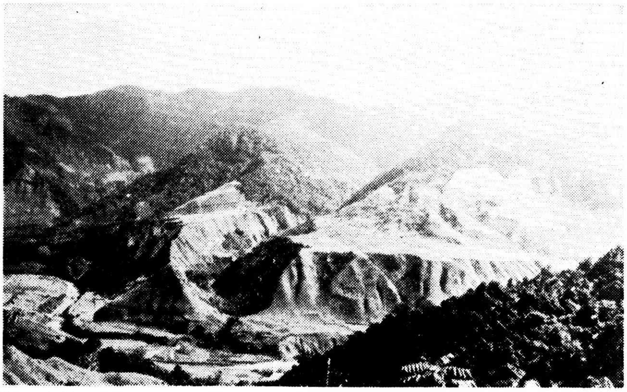

Fig. 22. The Magatsun Fan on the Left Bank of the Nanshisen River.

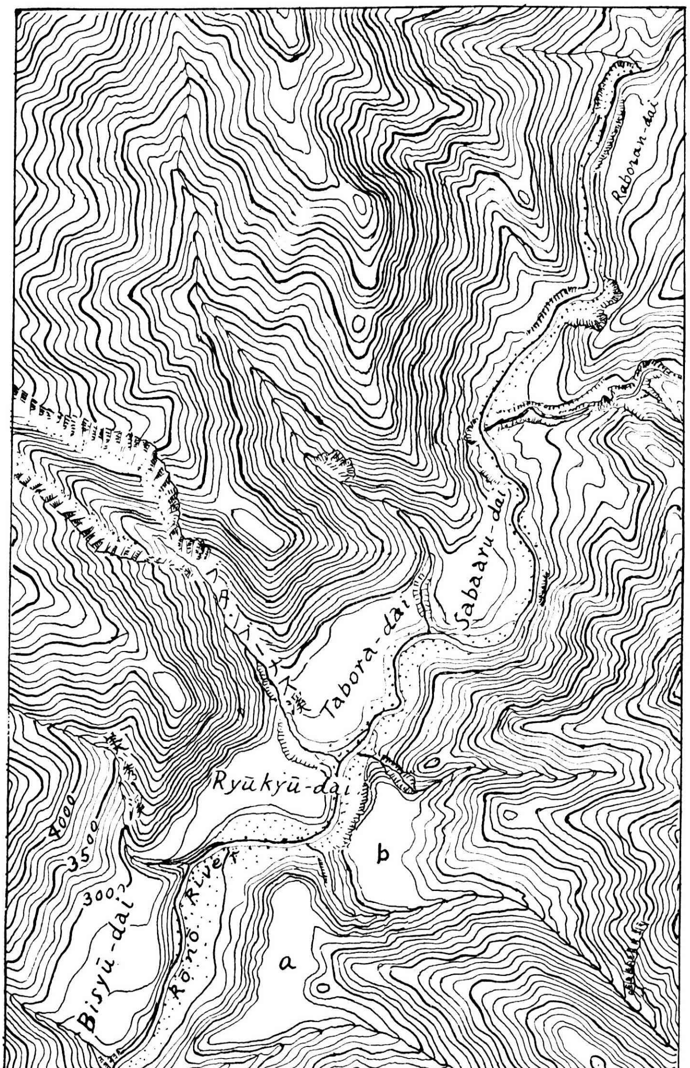

Fig. 23. Three Fans and Two Terraces (a and b) in the Valley of the Midstream Course in the Rōnō River.

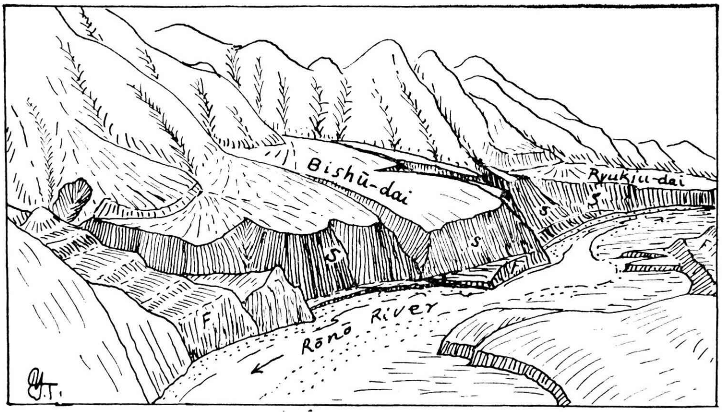

Fig. 24. A Sketch of Fans (Bishū-dai and Ryūkiū-dai) in the Midstream of the Rōnō River.
S sand and gravel F bed rocks

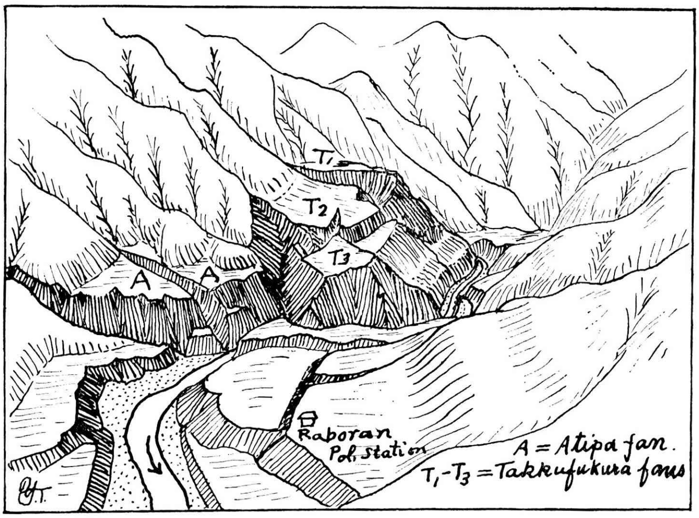

Fig. 25. Fans and Lower Terraces along the Upper Stream of the Rōnō River Reviewed to the North from the Top of Raboran Bluff about 4 km from the Sabar Fan in Fig. 24.

A tributary adjacent on the east to the Nanshisen River is the Rōnō River, a twin of the former river, and they both have longitudinal valleys. In this place six fans are developed mainly on the right bank of the Rōnō River. Beginning with the lowest they are: Yōshikyaku, Haisen, Bishū, Būnasu, Sabāru, and the Takkufukūra. Of these, Nos. 23, 24, and 25 form a confluent fan by the combination of a part of the fan sides. The young fan is to be correlated with the lower terrace, but according to my classification on the developmental procedure of alluvial fans (Tomita, 1937C), it corresponds to a graded fan (see Fig. 23).

Young Fans

A young fan has a surface that can be correlated with the FT plane of the lower terrace. According to my classification of fans (TOMITA, 1951) by means of degree of development, young fans correspond to the graded fans in equilibrium. A young fan is normal in form, and its development continues on the marginal part but is suspended at the apex where dissection has just started. Young fans are in a stage when the fan surface is the widest. Let us look at the areal distribution of the young fans. The Taihoku basin on the north Taiwan is a fault basin. Fans in intermediate and young stages of development are rare in its periphery. There is only the meager development of a young fan at the base of the Shinshō fault scarp. The reason for such a state is attributable to the depression which was followed by the formation of a temporary lake. Then the accumulated sediments became

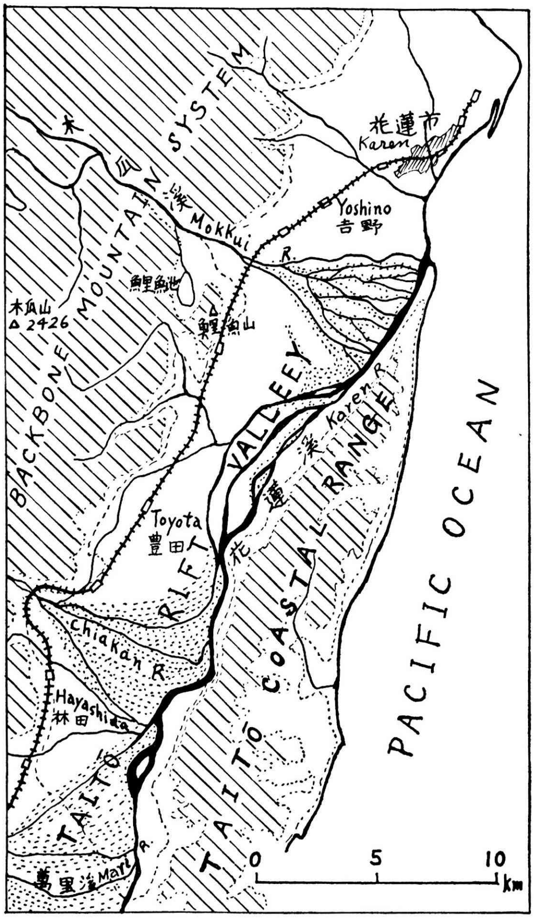

Fig. 26. The Immature (or Growing) Fans and the Site of Three Immigration Villages in the Northern Part of the Taito Right Valley.

dried so that it might have been formed under a deltaic environment rather than a fan.

In the central part of Taiwan in the southern part of the eastern margin of the Taichū basin some young fans are observed. The development of confluent fans is seen at the mouths of the Taikō River, Tōbenkō River and the Chikushikō River. In the southern part, a confluent fan is built east of the town of Toroku to form the Toroku fan district. East and south of the city of Kagi there are small young fans adjacent to the intermediate fans. On the southern margin of the eastern border of the Heitō (Pingtung) plain and along the southern half of the Chōshū (Chaoshou) fault scarp there is a development of typical young fans in the mouth of the Raisha River, the Chikatan River, and the Subon River (Fig. 18).

Immature Fans

In the Giran plain in the northern part of the eastern slope of Taiwan, young fans are found only at the base of the Shōkei fault scarp on the northwestern margin and on the southern margin, which is probably because the Giran plain is an aggraded plain. The most typical development of young fans in Taiwan is seen in the Taitō (Taitung) rift valley (Fig. 7). As the rift valley embraces a much wider plain than ordinary valleys, fans developing there are more like plain fans rather than valley fans, and they show the normal topographic features of plain fans. The fans (developed) on the Mokkui River, Chiyakan River, and Mari River are still in an early stage of development so are designated as so-called "immature fans." This immature (or growing) fan forms a confluent fan and the three government sponsored immigration villages of Yoshino, Toyota and Hayashida at the time of Japanese control, are located respectively on the adhering portion of the confluent fans (Fig. 26) to keep away from frequent flooding. The Ikegami fan, which is located at the mouth of the Rakuraku River on the west bank, south of the village of Tamasato on the south, and the Ōhara fan at the mouth of the Shinburo River on the south are graded fans in which dissective activity has just started. These fans seem somewhat older than the graded fan that is located at the mouth of the Pinan Ta River on the extreme south. The fans in the Taitō rift valley have been formed alternately on the east and west sides of the valley by the oscillatory crustal movement.

The differences in the young and old stages are closely related to the types of faults found in both sides of this rift valley. However, the problem will be discussed in the section on structural topography.

In the northern and southern extremities of this rift valley there are small graded fans at the mouths of small streams. Starting from the north on the west side of the rift valley are such fans as Okakai, Kararan, and Marankin and southward on the east side, south of Yamato are found the Basshi, the Reishisai, the Matarin, the Makutō, and the Taikaryō fans. Toward the south on the west side are the Izogan, Mariwan, Takopan, Kamuran, Kanaten, Rokuryo, Sun-nun-sun, Hatsushika, Taparakau and Shabakan fans. As these river canyons are small, the formational process ended in early stage of development.

III. Structural Topography and its Geomorphologic Process

A. Basin Topography

In Taiwan there are three representative basins, namely, the Taihoku, the Taichū, and the Hori, and all are fault basins formed by depression; they are not erosion basins. The Taihoku basin, as mentioned in the discussion on the fans in the Tōen tableland district in the previous chapter, was depressed between the Taihoku fault on the east, the Shinshō fault on the eastern margin of the Rinkō tableland on the west, and the Sankyaku fault, which has been formed by subsequent repeated crustal movements. This postulation was brought about in the studies on the geology of the Taihoku by Tan (1937, 1939). The geological survey by Makiyama (1930–34) and the opinion of Imamura (1944) on the basis of leveling data clearly confirmed the said postulation. No adequate survey has been made on the nature of the Taichū basin, but on its eastern margin there clearly is a fault, as mentioned before. This fault is linked with the Sansha fault farther north through the Taikō River and the Taian River, and toward the south it seems to join the fault east of Takeyama through Nantō. However, on the western margin of the basin there is no corresponding fault. As the tablelands of Kōri, Daito, Hakkei, and Heichō are all tilted toward the east, these planes can be called fault-angle basins formed by displacement on the east side.

Subsidence of the Taihoku and Taichū basins seems to have taken place subsequent to the formation of the LH plane and caused the LH plane to plunge into the basin. This postulation is based on the topographic surface. As seen in the Taihoku basin, this subsidence caused a change in the drainage channel of the original Tansui River which formerly flowed northwest near Sankyō-Ōka in the Tōen tableland, and made it flow into the basin, and the lower reaches came to end at the present Nankan River. The main stream started downcutting and resulted in the formation of the notable Taikei terrace group. As the upper terraces belong to the LT plane, the subsidence must have occurred after the formation of the LH plane and before the formation of the LT plane.

The Hori basin (Tomita, 1951B) is an intermontane basin in the central part of the island, where various kinds of basin groups are found. In linear arrangement from north to south are the Hori, the Gyochi, the Jitsugetsutan, the Tōsha, and Jūki basins. In the vicinity of these basins are a series of small basins, such as Sōnan, Rengechi, Sansakyaku-Mokaiketsu, Kita-Mokaiketsu, Byōran, Nishi Byōran, Yūsuikō, Higashi-Hokutan, and Kita-Tōsha. The Hori basin is the largest in areal extention as it covers 42 sq. km, but the initial surface of the basin has been already dissected, so when compared with other districts, it seems to have passed through a very complicated process of topographic change. The basin has been dissected by both rivers, the Hokkō-kei and the Nankō-kei, and can be divided into the higher (B and C in Fig. 27) and the lower (D and E in Fig. 27) basin planes built on the erosion surface. This erosion surface was formed after dissection, and the basin

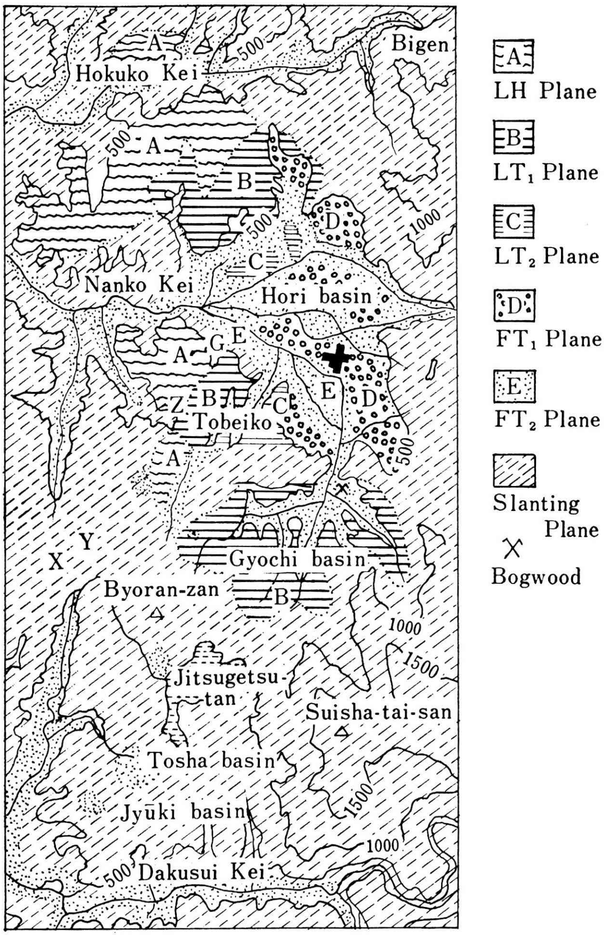

Fig. 27. Topographic Planes of the Hori (Puli) Basins.

plane retains the initial deposition plane. The former can be subdivided into two planes, and the latter can also be subdivided into two planes. The initial basin plane is not only distributed in the north and west-margins of the basin, but it is also retained on the spurs north of the Hokkō River.

The initial basin plane is also widely distributed in the area of Tōbeikō south of the Nankō River. All these surfaces are covered by lateritic soil on weathered gravel bed, thus indicating the LH plane.

From the above-mentioned areal distribution, the original form of the Hori basin can be imagined as being very large. It extends from the north bank of the Hokkō River on the north, and to the divide of Mt. Taiōhei (1,203 m) through the village of Kokusei on the northwest. From this point it extends to Mt. Shūshūtai shan (1,396 m) along the fault valley which crosses the pass of Sankakurei (890 m) (X in Fig. 27). The southern margin of the Hori basin extends from

Mt. Oshōtō (Y in Fig. 27), east of the pass of Sankakurei to Mt. Byōran then farther east to the boundary with the Gyochi basin.

The first higher basin plane (B in Fig. 27) of post-dissection is also a lateritic soil covered-gravel tableland, and it is still present in the north of the Nankō River, at such places as Taigyūkō and Sekkan tableland, east of a line connecting Taiheichō with Suibi, and also on the east side of the line linking Gyūsōshoku (G in Fig. 27) and the Sōnan-basin, (Z in Fig. 27), south of the Nankō River.

The second higher basin plane (C in Fig. 27) is developed at Suiakutsu and Shikōkō to Wugyūran north of the Nankō River; south of the Sa-kei only a small tableland plane retains the initial surface on the northeast margin of Tōbeikō tableland? This higher basin plane can be correlated topographically with the LT plane.

The lower basin planes occupy the present Hori basin; they are erosion planes of the Nankō River composed of a dark brown transported surface soil. The D plane covers the majority of the basin, and the E plane forms a flood plain of both the Nankō River and the Bai River. Both the D and E planes (Fig. 27) are bounded by an erosion cliff 2 to 5 m high.

The geology of the basin can be easily observed from the uppermost part to the basement rock because all the rock formations are exposed. The basement rock consists of alternating sandstone and slate belonging to the Hakurei formation. The overlying bed consists of white clay with an intercalation of fine-grained sandstone beds, and is overlain by a gravel bed. This gravel bed can be divided into upper and lower zones. The gravels of the lower zone are smaller than those of the upper zone. The major portion of the gravel of the lower zone is composed of pieces the size of a man's fist frequently intercalated with lenticular beds of sand and clay; stratification is obscure. The upper zone is composed of large gravel the size of a human head and does not show any stratification. The lower zone is a common alluvial deposit but the upper zone seems to have accumulated fanglometratically under a torrential streams. The white clay bed with fine sand is lake-bottom deposit; this conclusion has been more or less confirmed. Lignite and peat beds are intercalated with the clay bed in the vicinity of the confluence of the Taigyukō, which drains from the east, and the Suiryūtōkō, which drains from the western margin of the basin to Suiryūtō on the north. On the south bank of Hokkō River, the clay bed strikes N 30° E, and dips NW 30°, and the above-mentioned peat bed dips 40°–60° east. This shows that crustal movement occurred after the completion of this lacustrine deposition.

The Gyochi basin borders the Hori basin on the south. It is a dissected basin, but the dissection is still in the initial stage, so that the basin plane has been dissected upstream only by long narrow dendritic river systems. The basin plane is 700 to 800 m above sea level and the lowest elevation of the Hori basin ranges from 200 m so that the Gyochi basin is higher by 500 m; it is 300 m above the highest part of the Hori basin, and is 100 m above the initial basin surface of the basin.

The geology within the basin surface is well exposed along the dissected river valleys so that observation is facilitated. It is a lacustrine formation composed of gravel, sand, and clay; the beds generally lie horizontally, but in the middle part an apparent dip of 20° E is observable. In the southern and eastern margins of the basin, the gravel bed of fan-like accumulation is thick. In the vicinity of Gaikadōkō near the outlet where the water is conducted from the basin of the dissected valleys two lignite beds are found within a clay bed which underlies alternating beds composed of gravel and sand. The lignite has been utilized as a native fuel. The thickness of these lignite beds ranges from 30 cm to 40 cm; occasionally they attain a maximum of 80 cm.They dip slightly toward the north, and thin out toward the southeast.

The surface soil of the initial basin plane is a lateritic soil but in places lateritization has not taken place. It certainly is assignable topographically to the LT plane; it probably became a lake during the post-LH plane depression, and as accumulation proceeded the dissection process of the Nankō River on the north changed the lake into a dry basin and subsequently dissection began on the basin surface. At the beginning of this dissection process, the difference in heights between the Gyochi and Hori basins was more than several hundred meters, so that it is reasonable to imagine that an enormous amount of sand and gravel was transported energetically to the Hori basin from the Gyochi basin.

In the vicinity of Sekkan, at the erosion scarp of a higher basin plane of the Hori basin north of Hori town, there is a lateritic soil bed 2 m thick upon which rests a gravel bed 5 m in thickness. This gravel bed is in turn covered by a surface of lateritic soil 2 m thick. From this sequence it can be interpreted that the gravel derived from the Gyochi basin was redeposited on the original lateritic soil bed of the Hori basin and that this gravel bed was subsequently coverted into lateritic soil.

The Jitsugetsutan lake basin adjoins the Gyochi basin on the north and its elevation above sea level is 750 m. This lake is used as a reservoir for a hydroelectric power plant. The water of the lake is augmented by an inlet at Bukai dam by a water tunnel on the headwaters of the Dakusui River so that both the water level and depth are not constant, however, the depth when the water is full probably attains a maximum of 30 m. The following limnological description of this lake is found in a report by HARADA (HARADA, 1933; 1942). The natural water level of the lake is 726.8 m and the maximum depth is 4.6 m. The natural drainage outlet is situated in the Suishasuibi River at Suisha on the west bank of the lake. The discharged water enters the Suiri River then joins the Dakusui River by passing through Gojō. At a distance of 1 km from the lake shore the width of the river becomes about 50 m so that a dam was constructed at the shore of the lake.
However, if the lake bottom is exposed and abandoned in the natural state erosion will incise the lake shore in a short time and the water will be drained and the lake eventually will become dry, just in the same manner as in the Gyochi basin in the past. On the lake shore of Jitsugetsutan a thick lateritic soil rests on the Hori slate. It is probable that this lake basin was formed by the depression of the LH plane.

As to other small basins, some of them distinctly show faulting accompanying with shattering zones in their basin floors, but some others are supposed to be erosion basins produced by valley-head erosion on the LH plane. In either case, most of the basins present a typical basin topography as seen in small craters of volcano.

HAYASAKA (1930) made a preliminary report on the formational process of these basins and contended that depression occurred along the group of strike faults that run longitudinally throughout the island. Upwarping occurred at the same time and Jitsugetsutan, which was located on the top of upwarping remained as a lake to the present.

B. FAULT TOPOGRAPHY

As to the fault topography, the first features to be discussed is the fault valleys. Among the principal valleys in Taiwan, most longitudinal valleys can be said to be fault valleys. That the formation of some river bottoms has been influenced by such a disturbance is clearly manifested. Sometimes the mountain ridges on both sides of the river valley show dips that are gentle, but upon approaching the river valley gradually increase, and frequently, almost vertical dips can be observed in the valley floor. The reason for such a phenomenon is due to the interbedding of hard and soft rocks. In the horizontal beds the erosional process does not progress much, whereas in the vertical beds the downward erosion of the river bottom along the weaker beds have progressed greatly. It is probable that in some cases the drainage course has been determined by a strike fault, however, on close observation of the vertical formations along the river bottom, it also can be interpreted as an overturned high-angle fault. The basic structure of Taiwan is probably an imbricate structure which is attributable to overthrusting, as suggested to me by Bailey WILLS when he came to Taiwan. During the periods of physiographic development of the HE and LH planes, subdued topography was developed throughout the island.

Thus, the fault valleys observable at present have been dissected and further modified through subsequent erosional rejuvenation due to the land uplift, so differential erosion is well manifested. Some rivers seem to have gone through the fault-line valley process at least locally.

The most typical fault valley in Taiwan is the Taitō rift valley. FUNAKOSHI (1933) considers that the faulting movement on both sides of the rift valley is an earth wave* movement, on the basis of asymmetric distribution of fans. I agree with FUNAKOSHI, because I myself observed that the height of marine erosion caves on the Pacific coast at the east end of the Taitō mountain range varies from 5 to 30 m.

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* E. N. Earth wave ("Chiha" in Japanese) is a recent term advocated by G. IMAMURA, well-known Japanese geographer. It is, on the whole, similar to a kind of warping or active folding. IMAMURA used ocean waves as a means of comparison. IMAMURA, Gakurō, 1932, *Earth wave: Iwanami Lecture Series, Geography* (in Japanese).

The Taitō coastal range shows an échelon structure belonging to a left tilted m-type échelong structure, proposed by TOKUDA (1926–27). It is assignable to the Luzon arc rather than the Taiwan—Luzon arc. In Taiwan this arc is linked with the Ryukyu arc (Ketting) on the north (TOMITA, 1952).

As for fault cliffs, there is the Chōshū (Chaochou) fault cliff at the eastern margin of the Heitō (Pingtung) plain, as already mentioned (Fig. 18). The fans on the base of this cliff can be classified into old, intermediate, young, and growing (immatured) fans. These fans were formed alternately in the northern half and the southern half in the eastern meargin of the Heitō plain just as they were formed in both sides of a hinge fault. But, it is also probable that these fans exhibit a part of earth wave or active folding.

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