16. *A Geologic Interpretation on the Underground Structure of the Sititô-Mariana Island Arc in the Pacific Ocean.*

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In connection with the subject of the permanency of the ocean and Wegener's theory of drifting continents, many theories have been advanced regarding the geology of the ocean floor and its internal structure, for the apparent reason that they do not lend themselves so readily to survey as is the case on land. For example, there are a number of theories regarding the floor of the northern Pacific ocean. Notwithstanding the present obstacle, many geological and geophysical facts concerning the northern Pacific ocean have been brought to light by Japanese scientists, and the need for a new hypothesis on this part of the ocean has been felt in view of these new scientific results. In this paper the writer proposes a new geologic hypothesis of the underground structure of the Sititô-Mariana submarine ridge and the Japan trench considered from these new scientific results.

The Sititô-Mariana group of islands, together with the submarine ridge, which is a large, long bulge of the sea floor, branches off from the central part of the Japanese main island arc toward the southern part of the north Pacific Ocean.

In 1937, the Imperial Japanese Naval Hydrographic Office[1] published a bathymetric chart of the northern Pacific, which latter was recently resounded. This has greatly advanced our knowledge of the bottom topography of this ocean. According to this chart (Fig. 1), the deep Japan trench, which runs from the eastern coast of the Tisima island arc to the southern coast of the Caroline islands through the east coast of the Northeast Japan and the east coast of the Sititô-Mariana group, which is given in great detail, is narrower than before; that is, it is only about 200 km wide and has many deeps which exceed 8000 m. West of this trench, at its northern part, there is a large long, narrow bulge, where the Tisima island arc lies, and

1) *Bathymetric chart of the sea near Japan, Imp. Jap. Nav. Hydr. Off.* (1937).

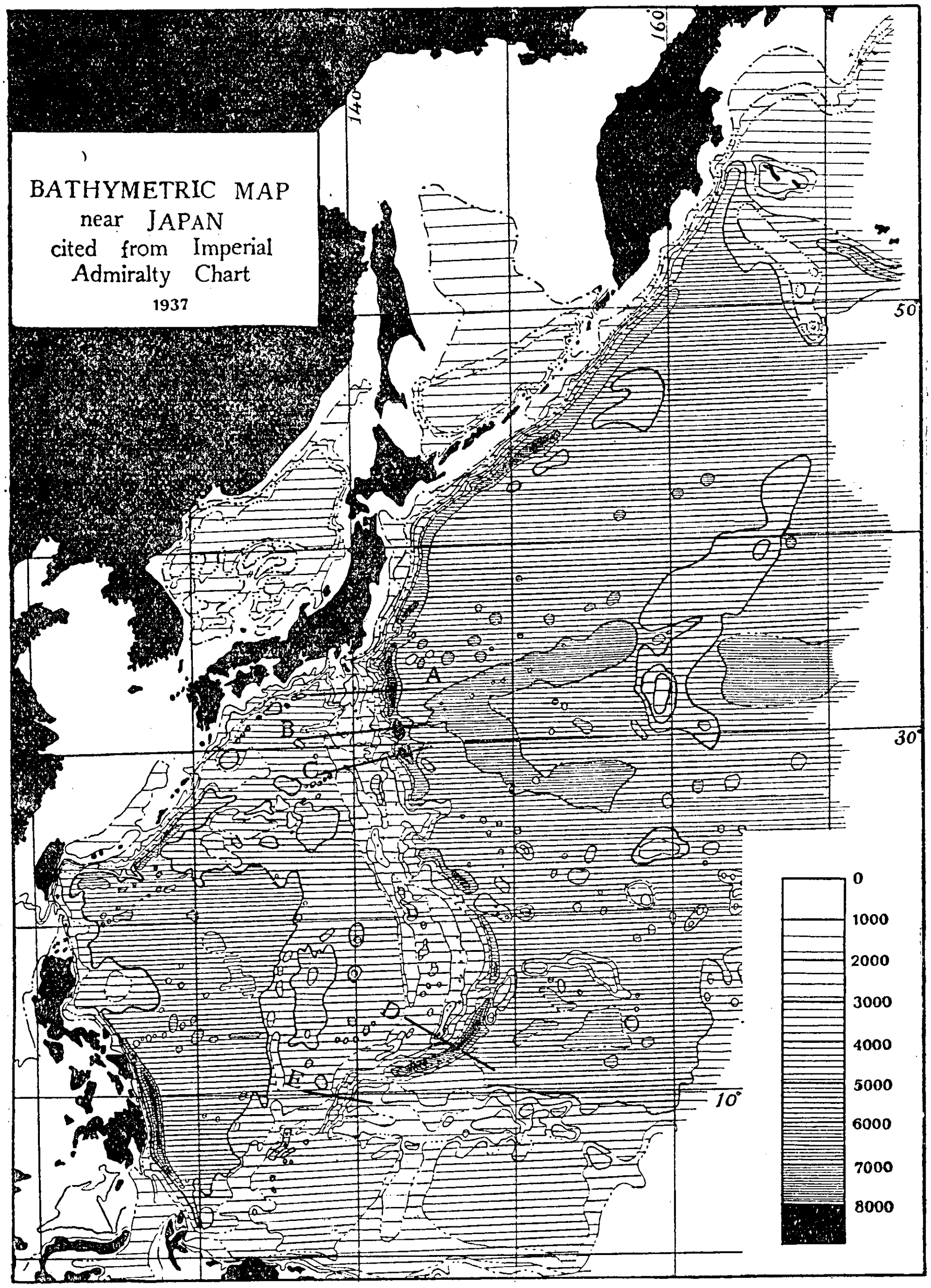
BATHYMETRIC MAP
near JAPAN
cited from Imperial
Admiralty Chart
1937
140
160
50
30
10°
A
B
C
D
E
0
1000
2000
3000
4000
5000
6000
7000
8000

Fig. 1.

at its central part a similar bulge where the Hokkaidô and Northeast Japan lie. On its southern part, we have the Sititô-Mariana island arc and the submarine ridge, both of which are situated west of the Japan trench. Consequently, if profiles perpendicular to the general trend of the trench are taken across the trench and the bulge, these profiles will show similar forms no matter where they are taken, as shown in Fig. 2, except near the central part of the Japanese island arc and Hokkaidô. Since this is characteristic of any profile as just mentioned, if the sea-level were neglected, the profiles near Tisima, those near Northeast Japan, and those near the Sititô-Mariana island arc and submarine ridge, may be regarded as being the same as those taken on the land part of Northeast Japan, at any rate from the megamorphological view point.

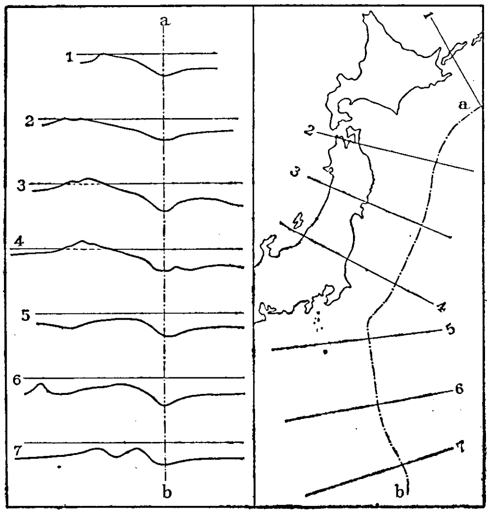

Fig. 2. Profiles perpendicular to the general trend of the Japan trench (ab). Vertical scale: horizontal scale=13: 1

Recently R. Tayama[2] made a morphological study of the coastal terraces that are developed on the coral islands of the Sititô-Mariana island arc, and concluded that they were Cainozoic upwarps of this island arc. According to him, the Mariana island arc generally has its convex side eastward in plan and is asymmetrically upwarped in elevation perpendicular to the general trend of the island arc. In this asymmetric upwarping, the east wing of this upwarping has steepened since the Pliocene age, while the slope of the west one has been lowered, as if the east wing were dragged downward by the subsidence of the submarine trench.

In other words the Sititô-Mariana island arc and submarine ridge may be a large upwarping zone of the earth's surface, and the Japan trench a deepening zone.

The writer[3] once criticized Prof. H. Yabe's paper and opinion ex-

2) R. TAYAMA, *Sci. Rep. Tôhoku Imp. Univ. in Japanese Language*, **28** (1937).
3) Y. OTUKA, *Jour. Geol. Soc. Tokyo (now Japan)*, **37** (1930), 439, pp. 175~178.

pressed that the Japanese island arc may be an upwarped zone. According to H. Yabe[4], who studied the submarine topography around the Japanese island arc, the higher terrace (his terrace "T" = (PN) in Fig. 3) on the land part corresponds to the deeper submarine terrace, and the lower (his "M" = (T) in Fig. 3) to the shallower one. If this inference is correct, to unite these contemporaneous two-levelled terraces into one, as shown in Fig. 3, we shall have to consider an upwarped surface containing these two levels, with the result that the Japanese island arc has to be upwarped along its long axis (as shown in Fig. 3) to explain the distribution of these contemporaneous two-levelled terraces, similar to the Sititô-Mariana island arc and submarine ridge.

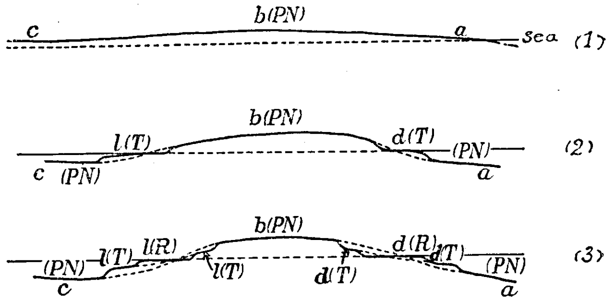

Fig. 3. Correlation of the terraces above and below the sea-level. Line abc in (1) (2) (3) shows the land surface during the latest Pliocene; full line $l(T)$ & $d(T)$ in (2) show the new erosion and sedimentation surfaces during Pleistocene; $l(R)$ & $d(R)$ are those during Holocene.

For this reason, the writer is not prevented by any morphological objections, generally speaking, from assuming the upwarping of the island arc and the downwarping of the submarine trench during the Quaternary age.

Recently C. Tsuboi[5] has called attention to the upwarping of the ground over which pass the bench marks across the island arc. It will not be surprising if this upwarp of the island arc generally agrees with the results of the precise levelling.

Geologically, the Sititô-Mariana island arc mainly consists of Cainozoic pyroclastics and volcanic rocks. Most of the islands on the submarine ridge are volcanic; while in the submarine trench no volcanic evidences have yet been found. The basal complex of these Cainozoic rocks are crystalline schist and some plutonic rocks which are exposed only on the island of Yap, but no pre-Tertiary sedimentary rocks are found on these islands.

According to R. Tayama[6], the schistosity of the crystalline schist

4) H. YABE, *Proc. Imp. Acad.*, **5** (1929), 9, p. 167.
5) C. TSUBOI, *Jap. Jour. Astr. Geophys*, **10** (1933), pp. 117~125.
6) R. TAYAMA, *Sci. Rep. Tôhoku Imp. Univ. in Jap. Language*, **19** (1935).

exposed on the island of Yap runs parallel to the long axis of the island, that is, the trend of the basal structure is almost parallel to the general trend of the southern part of the Sititô-Mariana submarine ridge and island arc.

Recently T. Tomita[7] summarized the preceding authours' views on the alkali rocks and published a map showing the distribution of the Tertiary alkali and alkalicalc effusive rocks in the world, as partly shown in Fig. 4. Although the distribution map contains certain hypothetical boundary lines, in connexion with the two kinds of rocks, it was an epoch making map of the kind.

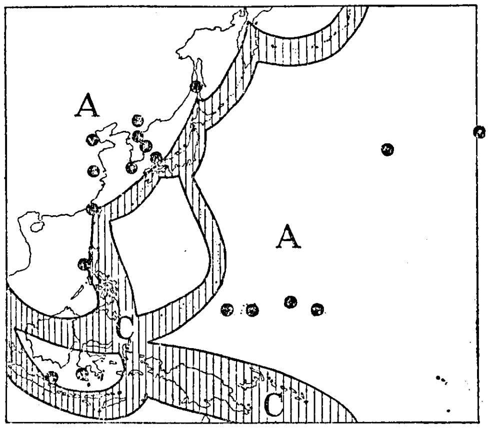

Fig. 4. Map showing the distribution of the Neogene effusive alkali rock (A) and alkalicalc rock (C) in the northern Pacific (Mainly after T. Tomita and M. Yosii.)

According to this map, although the effusive rocks of the Sititô-Mariana island arc are alkalicalcic, those of the eastern Caroline islands are alkalic. Since then M. Yosii[8] and H. Tsuya[9], who studied the distribution of the Cainozoic effusive rocks of the northern Pacific, have filled in the results in Tomita's map just mentioned. The boundary between the province of the Mariana alkalicalc rock and that of the east Caroline alkali rock is the deep submarine trench (Nero deep) southeast of the Mariana islands.

As seen in the chart (Fig. 1), the islands of Truck, Panope, and Kusai which belong to the east Caroline alkali rock province, are a group of isolated islands in which we find no characteristic features of the island arc nor those of a chain of submarine ridges as seen in the Sititô-Mariana group. Since according to Tomita's map (Fig. 4), the province of the alkalicalc effusive rock comes closely within the Tertiary tectogenetic zone of the world, a number of investigators have attempted to explain the origin of the alkalicalcic rock by means of the tectonic conditions prevailing in this zone. T. Tomita, in summarizing the views of previous writers on the origin of the alkali rock, conclu-

7) T. TOMITA, *Jour. Geol. Soc. Jap.*, 39 (1932), p. 613; pp. 684~687.
8) M. YOSII, *Sci. Rep. Tohoku Imp. Univ. in Japanese Language*, **17** (1935).
9) H. TSUYA's papers on the Sititô-Mariana published in these Bulletins.

des that the common interpretation is that the magma from which the alkali rock is derived may have effused through largh fissures from great depths in the earth's crust.

N. L. Bowen[10] fully discussed the influences of magma affected by the aluminous and siliceous sedimentary rocks, and noted that the increase in mass in anorthite (plagioclase) promotes the crystallization of rhombic pyroxene, which two minerals are common in alkalicalcic rock.

According to T. Tomita, the alkalicalcic effusive rocks often contain xenoliths of sedimentary rocks (aluminous and siliceous), while alkali rocks rarely contain them, which, if so, supports Bowen's findings. Consequently the original magma underneath the province of the Tertiary alkalicalcic effusive rock captures the aluminous and siliceous sedimentary rocks, which change the chemical composition of the magma. The extent to which this has occurred may be considerable.

As mentioned already, similar occurrences underneath the Sititô-Mariana submarine ridge may also have been considerable.

M. Matuyama[11] has measured the gravity anomalies on the Japan trench, using V. Meinesz's method, from a submarine of the Imperial Japanese Navy. The results of $(g_0-\gamma_0)$ are given, in the reports of the International Union of Geodesy and Geophysics.

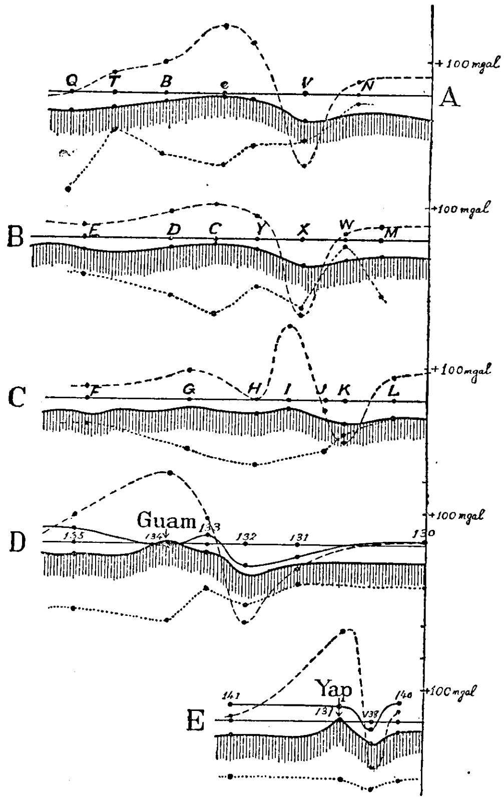

Fig. 5. Gravity anomaly (dash line) and isostatic anomaly (full line) on the line A···E in Fig. 1. (After M. Matuyama and V. Meinesz).

According to this report, the zone of negative gravity anomaly, generally speaking, falls on the Japan trench, and that of large posi-

10) N. L. Bowen, *The Evolution of Igneous Rocks*, (Princeton), (1928).
11) M. Matuyama, *I. U. Geod. Geophys., 6th Conf.*, (1935), *Japan Rep.* 2.

tive gravity anomaly on the Sititô-Mariana island arc and submarine ridge as shown in A, B, C in Fig. 5.

Bofore this investigation of M. Matuyama, V. Meinesz[12] measured the gravity anomaly near the islands of Yap and Guam, and calculated the regional isostatic gravity anomaly in this region (as shown in D, E in Fig 5), according to whose results, there is a characteristic distribution of isostatic anomaly similar to that of the gravity anomaly near the Sititô island arc reported by M. Matuyama. Although Matuyama's results have not been checked by Bouguer's and other corrections, judging from the topographic features and V. Meinesz's results of isostatic anomalies on the islands of Yap and Guam, the writer believes with the reference of isostatic condition that a relatively thick layer of material of low specific gravity (e. g. sedimentary rocks) lies below the submarine trench, material of high specific gravity lies relatively near the land surface of the submarine ridge and island arc.

Recently, a number of the deep-focus earthquakes that have occurred near Japan have been studied by K. Wadati[13], T. Ito[14], and S. Yamaguti[15]. Some of them originate 700 km below the earth's surface. According to these studies, some of these deep-focus earthquakes are distribute and parallel to the Sititô-Mariana island arc from Vladiovostock to the Mariana island arc. According to E. Tam[16] and E. F. Bellamy[17], the origins of shallow-focus earthquakes in this region are densely distributed in a similar manner to these of deep focus.

In Fig. 6b, the deep-focus earthquake origins are projected on a plane perpendicular to the general trend of the Japan trench, from which it will be seen that the origins of these earthquakes are distributed close to and parallel to inclined plane (dip about 30°, 45° & 60° west) which intersects with the land surface along the west margin of the Japan trench.

It may be inferred from the distribution of these origins, that they are closely related to the bulge and trench shown in Fig. 2.

Since the thickness of the earth's crust traversed by many earthquake waves is believed to be about 50～60 km, most of the deep focus earthquakes must have originated in the basaltic layer below the earth's

12) V. Meinesz, *Gravity expeditions at Sea*. II. Delft (1934).
13) K. Wadati, *Geophys. Mag.*, **8** (1935), pp. 303～325.
14) T. Itô, *Jap. Jour. Astr. Geophys.*, **11** (1934), 2.
15) S. Yamaguti, *Earthq. Res. Inst. Imp. Univ. Tokyô*, **15** (1937), pp. 170～177.
16) E. Tam, *Zeitschr. Geophys*, **4**, 7/8.
17) E. F. Bellamy, *Index Epicentr*, 1913～1930.

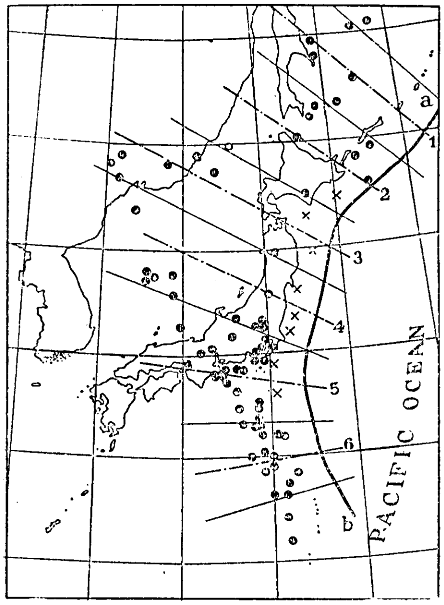

Fig. 6a shows the projection of origins of deep-focus earthquake (black circle) and the locality densely distributed by the origins of shallow-focus earthquake (cross). "ab" is the general trend of the Japan trench. Numerals show the number of segments almost equally divided by the vertical plane perpendicular to the general trend of the Japan trench.

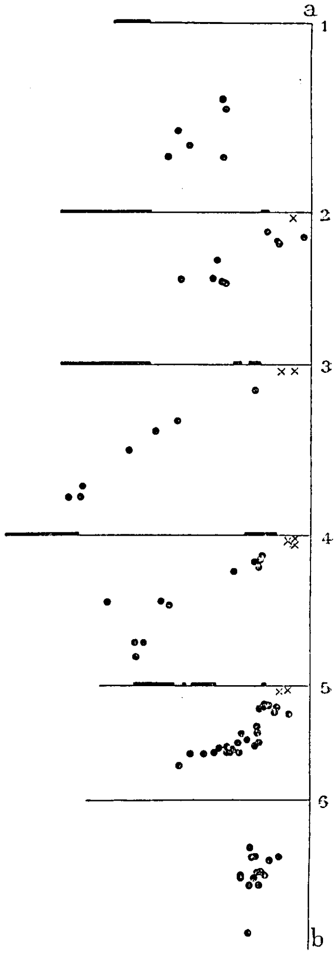

Fig. 6b shows the projection of origins of deep-focus earthquake on the plane perpendicular to the general trend of the Japan trench. Numerals show the number of segments the black circle is the origin of deep-focus earthquake. The cross is the locality densely distributed by the origin of shallow-focus earthquake. Vertical scale horizontal scale =1:1.

crust of sial, a number of the geologic phenomena witnessed on the Sititô-Mariana ridge and trench must be considered with reference to the peculiar conditions obtaining in this basaltic layer.

Petrologists and geophysicists believe the basaltic layer below the earth's crust or sial to be composed of ultrabasic or alkalic basaltic magma, which is plastic and in a semi-solid state under very high pressure and temperature.

As to the sort of disturbance that probably occurred in this basaltic layer, T. Ogawa[18] has advanced the opinion that, "since the pressure

18) T. OGAWA, *New Interpretation of Geologic Phenomena* (地質現象の新解釋), (1929), pp. 364~366.

increases with depth, the subcrustal layer may be in a highly plastic and solid-like condition although it is heated to a very high temperature. The process by which the disturbances travel from the interior of such plastic and solid-like matter to the surface may be the result of local changes in the pressure, which by disturbing the equilibrium of the basaltic layer, induce liquifaction and gasification of the subcrustal material under high pressure and temperature. Such liquified or gasified subcrustal material may ascend to the upper zone of low pressure from the lower zone of high pressure." If this explanation is true, this upward movement of material may, on the one hand, push the earth's crust upward, and on the other hand, iuduce downward movement of the neighbouring subcrustal layer to fill the space left by the upheaved part. This downward movement of the subcrustal layer drags the crustal part adhering to the subcrustal material owing to the high viscosity of the latter.

By this movement, the upheaved subcrustal material dissolves the xenoliths of the crustal part.

M. Ishimoto[19], in referring to the recent studies of H. Kawasumi, expressed the opinion that an earthquake is not necessary to explain the breaking of an elastic body, but that it may be explained by a mere change of pressure in an inclosed cavity. If his view is correct, deep-focus earthquakes might easily occur from mere change in pressure in the subcrustal layer mentioned above.

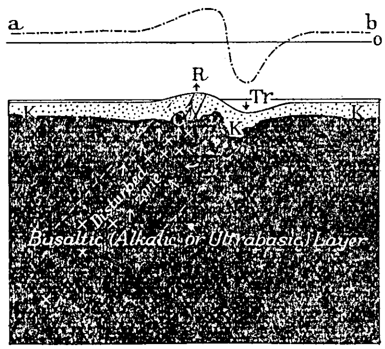

Fig. 7. Schmatic diagram showing the interpretation on the underground structure of the Sititô-Mariana submarine ridge and the Japan trench. ab=gravity anomaly or isostatic anomaly. R=submarine ridge. Tr=submarine ridge. K=earth's crust. C=alkalicalcic molten rock.

In the foregoing, the writer has enumerated and described the characteristic features of the Sititô-Mariana region, based on his geomorphological, geological, and geophysical studies of this island group.

The new interpretation of the Sititô-Mariana island arc and submarine ridge are schematically shown in Fig. 7.

There is a basaltic (alkalic or ultrabasic) layer under the earth's crustal layer. But local changes in pressure occurred at depths of less than about 700 km below the landsurface within the zone that dips

19) M. Ishimoto, *Disin*, 9 (1937), 10.

about 45° NW and intersects the landsurface with the general trend of the northwest margin of the Japan trench.

This local change in the pressure causes the highly viscous and semisolid state of the basaltic layer to become more fluid. The fluidified material moves from the lower horizon to the upper. This movement is accompanied by crustal upwarpings and volcanic activities on the earth's surface. This upward escape of fluidified material is compensated by the downward movement of the adjacent subcrustal material by a convexion like flow. The subcrustal material adheres to the aluminous and siliceous crustal part by virtue of its high viscosity, and drags it downward by the downward movement as mentioned above.

With this adhesion of the aluminous and siliceous crustal part to the subcrustal material, the chemical composition of the basaltic magma may change to an alkalicalcic one, which latter is a characteristic feature of the composition of the Sititô-Mariana islands.

Geophysically the mass defect on the Japan trench and the mass excess on the island arc and submarine ridge may prove to be the upward movement of the fluidified heavy subcrustal material which pushes up earth's crust and sometimes extrudes from it, while the downward drag of the light crustal part which deeply embeds into the subcrustal layer.

As stated above, although no geomorphological geological, nor geophysical evidences might contradict this new interpretation of the interior structure of the Sititô-Mariana island arc, it is not free from certain assumptions.

Although this interpretation presumes that the tectogenetic zone merely indicates an abnormal condition of the subcrustal layer in the earth's crust, a study of the history of the life cycle of this zone may conduce to a more concrete understanding of the abnormal conditions prevailing in the subcrustal layer. It is hoped that a more concrete knowledge of magmatic differentiation and the physical nature of the original magma will confirm this interpretation. These studies constitute not only the fundamental problems of crustal movement but also the fundamental problem of the origin of earthquakes.

The writer in his studies of the Tertiary geologic structure of Northeastern Japan, seeks a fundamental cause of the crustal movements that occurred during the Tertiary period, and is desirous of applying this new interpretation to the Tertiary tectonic history of northeastern Japan, and in doing so, considers the Sititô-Mariana island arc and trench as a youthful stage in the growth of the tectogenetic zone.

In conclusion, the writer wishes to express his sincere thanks to Prof. H. Yabe, Prof. M. Ishimoto, Prof. S. Tsuboi, Prof. C. Tsuboi, Dr. T. Tomita, and H. Kuno for their valuable discussions with him on this new interpretation.

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16. 七島・マリアナ海嶺の地下構造に關する一解釋

地震研究所 大塚彌之助

七島・マリアナ海嶺の地下の地質構造に關して，その海底地形・段丘・地質・岩石・重力・地震等の知られた事實から推定して，一つの地質學的解釋を述べた.
