9. *The Geologic Section along the Tanna Tunnel.**

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(Read Feb. 19, 1935.—Received Dec. 18, 1935.)

Introduction.

This paper embodies that part of the geological work of Idu district now in progress at the auspice of the Earthquake Research Institute, which is concerned particularly to the Tanna tunnel.

Along the east coast of the northern part of Idu peninsula, there extends a mountainous land, built up of thick piles of Tertiary and Quaternary volcanic rocks, forming the main divide of the district. The Tanna fault line, famous among seismologists for its behaviour at the time of the great Idu earthquake of November 26, 1930, runs meridionally on the western slope of the mountainous land. The district is also of geological interest, and many problems, as for example that of the origin of Tanna basin, a circular depression about 1 km across, situated on the Tanna fault, were much debated by geologists.

In 1934, the excavation of a railway tunnel traversing the abovementioned mountainous land in west-north-west direction, was completed; and the underground geological structure of the Tanna district, especially that beneath the Tanna basin, was brought into sight. The tunnel connects two towns Atami and Misima, and has total length of 25,603 feet or 7,804 meters.

The present paper contains the description of the geologic section along the eastern half of the Tanna tunnel, based on the observation along the tunnel wall, and the examination of rock specimens there collected, as well as on the general geological survey in the district.

The late Dr. Takeshi HIRABAYASHI described in 1925 the geology of those parts of the tunnel which were accessible at that time when the tunnelling from the both entrances was not much advanced.[1] When I examined the tunnel, the lining of the wall of the tunnel had been completed for most of these parts, so that my observation upon

* Communicated by S. TSUBOI.

1) T. HIRABAYASHI, On the geology of the Tanna basin. (Published from the Railway Department in 1925).

the actual exposures on the wall was confined only to the central part of its whole length, that is, between the points about 10,000 feet and 15,300 feet from the eastern entrance. Fortunately, however, complete series of rock specimens collected from the floor of the tunnel for the distance of 10,335 feet from the eastern entrance, were available to me. This ennabled me to determine exactly the distribution of different rock types, although the relations between them could be only inferred on the basis of my knowledge of the geology of the district. From these data, the geologic section given in Fig. 1 was constructed, which differs from HIRABAYASHI's in some essential points.

In the following descriptions, the numbers of feet indicating the position of each point in the tunnel refer to its distance from the eastern entrance.

Acknowledgement.

I wish to express my thanks to the Director and other members of the staff of the Earthquake Research Institute for many respects during the present work, and especially to Professor Dr. Seitarô TSUBOI for his kindness in reviewing this paper in manuscript.

Thanks are also due to Messrs. Hirosi ARIMA and Kyûgo ISIKAWA, the engineers in the Government Railway Department, as well as to Mr. Kôiti HIROTA, the geologist in the same Department, who kindly gave facilities for my geological survey in the tunnel.

Description of the Geologic Section along the Tanna Tunnel. (See Fig. 1)

***From 0 to 2,600 feet*:**

Compact andesitic lavas of the Ainohara beds (*lower Pliocene*?).

The Ainohara beds, composed of an alternation of dark green compact lavas of two-pyroxene-andesites and thin beds of tuffs or loose slaggy parts of the lavas, are spread to the north and west of Atami-mati.[2]

Along the tunnel wall, are exposed the lavas of this formation. They are massive, dark green, and very compact, between 0 and 1,900 feet, and massive greyish, between 2,112 and 2,600 feet. The latter is separated from the former by an intercalating thin bed of greyish white, pumiceous tuff (between 1,900 and 2,112 feet), indicating the two probably to represent separate flows.

These rocks are intensely altered along cracks or joints to a greyish blue or whitish clayey masses by the action of solfataric gases

2) Y. ÔTUKA and H. KUNO, *Bull. Earthq. Res. Inst.*, **10** (1932), 473.

or of hot-spring solutions. These clayey masses are frequently met with in other portions of the tunnel wall as well as in surface outcrops in the vicinity of Atami-mati. They will be referred to in the present paper as "solfataric clay".

Along the valley of Ainohara (see Fig. 1) runs a fault in the NW-SE direction, the southwestern side of which is uplifted relatively to the northeastern. This fault crosses the tunnel at the 1,050 ft point, where much solfataric clay is developed in the wall rock. The direction of inclination of the fault plane is unknown.

On the ground surface, the Ainohara beds are represented, in most places, by lavas, resting unconformably upon the Nonaka beds to be referred to later, but occasionally, by thin dikes cutting the latter. In the tunnel section Fig. 1, they are provisionally shown as lavas resting upon the Nonaka beds. According to HIRABAYASHI, the boundary plane between the two formations now in question as seen on the tunnel wall has a steep inclination toward the south.

Under the microscope, the lavas of the Ainohara beds occurring in the tunnel belong to a single type of two-pyroxene-andesite. It contains phenocrysts of plagioclase, augite, hypersthene, and magnetite, in a fine-grained compact groundmass. The rocks are in most instances altered to a considerable degree, with secondary chlorite filling the interstices between the primary crystals or replacing hypersthene phenocrysts. To this process the rocks owe their dark green colour and compactness.

The rocks occurring between 2,112 and 2,600 feet are, however, rather fresh in appearance, with distinctly visible phenocrysts of pyroxene in greyish matrices. Under the microscope, they are poor in secondary chlorite.

As shown in Fig. 1, the Ainohara beds are covered by the Tensyô-zan beds (a complex of basaltic lavas and agglomerates) which occur on the slope to the west of Atami-mati, but not inside the tunnel.

From 2,600 to 3,950 feet:

Dacitic tuffs and mudstones of the Nonaka beds (upper Miocene or lower Pliocene).

The Nonaka beds consist of an alternation of beds of tuffs of two-pyroxene-dacite and those of mudstones, and outcrop along the margin of Atami-mati.[3)]

Along the tunnel wall, they consist of an alternation of beds of

3) Y. ÔTUKA and H. KUNO, *op. cit.*, 473.

pale greyish mudstones, whitish or pale green pumiceous tuffs, and whitish tuff-breccias. According to HIRABAYASHI, they occasionally contain wood fragments, and show bedding planes, str. N 50° E, dip SE 6~12°.

From the general resemblance of their constituent volcanic materials, and from their stratigraphic relations, the Nonaka beds are correlated to the Hayakawa beds, which the latter form the base of the Hakone volcano and contain molluscan fossils of upper Miocene or lower Pliocene age.[4]

Under the microscope, the tuffs of the Nonaka beds occurring in the tunnel consist mainly of fragments of pumice containing phenocrysts of plagioclase, hypersthene, augite, and quartz, in a groundmass of colourless vesicular glass.

From 3,950 to 4,250 feet:

Lavas of the Basalts of the Hudô tunnel (Miocene).

They are, on the tunnel wall, massive, dark grey or black, and compact. Their petrographic characters are essentially the same as those of the type basalts occurring in the Hudô and Minakuti tunnels (Itô Railway Line), south of Atami-mati. In the last-mentioned tunnel, the basalts are covered unconformably by the Nonaka beds. In constructing the section of Fig. 1, the just-mentioned relation is assumed, because the actual relation at this particular point is unknown.

From 4,250 to 5,700 feet:

Altered andesitic lavas, tuff-breccias, and agglomerates of the Hirogawara beds[5] (lower Miocene).

In the eastern part, the lavas predominate, while in the western, the tuff-breccias and agglomerates. These rocks are in much altered condition, being penetrated by veinlets of calcite or zeolites. In this and other respects, these rocks resemble to some rocks of the Hirogawara beds, especially to those occurring at Sogayama, south of Atami-mati.

The Hirogawara beds are the oldest known formation in the north Idu district, and are correlated to the Yugasima series (lower Miocene) of the south Idu district.[6]

The lavas occurring in the tunnel show quite similar appearance to each other in hand specimen, carrying sporadic phenocrysts of

4) Y. ÔTUKA, *Jour. Geol. Soc. Tokyo*, **41** (1934), 564.
5) Corresponding to the Sogayama beds in the earlier paper: Y. ÔTUKA and H. KUNO, *op. cit.*, 472.
6) R. TAYAMA and H. NIINO, *Report of Saitô Hôonkai*, **13** (1931).

cloudy plagioclase and black augite in a black compact matrix. Augite usually shows a good crystal outline. Under the microscope, these rocks belong to a single type of olivine-pyroxene-andesite with a glassy groundmass. Augite is the only mineral that is free from alteration.

In this part of the tunnel now under consideration, more fresh basaltic rocks are also met with at three separate places. They have the same characters as those of the Basalts of the Hudô tunnel characterized in the above. In Fig. 1, these basalts are shown provisionally as resting upon the undulating surface of the Hirogawara beds. But it is as well possible that, at these particular points, they are separated from the Hirogawara beds by sets of closely-spaced faults.

From 5,700 to 6,500 feet:

Lavas of the Basalts of the Hudô tunnel (Miocene).

Massive, dark grey, compact basalts quite similar in character to the Basalts of the Hudô tunnel appear again in this part of the tunnel.

The Basalts of the Hudô tunnel occurring between 3,950 and 6,500 feet are somewhat variable in petrographic characters. In hand specimen, they are compact and dark grey or black in colour, often with indistinctly visible phenocrysts of plagioclase and pyroxene. Under the microscope, they are mostly hypersthene-basalts carrying phenocrysts of calcic plagioclase and hypersthene, rarely with those of augite. But some of the rocks are olivine-basalts carrying phenocrysts of calcic plagioclase and olivine. The groundmasses are typically basaltic in texture, ranging in granularity from fine-grained to coarse-grained types. They consist of plagioclase, monoclinic pyroxene, magnetite, cristobalite, and pale brown glass. The rocks are often more or less altered, with carbonate mineral completely replacing olivine, and chlorite filling the interstices between the primary crystals.

From 6,500 to 8,000 feet:

Basaltic lavas and scoriae of the Hata beds (upper Pliocene?).

In this part of the tunnel, a few compact lavas occur among thick piles of purplish red scoriae or scoriaceous lavas. The rocks are quite free from any kind of alteration. In this and other petrographic features, the present lavas resemble to the rocks of the Hata beds to be described later.

Inferred from the quite unaltered condition of the rocks, the Hata beds may be probably younger than the Basalts of the Hudô tunnel occurring immediately adjacent to the east, and than the Acid Andesites occurring immediately adjacent to the west. However, it is not impossible that these formations are bounded by faults on the tunnel wall. But this is rather improbable, because no fault has been observed by HIRABAYASHI at the boundary points.

From 8,000 to 9,050 feet:

Lavas of the Acid Andesites (Miocene or lower Pliocene?).

They are massive, more or less compact, and accompany subordinate scoriaceous parts. They are intensely altered to the solfataric clay already mentioned, especially between 8,200 and 9,000 feet.

The present formation is not correlated to any of the formations that appear on the ground surface. But from the highly altered condition of the rocks, it is inferred to be of rather old age (Miocene or lower Pliocene), at least older than the Hata beds, though younger than the Hirogawara beds. The above-mentioned alteration of the rocks of the present formation to the solfataric clay may have probably taken place prior to the formation of the Hata beds, since the rocks of the latter beds are entirely unaffected by this action.

The rocks of the Acid Andesites are clearly separated by a fault at the 9,050 ft point from those of the Hata beds occurring immediately to the west. This fault corresponds to the fault indicated by the unusual topography on the main divide at the point just above the tunnel, where the road from Atami-mati to the Tanna basin crosses the divide. This fault strikes N 45° W, and dips about 70° or more toward the southwest. The direction of the displacement along this fault is unknown. At the time of the great north Idu earthquake of November 26th, 1930, the concrete wall of the tunnel was cracked in N 45° W direction at the 9,050 ft point, the point where the fault in question crosses the tunnel.

Another fault was observed by HIRABAYASHI at the 8,218 ft point.

The rocks of the Acid Andesites are, in hand specimen, usually light grey in colour, showing sporadic phenocrysts of plagioclase. Under the microscope, they belong to a single type of two-pyroxene-andesite containing phenocrysts of plagioclase, hypersthene, augite, and magnetite, in a fine-grained groundmass consisting of plagioclase, monoclinic pyroxene, magnetite, and cristobalite, either with or without glass base.

From 9,050 to 12,900 feet:

Basaltic lavas and scoriae of the Hata beds (upper Pliocene?).

The name Hata beds is given to a thick complex of basaltic lavas, scoriae, and tuffs, which outcrops on the lower part of the steep slope rising from the eastern margin of the Tanna basin. At Simotanna, west of the Tanna basin, one of the lavas of this formation is covered unconformably by pumiceous mudstones of the Simotanna beds which are considered by Y. ÔTUKA as of lower Pleistocene age.[7] From this stratigraphic relation, as well as from the quite unaltered condition of the rocks, the age of the Hata beds may be inferred as upper Pliocene.

On the tunnel wall, the present formation consists of a complicated alternation of compact lavas (usually less than several meters in thickness) and fragmental materials such as scoriae, tuffs, tuff-breccias, and agglomerates, the latter predominating the former greatly in amount. Dikes are rather rare. The abundance of purplish red scoriae and beautiful yellowish tuff-breccias is a characteristic feature of this formation. Spindle-shaped bombs attaining to 2 feet in length are occasionally found in the scoria beds. Such bombs are also found occasionally from the surface outcrops of the Hata beds along the eastern margin of the Tanna basin. This occurrence of bombs was once taken erroneously by some previous authors as an evidence of the crater origin of the Tanna basin. The rocks of the Hata beds occurring in the tunnel are almost free from any kind of alteration.

Besides the above-mentioned fault at the 9,050 ft point, two remarkable faults are also seen, namely, at 11,200 and 11,500 ft points.

The fault at the 11,200 ft. point corresponds probably to the meridional fault which is indicated by a slicken-side at the foot of the steep scarp along the eastern margin of the Tanna basin.

The fault at the 11,500 ft point appears on the tunnel wall with a slicken-side. It strikes north-north-west and dips steeply toward the west. On the ground surface, this fault plane is concealed beneath a thick talus that fringes the foot of the above-mentioned steep scarp. It has been reported[8] however that, at the time of the great north Idu earthquake, a meridional earthquake fissure appeared upon this talus slope. The position of this fissure corresponds exactly to the upward prolongation of the fault plane observed in the tunnel.

Besides the above-mentioned faults, there may be found several less significant ones between 9,050 and 11,500 feet. But it is rather striking that, except a few quite insignificant ones, no fault has been detected between 11,500 feet and 13,850 feet, the latter being the point where the famous Tanna fault crosses the tunnel.

Between 9,050 and 11,500 feet, layers of lavas and fragmental

7) Y. ÔTUKA, *Bull. Earthq. Res. Inst.*, **11** (1933), 547.
8) Y. ÔTUKA, *Bull. Earthq. Res. Inst.*, **11** (1933), Pl. XXVI.

materials of the Hata beds show moderately steep (up to 40°) inclinations toward the north or northwest. These inclinations agree well with those of the same formation as seen in the surface outcrops along the eastern margin of the Tanna basin, that is, just above this part of the tunnel now under consideration.

But on the west side of the fault at the 11,500 ft point, these layers show a westward inclination, with angles ranging from 40° in the immediate west of the above-mentioned fault, to 10° in the further west. They are then abruptly folded at the 12,711 ft point, and assume a renewed inclination toward the southeast with an angle of 50°. At the 12,900 ft point, these folded layers are truncated clearly by a plane of unconformity, which inclines toward the west and is overlain by stratified tuffs and agglomerates of the Taga volcano to be mentioned later. The rocks of the Hata beds occurring immediately below this plane of unconformity scarcely show signs of decomposition due to weathering. The relations as above mentioned are shown in Fig. 2.

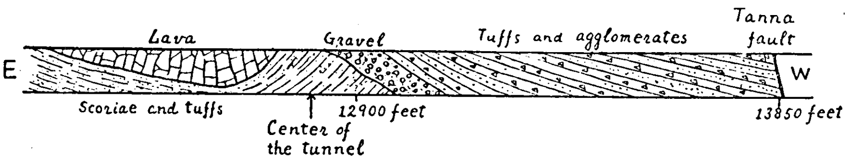

Fig. 2. A sketch of the exposure along the tunnel wall between 12,200 and 13,850 feet.

The compact lavas of the Hata beds that occur in the tunnel between 6,500 and 12,900 feet, are quite variable in petrographic characters. In hand specimen, they are dark grey or black in colour, and either compact or slightly vesicular. Sometimes they carry abundant visible phenocrysts, but sometimes they are almost non-porphyritic. In the porphyritic representatives, beautiful crystals (up to 5 mm in length) of clear white plagioclase, clear yellow olivine, and dark green augite are usually seen.

Under the microscope, these rocks vary in type from more basic olivine-basalts to less basic augite-hypersthene-basalts. Phenocrysts of calcic plagioclase are always present. Those of pale green augite are usually present, being especially abundant in the rocks of intermediate basicity, and sometimes absent in the most basic ones. Phenocrysts of olivine and those of hypersthene occur with a reciprocal relation to each other in amount. The former is abundant in the more basic rocks, while its place is often taken by the latter in the less basic ones. Phenocrysts of magnetite are seen only in some of the less basic rocks in which those of olivine are usually absent.[9]

In texture, the groundmass varies from fine-grained compact type, through medium-grained intergranular type, to coarse-grained doleritic type. The constituent minerals of the groundmass are plagioclase, monoclinic pyroxene, magnetite, and cristobalite, either with or without pale brown glass.

Some of the olivine-basalts of the Hata beds may be probably the most melanocratic representatives of the common volcanic rocks of Japan.

It is interesting to note that the less basic types (augite-hypersthene-basalts) tend to occur toward the eastern part of the tunnel, while the more basic types (olivine-basalts) toward the western part of the tunnel and in the surface outcrops of the formation. In other words, the lavas of the present formation become more basic in composition toward the upper horizon of the series.

The only example of alteration is seen in a specimen collected at a point very close to the fault at the 9,050 ft point, where phenocrysts of olivine are completely replaced with chlorite.

***From 12,900 to 15,000 feet*:**

Andesitic lavas and tuffs of the Taga volcano (lower Pleistocene).

The Taga volcano consists of thick piles of basaltic and andesitic lavas interbedded with tuffs and agglomerates. It extends from the south of Aziro (5 km south of Atami-mati) to Atami pass (4 km northwest of Atami-mati). At Simotanna, west of the Tanna basin, some of the lavas of this volcano is seen to cover the pumiceous mudstones of the Simotanna beds (lower Pleistocene). From this and other facts, the age of the present volcano is inferred to be lower Pleistocene.

The lavas and the fragmental materials appearing in the Tanna tunnel are those representing only the intermediate stage of the history of the volcano now under consideration. In the section Fig. 1 is also shown another group of lavas underlying the lavas of the intermediate stage, which will be referred to as the lavas of Wada type (olivine-two-pyroxene-andesites). However, the lavas of Wada type do not appear on the tunnel wall.

On the tunnel wall, only a few sheets of lavas of the Taga volcano

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9) Such a tendency of the association of the porphyritic minerals in rocks of different basicity is a general feature of many suits of volcanic rocks in the north Idu district.

are intercalated between thick beds of yellowish tuffs and agglomerates. These rocks are entirely free from any kinds of alteration.

As has been already mentioned, the present formation is separated from the easterly lying Hata beds by a thin gravel bed that rests directly upon the plane of unconformity truncating the latter formation. The pebbles of this gravel bed are derived mostly from the rocks of the underlying Hata beds, and are subangular in form.

The tuffs and agglomerates of the Taga volcano show distinct stratification planes dipping toward the west, with angles ranging from 40° at the immediate west of the above-mentioned gravel bed to 10° at the east of the Tanna fault. These relations are shown in Fig. 2.

Although no sheet of lava appears on the tunnel wall between the Tanna fault and the junction point of the Taga volcano with the easterly lying Hata beds, a boring at the Tanna basin carried out by the Railway Department (Boring D in Fig. 1) revealed the existence of three sheets of compact lavas lying immediately above the beds of tuffs and agglomerates occurring in the tunnel. It must be noted that one of the lavas detected by the boring is entirely the same in petrographic characters as that occurring at the summit of Takidiyama (672·2 meters), 1 km north of the highest point in the section Fig. 1. They belong probably to one and the same flow.

At the junction of the Taga volcano with the westerly lying Hata beds, a sheet of somewhat scoriaceous lava is seen to lie upon the former, dipping gently toward the east.

The famous Tanna fault, which runs meridionally through the center of the Tanna basin, crosses the tunnel at the 13,850 ft point with a remarkable development of fault breccia. At the time of the great north Idu earthquake, this fault caused a remarkable deformation upon the ground surface as well as upon the tunnel wall. It has been reported that a new slicken-side appeared crossing the tunnel, along which the western block was shifted southward horizontally for a distance of about 8 feet relatively to the eastern. It is interesting to note that this slicken-side had a northwest strike in spite of the general meridional trend of the earthquake fault appeared on the ground surface. It follows then that the actual underground displacement, at least in the neighbourhood of the Tanna tunnel, took place along a series of parallel gliding planes arranged *en echélon*.

By comparing the position of the earthquake fault appeared on the ground surface with that of the slicken-side appeared in the tunnel, it may be inferred that the plane of the Tanna fault inclines steeply toward the west, or is nearly vertical.

The lavas of the Taga volcano occurring in the tunnel and detected by the boring are, in hand specimen, usually compact and dark grey in colour, carrying visible phenocrysts of abundant plagioclase and a few pyroxenes.

Under the microscope, they are usually basic two-pyroxene-andesites almost transitional to basalts in mineral composition. Olivine-bearing type is also found.

From 15,000 to 15,300 feet:

Basaltic lavas and scoriae of the Hata beds (upper Pliocene?).

The lavas have gentle inclinations toward the east.

It is certain that the rocks of the present formation extend further to the west of the point 15,300 feet.

The rocks are fresh olivine-basalts differing in no respect from those of the same formation already described.

The lacustrine deposits of the Tanna basin.

The result of the borings in the Tanna basin, carried out by the Railway Department, has shown that the surface of the basin in question is covered by beds of sandy muds and gravels of about 50 meters in thickness.[10] They are probably lacustrine and fluviatile deposits.

On the Geologic Structure of the Tanna Basin.

Two remarkable features regarding the geologic structure of the basin are to be noticed from the above descriptions and also from the section Fig. 1: —

1) The layers of the lavas and the fragmental meterials of the Hata beds and of the Taga volcano, as well as the plane of unconformity between these two, incline toward the center of the basin. Probably they form a syncline or a basin structure.

2) Relative vertical displacement of the blocks on both sides of the Tanna fault is apparently slight. (See the symmetrical disposition of the rocks of the two formations, the Hata beds and the Taga volcano, on both sides of the Tanna fault in Fig 1).

These features show that the Tanna basin is not a mere "Graben" nor was originated simply through a sort of kettle depression, as has been suggested by some earlier authors, but was originated mainly through the down-warping of the layers of the lavas and the fragmental materials of the Taga volcano which formed primarily the land

10) T. WATANABE, On the geology of the Tanna basin. (Published from the Railway Department in 1925.)

(震研彙報 第十四號 圖版 久野)

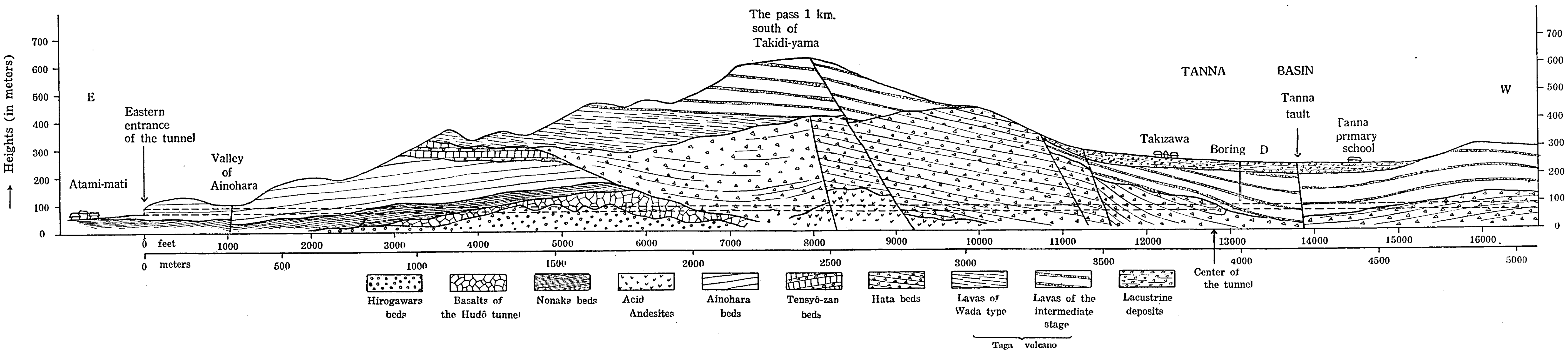

Fig. 1. The geologic section along the eastern half of the Tanna tunnel.

surface of the district. This problem will be discussed more fully in another paper which is now under preparation.

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9. 丹那隧道の地質斷面圖

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丹那隧道内に於ける實際の岩石露出面の觀察，多數の岩石標本の採集，並びに隧道附近地表面の地質調査等の結果を基にして，丹那隧道東半部の地質斷面圖（第１圖）を作製した．本論文にては，此の斷面圖に就いて各部分に於ける諸種岩層の產狀，相互關係，構造並びにその構成物質の岩石學的性質の大略等を記載した．

本研究の結果，此の附近地域の地質構造が可なり明になつた．特に今まで多數の學者によつて議論されて來た丹那盆地の地下構造が判明した．丹那盆地は從來唱へられた如く火口跡でもなく單なる地溝でもなく，又單に鍋狀陷沒のみによつて生じたものでもない．それは多賀火山の噴出物層が主として撓曲沈降して生じた構造盆地である事が分つた．尙本盆地の成因に關する詳しい議論は他の機會に讓る．
