57. *On the Displacement of the Tanna Fault since the Pleistocene.*[*,1)]

By Hisashi KUNO,

Geological Institute, Imperial University of Tokyo.

(Read Nov. 19 th, 1935.—Received Sept. 21, 1936.)

Introduction.

The Tanna fault runs meridionally through the western slopes of the volcanoes that are arranged along the eastern coast of north Idu. Owing to its fresh fault-scarp topography, this fault has received considerable attention from geologists.[2)] At the time of the north Idu earthquake of November 26 th, 1930, an earthquake fault appeared along the foot of the fault-scarp, accompanied by ground disturbances. It should interest geologists and seismologists to trace the geologic history of this fault and to compare its history with what occurred at the time of the earthquake.

The purpose of the present paper is to discuss the nature and the amount of displacement of the Tanna fault during geological times as deduced from geological and geomorphological observations made in the region. The conclusion reached is that, since the Pleistocene, the block on the western side of the fault has been displaced horizontally about 1 km southward and elevated about 100 meters in its southern part, relatively to the block on its east. The nature of this displacement is similar to that which occurred at the time of the earthquake of 1930.

This fault traverses the centre of the Tanna basin, which is a circular depression about 2 km across. The underground structure of this basin was fully investigated along the wall of the Tanna railway tunnel, which was excavated underneath the basin, details of which have been already given in an earlier paper.[3)] The main topic discussed in this paper is the relation between the geomorphological development of the basin and the Tanna fault displacement.

---

* Communicated by S. TSUBOI.

1) Already published in Japanese: H. KUNO, *Geogr. Rev. Japan*, **12** (1936), 18.

2) N. YAMASAKI, *Jour. Geol. Soc. Tokyo*, **26** (1919), 165.
T. WATANABE, "On the Geology of the Tanna Basin." (Published by the Railway Department in 1925).

3) H. KUNO, *Bull. Earthq. Res. Inst.*, **14** (1936), 92.

Acknowledgement.

My geological survey of the northern part of Idu Peninsula, a part of the results of which forms the topic of this paper, was carried out under the auspices of the Earthquake Research Institute, Tokyo Imperial University. To the Director and members of the staff of the said Institute I wish to take this opportunity of offering my heartiest thanks for many courtesies received, particularly to Professor Dr. Seitarô TSUBOI who was so kind as to go over my manuscript.

Outline of the Geology and Geomorphology of the District.

The district concerned in this paper, which occupies the eastern half of north Idu, is a mountainous land situated between the Kanô-gawa plain and Sagami Bay. Its general topography is shown in the map Fig. 1.

The figure shows only the contour lines for every 100 meters as reproduced from the 1/50,000 topographic maps "Atami" and "Numadu", published by the Land Survey Department. For further details, the reader is referred either to the original maps or to the 1/25,000 maps "Atami", "Aziro", "Misima", and "Nirayama", published by the same Department.

In this district, three partly demolished volcanic cones of lower Pleistocene age are built upon a foundation of thick accumulations of Tertiary volcanic rocks. These volcanoes, enumerated from the south, are Taga, Yugawara, and Hakone. They were erupted in the order named.

The semi-circular ridge that runs from a point south of Aziro, through Yamabusi-tôge, to a point north of Kuro-dake (Fig. 1), corresponds to that part forming the southern to the western margin of the caldera of the Taga volcano. A gentle periclinal slope of the volcano is still preserved outside of this caldera margin. The semi-circular ridge that runs from a point northeast of Atami-mati, through Iwato-san and Zyukkoku-tôge, to Kurakake-yama of the Hakone district (situated beyond the northern limit of the map Fig. 1), corresponds to that part forming the southern to the western margin of the caldera of the Yugawara volcano. Outside of this caldera margin, mostly in the western part, a gentle periclinal slope of the volcano is still preserved. Thus the western slopes of these two adjacent volcanoes form one continuous slope on the western side of the main ridge, or divide, that runs meridionally through the middle of the map Fig. 1. In the northern extension of this slope the contour lines change their directions to

NW–SE. This area corresponds to the southwestern slope of the Hakone volcano. In the map Fig. 1, the boundaries between these three volcanoes are marked with broken lines.

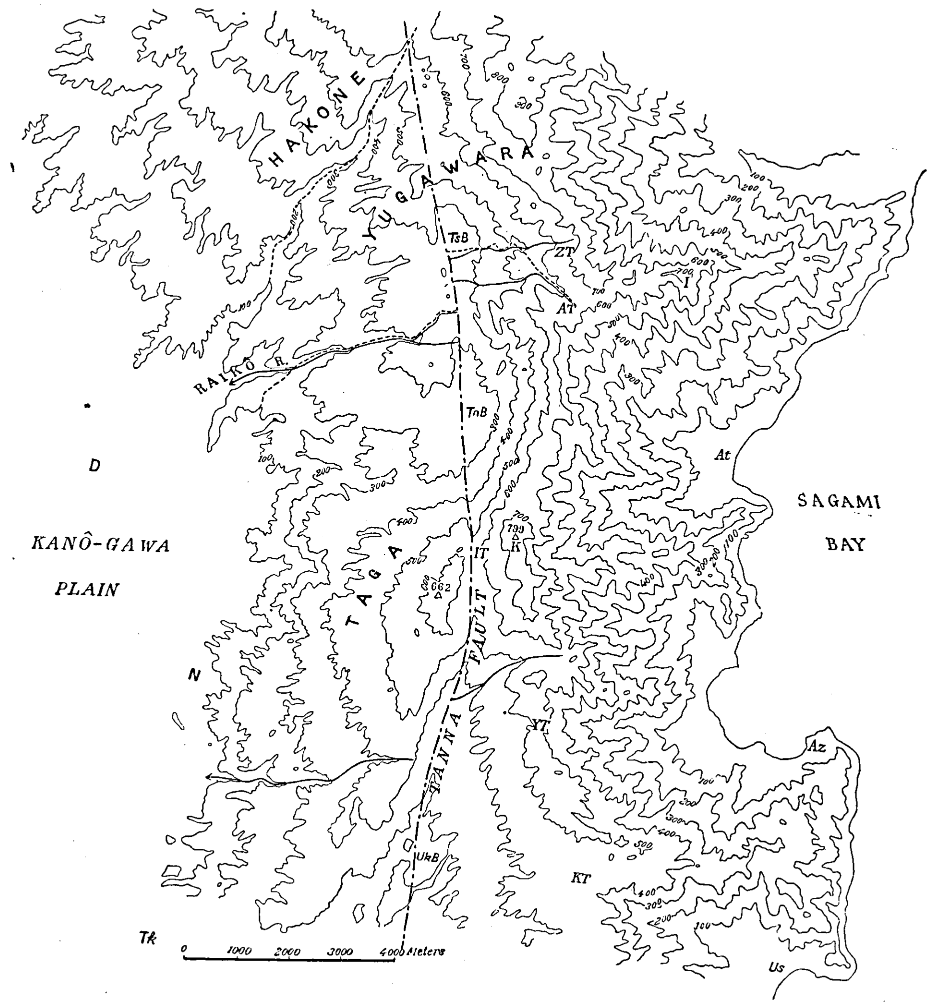

Fig. 1. Topographical map of the north Idu district. The figure shows only the contour lines for every 100 meters. Full lines—river courses. Broken lines—boundaries between the volcanoes. Chain—Tanna fault line.
At—Atami-mati, Az—Aziro, Us—Usami,
ZT—Zyukkoku-tôge, AT—Atami-tôge, K—Kuro-dake,
YT—Yamabusi-tôge, KT—Kameisi-tôge,
TsB—Tasiro basin, TnB—Tanna basin,
IT—Ikenoyama-tôge, UkB—Ukihasi basin,
D—Daiba, N—Nirayama, Tk—Takyô.

The Tanna fault, with which this paper is concerned, traverses meridionally the central part of the slope on the western side of the main divide just mentioned (shown with a chain in Fig. 1). Three circular or elliptical depressions, Tasiro, Tanna, and Ukihasi (enumerated from the north) lie along this fault line.

To the north of the Tasiro basin, the Tanna fault becomes indistinct, geologically and geomorphologically, its trace being irrecognizable beyond the northern limit of the chain in the map Fig. 1. On the other hand, this fault extends beyond the southern limit of the map Fig. 1, and is traceable as far as Kadono, about 10 km southwest of Ukihasi, thus forming a curved course convexing eastward.

The position of the Tanna fault plane as observed on the wall of the Tanna railway tunnel already mentioned, deviates slightly westward from the earthquake fault that made its appearance on the ground surface in 1930. This indicates that the fault plane inclines steeply westward.[4]

The general agreement between the inclinations of the strata of the various volcanic material and those of the land surface shows that erosion has modified but little the original form of the western slope of the main divide, and that the major undulation of this slope (including the Tasiro and Tanna basin and the elevated area between Kuro-dake and Nirayama) is mainly the result of warping which affected the present district.

Geological and Geomorphological Observations along the Tanna Fault.

(1) It is well known that a fresh fault scarp facing eastward is developed along the western side of the Tanna fault line (Figs. 1 and 2). The height of this scarp varies in different parts of the fault line, it being higher where the land surface inclines generally southward than where it inclines northward. For example, the scarp is higher in the northern parts of the Tasiro and Tanna basins than in their southern parts (cf. Fig. 2). Moreover, the scarp is almost irrecognizable on the northern side of Ikenoyama–tôge, while it attains to a considerable height on the southern side, namely, between Ikenoyama–tôge and Ukihasi.

It is worthy of note that the scarp at the northwestern corner of the Tasiro basin disappears a short distance northward, thus assuming the form of a depressed triangle (cf. Fig. 2).

4) H. KUNO, *Bull. Earthq. Res. Inst.*, **14** (1936), 101.

(2) The gentle slope that spreads out on the western side of the Tanna fault is dissected by numerous valleys directed westward. A few of these valleys extend their channels up to the Tanna fault line and traverse the fault scarp, giving rise to windgap topographies. Examples of this are found in two southern tributaries of the Raikô river, east of Daiba (Fig. 1), which traverse the scarp at two points immediately southwest of Karuisawa (Fig. 2), and also in a valley 2 km south of Nirayama, which traverses the scarp at a point 2 km north of Ukihasi (Fig. 1). This shows that these channels had been extended further to the eastern area before the fault scarp came into existence, and that their eastern parts were cut off from the western by the subsequent fault displacement.

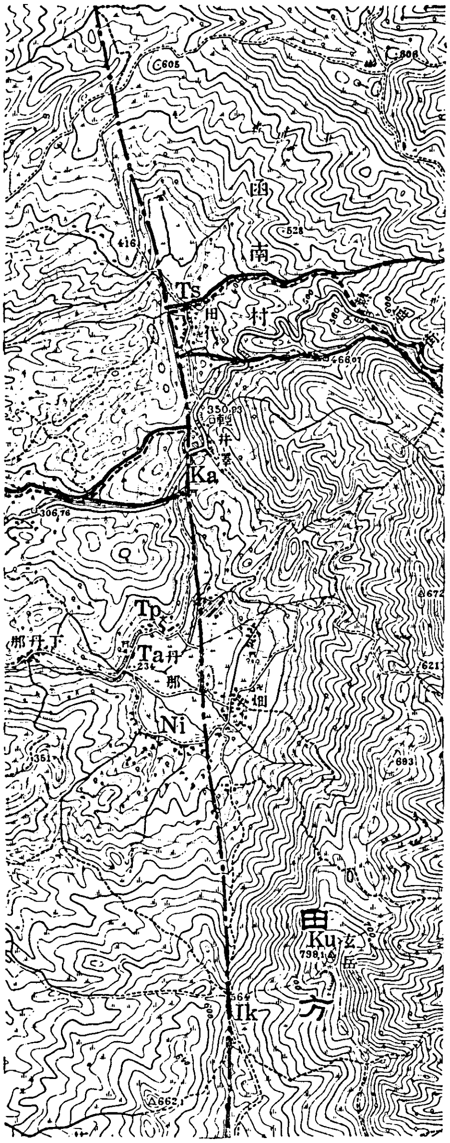

Fig. 2. Topographical map (1/50,000) of the neighbourhood of the Tanna and Tasiro basins. The heights are expressed in meters. Ts—Tasiro, Ka—Karuisawa, Tp—Tanna primary school, Ta—Tanna, Ni—Niiyama, Ik—Ikenoyama-t ge, Ku—Kuro-dake.

An examination of the topographical maps Figs. 1 and 2 will show that the valleys in the eastern area, which may be regarded as corresponding respectively to the above-mentioned three in the western area, are the valley running from Zyukkoku-tôge to a point immediately north of Tasiro, that from Atami-tôge to a point immediately south of Tasiro, and that from a point north of Yamabusi-tôge to a point 3 km south of Ikenoyama-tôge. In Figs. 1 and 2, these valley courses on both sides of the fault are marked by full lines. It is important to note that every valley course marked in these figures on the western side of the fault is invariably situated about 1 km south of the corresponding one on the eastern side.

(3) A marked contrast in the distribution of land reliefs is noticed on both sides of the Tanna fault. In the neighbourhood of Ikenoyama-tôge, for example, the highest part of the land on the western side lies between triangulation point 662 meters and Nirayama, while on the eastern side it lies between Kuro-dake (799 meters) and Ikenoyama-tôge. The former is situated about 1 km south of the latter.

(4) As will be seen from Figs. 1 and 2, the boundary line between the Taga and Yugawara volcanoes on the western side of the fault lies about 1 km south of that on the eastern side.

Amount of Fault Displacement.

The facts mentioned in the preceding paragraphs (2) .... (4) lead us to the conclusion that the block on the western side of the Tanna fault has been displaced horizontally about 1 km southward relatively to the block on its east[5] after the present district had been subjected to warping and had been dissected by consequent valleys. This alone, however, is insufficient to explain the unequal height of the fault scarp mentioned in (1) of the preceding chapter.

In order to eliminate the effect of the above-mentioned horizontal displacement from the present topography and the distribution of the rocks, the map Fig. 1 was modified in the following way. The map was cut into two parts along the Tanna fault line, and the western part displaced northward along the fault line for a distance corresponding to 1 km, after which the two parts were again joined to each other. Each contour line in one part of the map was again joined to the corresponding one in the other across the fault line. The complete map thus obtained is shown in Fig. 3. The valley courses, the boundaries between the volcanoes, and the Tanna fault line, are marked as in Figs. 1 and 2.

In this map, the three valleys in question are seen to run along quite simple courses across the fault line, and the southern boundary of the Yugawara volcano is represented by a smooth line. Moreover, the highest parts of the neighbourhood of Ikenoyama-tôge are disposed symmetrically on both sides of the fault line.

On the other hand, the map Fig. 3 shows a fault scarp topography

5) From the distribution of valley courses in the neighbourhood of the Tasiro basin, Y. OTUKA also inferred the southward displacement of the block on the western side of the Tanna fault (Y. OTUKA, *Bull. Earthq. Res. Inst.*, **11** (1933), 555). He gives the amount of this displacement as 4 km, which however is a misprint for 1 km.

developed symmetrically on both the northern and southern sides of Ikenoyama-tôge. Along this scarp, a marked discontinuity is seen in the slope of the Taga volcano. Thus, if the surface of the slope on the western side of the scarp were produced eastward, this imaginary

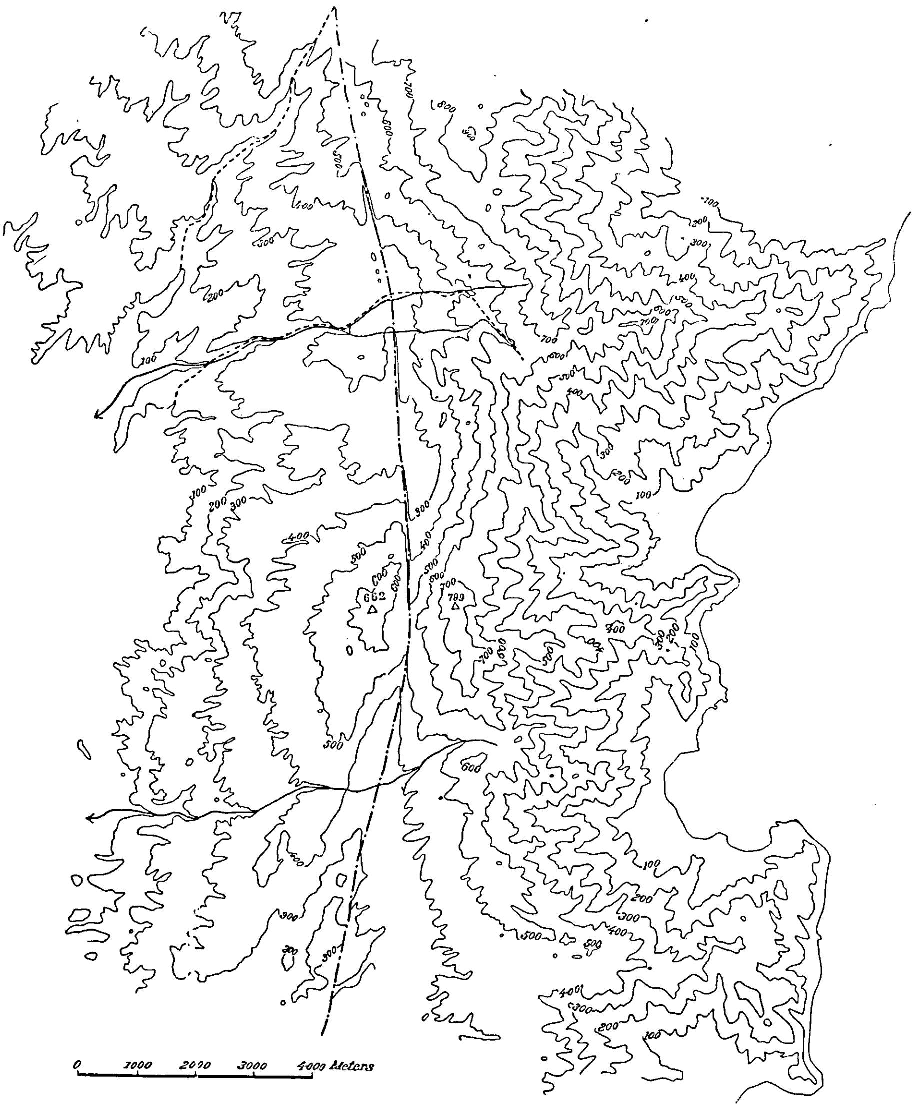

Fig. 3.

plane would pass above the actual surface of the slope on the eastern side. Therefore, it may be inferred that the western block here has been elevated relatively to the eastern block, the amount of which elevation is estimated to be about 100 meters or more.

In order to eliminate the effect of the above-mentioned vertical displacement, the map Fig. 3 was modified so as to represent a topography in which the block on the western side of the fault has sunk

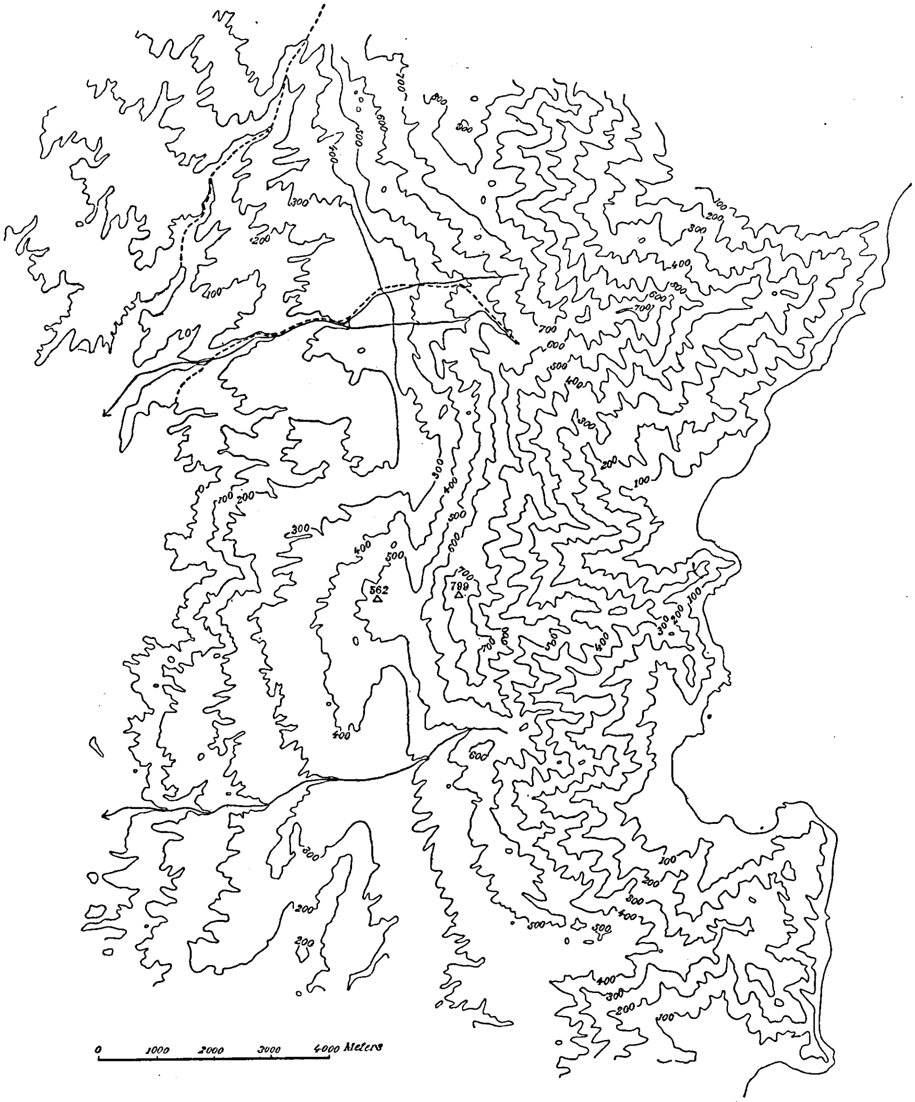

Fig. 4.

100 meters uniformly throughout the whole length of the fault from the position shown in Fig 3. Each contour line of the western block of Fig. 3 was reduced 100 meters in altitude, and again joined to the

corresponding lines of the eastern block. The map thus obtained is shown in Fig. 4, in which the valley courses and the boundaries between the volcanoes are marked as in the preceding figures. This map may be regarded as approximately representing the topography in which the effects of both horizontal and vertical (uniform vertical displacement assumed) displacements have been eliminated.[6]

In the map Fig. 4, the fault scarp topography in the neighbourhood of Ikenoyama–tôge has mostly disappeared. The western slope of the Taga volcano shows no discontinuity, being represented by that of a simple volcanic cone.

Along the northern part of the fault line, however, a scarp facing westward is found on the slope of the Yugawara volcano. Here the slope of the volcano shown in the map Fig. 3 is more continuous than that shown in the map Fig. 4. This fact suggests that scarcely any vertical displacement occurred in the northern part of the fault line, whence it follows that the amount of elevation of the block on the western side of the fault, which attains to 100 meters or more in the southern district, diminishes as one goes northward.

The discussions given in the foregoing pages are summarized as follows:

The slopes of the Taga and Yugawara volcanoes were subjected to warping, which caused subsidence of the Tanna and Tasiro basins and elevation of the area between Kuro–dake and Nirayama. The slopes were dissected by consequent valleys. Later, the district was disturbed by the Tanna fault which occurred in the central part of the abovementioned slopes. The block on the western side of this fault was displaced horizontally about 1 km southward for the greater part of the fault line, and was elevated about 100 meters or more in its southern part, relatively to the block on its east. This elevation of the western block diminishes in amount toward the northern part of the fault line.

The foregoing view makes it easy to explain the unequal height of the fault scarp along the fault line (cf. (1), p. 622). In the same way, the peculiar shape of the fault scarp at the northwestern corner of the Tasiro basin (cf. (1), p. 622) may be explained as having been formed by the southward horizontal displacement of the western block. The absence of fault scarp topography farther north of the Tasiro basin may be partly due to the smallness of the vertical displacement.

It is interesting to note that the fault displacement that occurred

6) Although the effects of the displacements have been eliminated, that of the erosion which acted intensely along the fault line may be remained.

at the time of the earthquake of 1930, is very similar in character to the above-mentioned displacement that occurred in geological times. Thus, according to C. TSUBOI[7] and Y. OTUKA,[8] the block on the western side of the Tanna earthquake fault was displaced horizontally 2 or 3 meters southward, and was slightly depressed in the northern district (north of the Tanna basin) and elevated in the southern (south of the Ukihasi basin), relatively to the block on its east. It will be seen that the fault displacement that occurred at the time of the recent earthquake is a repetition of the fault activity that has taken place in geological times.

Although in the foregoing pages, the fault displacement has, for convenience, been discussed as if it had occurred in two distinct directions, horizontal and vertical, it is scarcely nescessary to add that, actually, the displacement must have occurred in a direction generally with both horizontal and vertical components.

History of the Tanna Fault.

In the northwest of the Ukihasi basin, the surface of the fault scarp is covered by gravel beds that show, although indistinctly, horizontal stratification planes. The pebbles are slightly water-worn and subangular in form. The manner in which these pebbles are arranged shows that these gravel beds were deposited by a river that ran from north to south. This river was probably formed along the Tanna fault line which had then made its appearance. The presence of the gravel beds almost up to the top of the scarp indicates that the former was already deposited during the earliest stage of the fault activity and was later uplifted. The probability is therefore strong that the fault displacement was accomplished, not in a short time, but intermittently through a long period of time.

As the eruption of the Taga volcano dates to lower Pleistocene, it follows that the fault displacement is post-lower Pleistocene in age. As to whether or not the fault existed prior to the eruption of the Taga volcano, scarcely anything is known.

Geomorphological Development of the Tanna Basin.

The origin of the Tanna basin has been the subject of much debate by previous writers. Most of these writers seem to have overstressed the importance of the Tanna fault displacement as a factor in the

7) C. TSUBOI, *Bull. Earthq. Res. Inst.*, **9** (1931), 271.
8) Y. OTUKA, *Bull. Earthq. Res. Inst.*, **11** (1933), 530.

geomorphological development of the basin. However, as already mentioned, it is highly probable that the basin had subsided prior to the fault displacement. Besides, it should not be overlooked that the fault in question passes through the centre of the basin. This fact, taken together with the nature of the fault displacement, suggests that the geomorphology of the basin can hardly be explained by the fault displacement alone.

The observations on the Tanna district and along the wall of the Tanna tunnel have yielded ample data on the geologic structure of the basin, a detailed account of which has been already given in an earlier paper,[9] so that only the results of the observations are given here in brief.

The strata of volcanic material, that make up the Taga volcano and the Hata beds lying underneath the former, incline gently toward the centre of the basin, roughly agreeing with the surface topography. They probably form a syncline or a basin structure. The Tanna fault in question traverses the centre of this basin structure. The relative vertical displacement of the strata caused by the fault is apparently slight. Along the eastern margin of the basin, we find a set of meridional faults closely spaced to each other, the blocks on the western side of which are down-faulted stepwise toward the basin (see Fig. 1, paper just cited).

From these facts, it may be inferred that the Tanna basin is a structural basin formed chiefly through down-warping of the slope of the Taga volcano. Probably, the basin thus formed was rather simple in topography. The subsidence of the basin may have been augmented by dislocation caused by the step-faults along its eastern margin.

Later, the basin was traversed by the Tanna fault through its centre. As a result of this fault displacement, which occurred mostly in a horizontal direction, the basin was changed somewhat with complexity added to its topography. Thus, the hill which now lies back of the Tanna primary school (see Fig. 2), and which once formed a part of the more northerly lying mountain, was projected southward into the basin. The gently sloping area that now forms the background of Niiyama, southwest of the basin, was at one time situated in the central part of the basin. It was displaced southward and elevated slightly by the fault displacement. This view is supported by the occurrence in this area of a lacustrine deposit, consisting of stratified clays, up to a point about 100 meters above the present surface of the

9) H. KUNO, *Bull. Earthq. Res. Inst.*, **14** (1936), 101.

basin.

Although it is emphasized in the foregoing discussion that the fault displacement itself played only a subordinate role in the development of the Tanna basin, it is not to be overlooked here that all the three basins, Tasiro, Tanna, and Ukihasi, are arranged on the fault line. This fact suggests that the genesis of these basins has something to do with the Tanna fault.

Summary.

Warping of the slopes of the Taga and Yugawara volcanoes (lower Pleistocene) caused subsidence of the Tanna and Tasiro basins and at the same time elevation of the area between Kuro–dake and Nirayama. Later, this district was affected by the Tanna fault. The block on the western side of the fault was displaced about 1 km horizontally southward for the greater part of the fault line, and was elevated about 100 meters or more in its southern part, relatively to the block on its east.

The fault displacement that occurred at the time of the earthquake of 1930 is similar in character to the above–mentioned displacement that occurred in geological times.

The fault displacement itself is not the sole cause of the origin of the Tanna basin. This basin was formed chiefly through down–warping of the volcanic slope. As a result of the fault displacement, the topography of the basin became somewhat more complex than it had been before.

Addendum.

It is interesting to note that the horizontal component of the Tanna fault displacement attains to nearly 10 times that of the vertical. Displacement with dominant horizontal component along an almost vertical fault plane is often caused by differential movements of the front of an overthrusting block. But the Tanna fault is quite independent of any thrust faults.[10]

The importance of the horizontal component in an ordinary fault displacement seems generally to be overlooked. For example, when a series of monoclinal strata is displaced by a dip-fault, and an older stratum on one side of the fault comes into contact with a younger on another side, the block on the side of the older stratum is inferred as

10) S. AWADI recognized horizontal displacements in several NW-SE faults on the slope of the Yugawara volcano east of the Tasiro basin (T. TSUJIMURA and S. AWADI, *Geogr. Rev. Japan*, **10** (1934), 1122). It is probable that fault displacements with dominant horizontal components are common in north Idu and adjacent district.

having been elevated relatively to the block on the other side. But this inference is not necessarily correct if the horizontal component in the fault displacement is taken into consideration. The same result should obtain when the block on the side of the older stratum is displaced horizontally toward the direction of the dip of the strata. It follows therefore that the true direction of a fault displacement cannot be inferred merely from the contact relation of rocks of different ages at one point alone, or from the manner of displacement of a series of monoclinal strata.

---

57. 更新世以後に於ける丹那斷層の運動に就いて

東京帝國大學 地質學教室　久　野　久

丹那斷層に沿ふた地域に於ける地質學的並に地形學的觀察の結果を基にして，更新世以後に於ける本斷層の運動を推定した．其の結果，斷層の西側の地塊は，東側の地塊に對して，南方に向つて約 1 km 水平に移動し，且つ本斷層線の南部（浮橋—池ノ山峠間）に於いて約 100 m 若くばそれ以上隆起して居る事が判明した．

此の地質時代に行はれた斷層運動は昭和 5 年（1930 年）11 月の北伊豆地震の際の丹那斷層の運動と其の性質が極めて類似して居る．

丹那斷層の運動そのものは，丹那盆地成因の根本的要素ではない．同盆地は多賀火山の斜面に働いた撓曲によつて沈降したものである．丹那斷層の運動の結果は本盆地の地形を以前より複雑にしたに過ぎない．
