Geotectonics of the Pacific Concerning the Japanese Island
—I. The Fossa Magna, the Shichito and the Ogasawara Salients—

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Abstract

A long chain of Post-Jurassic granodiorite batholith extends along the Pacific coast, under NE. Honshu, between the Bōsō Peninsula and the west of Hokkaido, about 550 km. in length and more than 300 km. in width. In the Kurile I., a huge mass of granodiorite batholith is remarked to extend also under the submarine ridge, which covers 1,200 km. more in length from Nemuro to the Simusi I., though its width be unknown. In the southern I. which belongs to Fuji volcanic zone, an occurrence of the same batholith is supposed, further, to exist under the Shichito volcanic ridge by the submarine gravity survey, though the actual fragment of the batholith is not yet discovered in the volcanic ejected mass.

From these discoveries we may suppose the existence of the long chain of granitic batholith under those submarine ridges such as the Aleutian where the occurrence of granite is reported to be found, the Mariana where a granitic gravel is done in the Tertiary of the Saipan I., and the Kermadec salient where the boulders of granite are done in the ejected volcanic mass of the Sunday I. These granodiorite batholiths surround the Pacific with those of the coast range and the Sierra Nevada of N. A. and may have the closest relation to the Pacific basin.

Both of the trenches and the earthquake zones (intermediate and deep earthquake of Profs. Gutenberg and Richter) are distributed along the Pacific margin outside the North American coast where they are not yet found. In the Asiatic coast of the Pacific, where there is a trench along the granodiorite batholith is mass defect on the trench usually shown, but mass excess is on the batholith, while in N. A. where there is no trench and no intermediate and deep earthquake along the Pacific coast, gravity anomaly is always negative in the batholithic region. There seems to be a conflict between the batholith and gravity anomaly, but it is not so if we accept the view of Prof. Lawson who takes up the Laccolith conception of the Great Basin granite.

The Nippon Trench is most prominent in length, width and depth. It covers about 2,900 km. in length, 100 km. more in average width and 10.6 km. in maximum depth. It may be subdivided into 4 parts from the geophysical and geotectonic points of view; from N. to S., the Kamchatka, the Kurile, the

Sanriku and the Shichito Trenches. The Shichito Trench is most sinuous in form and 5 deeps are contained in the long basin. Its trend is NS., but is rather convex toward W. and touches the Shichito ridge on its convex side, as if it gave an underthrust to the ridge from the oceanic side between the Ogasawara ridge and the Bōsō Peninsula. But there are inland regions containing more important geologic structure which manifests the underthrust of the Pacific such as the Fossa Magna, NE. Honshu, Hokkaido and the Kurile Is.

The granitic batholith which lies under the Shichito submarine ridge extends from NNW. to SSE., parallel to the Shichito Trench, and is subjected to the enormous pressure of the trench which may have acted from E. to W. obliquely to the trend of the batholith. In consequence, shearing zone is formed within the batholith which penetrates deeply within the earth. The volcanoes on the Shichito submarine ridge are arranged in a straight line which coincides with both the trend of the ridge and the trench; it may be the shearing zone, produced in the batholith, through which the volcanoes may have erupted out.

As to the origin of the Fossa Magna 3 phases may be distinguished: 1) The pushing of the Shichito batholith into the outer zone of Middle Honshu, by the lateral thrust of the Shichito Trench and the consequent occurrence of the great curving of the Median line, which is manifested by the Toyohashi-Suwa-Bōsō arc. 2) The making of the Itoigawa-Nirazaki-Atami line, along which the occurrence of the 60 km. shifting of the east wing of the Toyohashi-Suwa-Bōsō arc by the continual thrust of the Shichito Trench. 3) On the western wall of the Fossa Magna, the building up of the Echelon of Akaishi, Kiso and Hida Mt. range which is subjected to the shearing pressure of the 60 km. shifting of the eastern wing.

The time of the tectonic movement is assigned to the beginning of Miocene. The Orogenesis seems, however, to have twice occurred in history, the first, in the beginning of Miocene, and the second in the early Pleistocene. The latter movement is considered to be the repetition of the movement of Miocene, that is, the pushing of the Shichito batholith into the Misaka series containing Lepidocyclina, which formed an arc of the Misaka-Miura-Bōsō, while the eastern wing of the Fossa Magna is subjected to the lateral thrust from the Shichito Trench, which is manifested by the geologic structure of the Neogene series deposited in the Fossa Magna and the Bōsō Peninsula.

The Kurile batholith whose directrix is from NE. to SW. is subjected to the underthrust from the Kurile Trench, which acted on the former from E. to W. obliquely. Accordingly the shearing stress acted parallel on the trend of the batholith, pulled the frontal portion of it toward SW. against the main portion of the same and produced compression Echelon cracks within the latter, through which the volcanoes erupted out, while the advancing of the frontal portion pushed the Hidaka and the Yubari ranges, the latter of which consists of Palaeozoic, Cretaceous and Tertiary, and thrust them over the Fore-land,
the northern terminal of granodiorite batholith of NE. Honshu.

The Shichito and the Kurile submarine ridges manifest one of the Pacific movements which act as underthrust on the continental margin, of which, however, most striking may be the Halmahera thrusting. The Andesite Line which bounds the Sima crust of the Pacific from the Sial of the continent protrudes between the Mariana-Palau group and New Guinea, where it reaches the Tobi submarine ridge to the east of Halmahera. The Echelon of the Palau I. and the Yap I.; the remarkable turning to the west of the South Mariana Trench; the WWN.-EES. trend which New Guinea takes; the apparent drag of the east end of the New Britain I. by the New Ireland I.; the NW.-SE. trend of the Solomon I. like the asymmetric Echelon of Dr. Tokuda who tried the mechanism by pushing with his finger a sheet of Japanese paper mounted on some paste. These geotectonic structures manifested around the protrusion of the Sima crust of the Pacific may suggest the lateral thrusting of the Pacific basin, from E. toward Halmahera, which may well be termed "Halmahera thrusting.” The thrusting may have affected the Banda Sea where Dr. Meinesz drew the axis of strip of negative anomalies between the Ceram I. and the Philippine Trench, and Dr. Umbgrove defined the wind of Timor- east Celebes zone. Moreover, the Halmahera thrusting may have contributed to the building up of the Central range of New Guinea which was thrust over from NE. Pacific side.

The zone of the intrusion of the Post-Jurassic granodiorite batholith, which is succeeded by the andesite eruption of Tertiary and Recent; the zones of intermediate and deep earthquakes and the zone of deep lasting trenches,—the three zones are the most prominent tectonic features of the continent around the Pacific which acts on the margin of the former as the underthrust. There is, however, another movement which from the continent acts on the Pacific mass as the overthrust. The inland geologic structure along the Japan Sea coast is rather predominated by the latter movement which may be extended to the foot of the Hsingan of the Asiatic continent beyond the Japan Sea. Dr. Richthofen believed the existence of the pulling force of the Pacific basin, by which the border-land of the Pacific was torn up and produced three step faults at the foot of Hsingan, Sikkota alin and the east coast of NE. Honshu. The writer, however, suspects the existence of two opposite forces, one of which coming from the ocean, the other, going from the continent. The former acts on the continental margin as the underthrust, while the latter pushes the continental block and acts on the oceanic mass as the overthrust. Of the three tectonic features mentioned above, the making of the trench and the intrusion of the granodiorite batholith may be due to the underthrust of the Pacific, though there may be some exception in the case of Andesite eruption. As to the zones of intermediate and deep earthquakes, the lateral thrust which pushes the continental block toward the ocean may have some relation to them in the sense of Dr. Bemmele's Meso-undation.
Introduction

The geologic and geophysical studies of the Pacific belong to such a late date as the year 1920. Hence geotectonic history cannot but be young, yet the following five eminent pioneers, Dr. B. Willis and Dr. G.H. Hobbs of North America, Dr. P. Marshall of New Zealand, Dr. B. Koto and Dr. S. Fujiwara of Japan should be remarked.

Dr. Willis is a forerunner of the geotectonic study of the Pacific; he believed that a lateral thrust from the ocean had acted on the continental margin as the underthrust, while one from the continent had done on the oceanic mass as the overthrust. When the Third Pacific Science Congress was held at Tokyo in 1926, he came to Japan as delegate of North America, and referring to his paper on the Geotectonics of the Pacific read then there, Mr. E. Sagawa, an engineer of the Mitui Mining Co. Ltd., asked him about the validity of his view concerning the popular idea of Japanese geologists that the arc of the main island of Japan is the result of force acting from the continental side. Dr. Willis replied that one force acting from the continent pushed the surface block toward the ocean, while another from the ocean acted as a sort of undertow.

Dr. Hobbs believes that a lateral thrust from the ocean acts on the continental margin as the underthrust. His opinion was that the arcuate islands are being thrust from the front of the arc by a lateral thrust caused by the depression of the ocean bottom.

In the Third Pacific Science Congress mentioned above, Dr. Marshall also came to Japan to attend the congress, as a delegate of New Zealand. His view concerning the study of the Pacific was rather expressed in the Second Pacific Science Congress (1923) held at Sydney, where he published a paper “General Statement on the Structure of the Pacific Region”, in which he expressed his opinion thus:— “Before it is possible to attack the subject in an intelligent manner, it is necessary to have a clear understanding as to the true structural boundary of the great ocean basin. It is perhaps unreasonable to expect that this should be of a clear sharp-cut nature, for such an immense earth feature may obviously have a border of a considerable width surrounding it, yet all influencing the basin itself, which in turn must react upon it.” He supposed an existence of the border-land surrounding the Pacific, which connects the continent and the ocean, and as an instance for this he suggested the depressed continental sea containing New Zealand, the Kermadec, the Tonga, the Fiji and the Solomon Is. Dr. Marshall asked the co-operation of the scholars concerned in the countries which border the Pacific ocean and suggested that they should give the abstracts of the following items: 1) Nature and position of the actual margin of the Pacific basin; 2) Periods and nature of orogeny; 3) Periods of marine transgression; 4) Periods of plutonic intrusion and its relations to orogeny; 5) Periods of volcanic activity, nature of the
volcanic rock, and its relations to orogeny; 6) Movements of the strand line and their relations to seismicity; 7) Sedimentation, especially in regard to glauconite; 8) Variations in climate.

Though Dr. MARSHALL's statement was made 30 years ago, his advice still remains valid as the general principle of the methodical study of the Pacific. Of these items of his, some are the problems most important to the Japanese Is. and should be treated in this paper.

In Japan Dr. B. KOTO, Emeritus Prof. of the Geol. Inst. of Tokyo Univ. was a scholar who devoted his life to the geological study of the Japanese Is. In 1932, he published his last paper, "The Rocky Mountain Arcs in Eastern Asia", in which he traced the Rocky mountain arcs throughout Canada, Alaska toward Asia. He considered the Stanovoi of Siberia, the Great Hsingan of Manchuria, and the dividing ridge of South China, as the continuation of the Rockies. His aim was to study the geotectonics of the Pacific surrounded with the Rockies and Asiatic Rockies, that he might come to the clear understanding of the geotectonic structure of the Japanese Is. He says in his paper as follows:— "N. American Rockies is approximately straight, while on the Asiatic quarter it forms series of arcs or crescents with incurves or junctures I–IV. The Asiatic Rocky mountains, analogous to the N. American, makes the watershed of the inland plateau and the low maritime belt. The variance of physiography is, however, caused by the asymmetry of the oceanic bottom on both sides, our shore being characterized by the presence of four foredeeps 9,000 m. deep. These deeps made lateral acute underthrusts toward the Asiatic margin, and the reverse reactionary shifting of superficial crust in the Quaternary period toward the front geosyncline resulted in overthrusting and downfaulting with steep front and gentle backside, the latter associated with linear volcanic vents, causing the formation of remarkable series of bow-shaped ridges on the maritime region. From north to south of the Asiatic Rocky arcs the Stanovoi is backed by the east Siberian cold plateau, the Hsingan by the Mongolian, the Tahanshan, west of Peiping, by the Shan-si highland and lastly the arc of South China, enclosing the Karst plateau of Yunnan-Kweitsyo provs. by the easterly-lying lower belt of South China terra incognita bordered by rias coast."

Dr. FUJIWARA was a geophysist who studied the vortex phenomena in gas, liquid, and solid. He believed in the existence of a lateral thrust around the Pacific, which moved sinistrally and acted obliquely, not normally, on the continental margin of the Pacific. He called the movement as the Pacific movement and attributed the Kwanto earthquake to the lateral thrust which was accumulating under Sagami Bay and made a sudden vortex motion. He studied also the Echelon cracks associated with the earth vortex, which are divided into two kinds; the breaking and tearing Echelon cracks whose mechanism and principles he wrought out.

During the past 80 years the work of the Japanese geologists was the
Fig. 1. Distribution of the gravity anomalies in NE. Honshu, Hokkaido and the Nippon Trench (after Kumagai, but partly modified by Seismological and Geological data). The area of negative anomaly (Free-air) off land is shaded, while the area of positive (Bouguer) on land, which may be occupied by the Granodiorite batholith, is stippled. The contour interval for both negative and positive anomalies is 50 mgals. It may be observed that the negative belt diverges locally from the deep, and that the positive belt has borne relation to the negative belt of the sea floor.

The median line is detached and shifted when it approaches the Nippon Trench. The zone of deep-seated earthquake approaches the Shichito ridge, where the pushing of the Pacific is strong, while the zone gets far from the Sanriku Trench.
geologic mappings, the accumulation and description of the facts whose synthesis, however, was made by such authors as Naumann, Harada, Koto, Ogawa, Yabe, Suess, Richthofen and others on the basis of land geology. The study of the geology of the seas has been little attended to, though not without good reasons; but, in 1934, a submarine gravity survey was carried on by Drs. Matuyama and Kumagai. Since then the geotectonics of the Pacific of the Japanese Is. have been brought to the current topic by some geologists, but not yet in general. At present the Japanese domain is restricted to the four islands—Hokkaido, Honshu, Shikoku and Kyushu. But during the past 40 years Japanese geologists have had precious experiences about the Kurile, the Ogasawaras, the Marianas, the Caroline, the Ryukyu, Formosa Is., and the Asiatic continent, Manchuria and Korea. All these materials carefully studied, are in the hands of those who are devoted to the study of the Pacific.

In Japan, there is such a geologic structure as folds, faults and volcanic ranges whose origin may be due to a compression from the oceanic side, while there is another originated by a lateral thrust from the continental side. These two kinds of geologic structures are treated in this paper in the following order: I. The Fossa Magna, the Shichito and the Ogasawara salients; II. The Nankai Trench and the block movement of Shikoku; III. The Kurile batholith and the geotectonics of the Kitakami Mountainland.

The Zone of Granodiorite Batholith

In NE. Honshu, there are outcrops of granodiorite in the mountainous lands of Kitakami and Abukuma, whose period of intrusion may be inferred as the late Jurassic. In the gravity survey of NE. Honshu, Dr. Kumagai noticed the existence of the heavy basic rock and remarks thus:— "This plutonic rock forms a huge igneous mass, which widely intrudes below the sedimentary rocks of the land and the continental shelf and slope of the Pacific Ocean; its horizontal width is therefore about more than 300 km., its longitudinal extent may be supposed as great as that of NE. Honshu, that is, about 550 km. Its upper surface slopes towards the Pacific and the Japan Sea, with its crest near the Pacific coast. This huge igneous mass may be regarded as batholith." Thus he supposed the extension of batholith from the Bōsō Peninsula to the west of Hokkaido throughout the Abukuma and Kitakami mountainous lands.

In the Kurile Is. also as in the case of NE. Honshu we may suppose the existence of granodiorite batholith. In Kunasiri and Iturup volcanic Is. of the Kurile, Messrs. Yokoyama and Isikawa discovered an occurrence of granitic gravels in the beach sand, many years ago. Of late, Messrs. Nemoto and Watanabe discovered the actual exposures of granodiorite in the Urup volcanic Is. of the Kurile, while Profs. Suzuki and Sasa obtained fragments of granite, found in the volcanic agglomerate in the Simusi I. and Paramusiri I,
northernmost Is. of the Kurile, in the neighbourhood of Kamchatka. Dr. KUMAGAI noticed an existence of high positive anomaly in the region of Nemuro and drew a positive isanomaly line which extends from Hokkaido to the west of the Kurile. From these facts mentioned above, we may infer the distribution of granodiorite batholith under the Kurile volcanic Is. chain, parallel to the trend of the Nippon Trench; whose length may be about 1,200 km. from Nemuro to the Simusi Is., though its width be uncertain.

On the other hand, in Aleutian, an occurrence of granite is reported to have been found under the volcanic Is., and we may infer an existence of granodiorite batholith, as in the case of the Kurile.

In N. A. the granodiorite batholith of the late Jurassic, developed in Sierra Nevada is most prominent, of which Dr. SCHUCHERT describes as follows:— “While the Pacific border of N. A. was being folded, the earth shell was also invaded by deep-seated igneous rocks (granodiorite) on a large scale. Magmas in great volume intruded, forming the great chain of batholith now exposed by erosion along the Pacific border from Lower California to the Alaskan Peninsula. In comparison with this intrusion, all post-proterozoic igneous phenomena fade into insignificance. The batholith of the Sierra Nevada is 400 miles long and has a maximum width of 80 miles, while in the international boundary there are twelve batholiths that have a combined width of 350 miles. Farther north appears the coast range batholith, probably the greatest single intrusive mass known, which extends unbroken for 1,100 miles into the Southern Yukon country, with a width of from 30 to 120 miles. It is thought that while these intrusions began in the Middle Jurassic time, the main injections took place at the close of the period, extending into the Comanchian time, and that less significant upwellings went on even to the close of the Mesozoic Era.”

The post Jurassic disturbance, in which the granodiorite batholith was intruded, is termed by SCHUCHERT as “Sierra Nevada disturbance.” It was, however, termed at first as the “Cordilleran Revolution,” by Dr. SMITH which was denied by the former because he believed that the deformation of the crust did not have the extent of a world-wide revolution. As stated above, however, at present the wide intrusion of the post-Jurassic granodiorite is discovered in NE. Honshu, in the Kurile, and probably in the Aleutian. These batholiths, with those of N. A. surround the Pacific basin, suggesting an event which has the closest relation to the Pacific basin.

In the Third Pacific Sc. Congress (1926) held in Tokyo, Prof. LAWSON of the California University sent a paper concerning the “Cordilleran Shield” in which he says as follows:— “The post Jurassic orogenic movement as the great revolution raged throughout the western margin of the continent at the end of the Jurassic. The folding of strata extends from the Wasatch to the western flank of the Sierra Nevada, and probably beyond to what is now the floor of the Pacific. Subsequent to the folding of that region there were raised
the deformed and dynamically metamorphosed rocks from below, great invasions of granite magma. These intrusions, if we may judge by the present extent at the surface, were largest on the western side of the province, that of the Sierra Nevada being most important. Between the Sierra Nevada and the Wasatch there are many exposures of granite in the Basin Ranges; but none is comparable in surface to that of the Sierra Nevada. Their horizontal extent at depths not yet reached by erosion can scarcely even be guessed, but it may be very great. With this post-Jurassic granite of the Basin Range province have been correlated the extensive granites of the northern coast, extending from Cascades of Washington across British Columbia and far into Alaska, and also the granite of the coastal region of Mexico.

"The granite, as a subcrustal magma, was continuous for thousands of miles in a longitudinal direction, parallel to the elongation of Cordillera, and in view of this the assumption that it has a width of 700 or 800 miles across the Great Basin does not seem to be too rash. If this be so, then it is clear that the crust, which formed the roof of this vast batholith from the coast to the Wasatch, must have become progressively weaker against tangential pressure as the batholith developed upward.

"This view of course involves apparently an astonishing shortening of the arc of the earth's crust. Meridional distribution of the granite as a primary constituent of the cordillera for thousands of miles further suggests that the crustal shortening was latitudinal in direction and on a grand scale.

"Many of the granites of the Great Basin exhibit a very limited amount of metamorphism and therefore, these granites are considered to be laccolithic in characters."

Prof. LAWSON's Laccolithic conception about the Great Basin granites is most important for the correlation of the geotectonics of the Pacific between N. A. and Asia. The zone of granodiorite batholith associates usually with the trenches in Japan, Kurile, Aleutian, Marianas and Kermadec. In these provinces isostatic anomaly shows usually negative on the trench but positive on the continent along the coast. On North American side, there is no trench along the coast of California, while there develops the long huge mass ofgranodiorite batholith in the continent, where a zone of negative isostatic anomaly is stretching along the coast far beyond international boundary to the north. There seems to be a contradiction in the mutual relations, between the batholith and the isostatic anomalies, but not so, if we accept LAWSON's theory.

The intrusion of granodiorite batholith was the pluton around the Pacific at the post-Jurassic time, in which course of time the trench was made by the batholith between the continent and the Pacific basin. The pluton, however, was the forerunner of the volcanism from the Tertiary to the Recent ages.

The Nippon Trench

By tracing out the 5-6 km. isobath of the "Depth curve chart of the
adjacent seas of Japan 1/8,000,000 (No. 6901)" published in 1952 by the Japanese Hydrographical Department, one may define the outline of the Nippon Trench which lies just at the foot of the continental slope and shuts the Pacific abyssal basin from the continental I., such as Kamchatka, Hokkaido, NE. Honshu and the submarine ridges of the Kurile I., Shichito and Ogasawara. It extends along the above-mentioned islands and covers about 2,900 km. in length, and about 100 km. in width. As a whole, it presents an appearance of both subcircular, and somewhat subangular swinging arc, bulging out toward W. It is not concordant with the geologic trend of the mountain ranges of NE. Honshu and Hokkaido running to NNW.-SSE. The Hidaka range of Hokkaido, which is parallel to the Kitakami and Abukuma ranges of NE. Honshu meets acutely the trench, while the ES. elongation of the Kwantu range of the Kwantu district intersects it at right angles. These facts show that the trench is a dislocation in geologic characters.

From the physiographic and geotectonic points of view the Nippon Trench may be subdivided into four trenches; the Kamchatka, the Kurile, the Sanriku, and the Shichito. Of these four, the Shichito Trench is most sinuous in its form and five deeps (above 9 km.) are contained in the long basin. Its trend is NS., but rather convex toward the west and touches the Shichito submarine ridge on its convex side, as if it gave an underthrust to the ridge at the foot of steep slope whose height is 9 km., from the oceanic side between the Ogasawara ridge and the Bōsō Peninsula. According to Dr. KUMAGAI, in the Shichito Trench the minimum value of gravity anomalies coincides with the maximum depth of the trench, resembling in its character the Nero Deep of the Mariana Trench, while in the Sanriku Trench the value does not coincide, but is considerably shifted landward.

The Sanriku, the Kurile and the Kamchatka Trenches are rather simple in their form and do not contain so many deeps as the Shichito. They are united together to the S. of the Paramusiri I., to the E. of the Tsugaru strait and the E. of the Cape of Inubo respectively; at the junction, however, there is no special form outside the Shichito Trench which turns into profound depths to the E. of the Cape of Inubo, and contains the Ramapo deep (10,680 m.) in its greatest depths.

In regard to the trenches and the oceanic basins there are precious studies made lately by such scholars as GUTENBERG, RICHTER, V. MEINESZ, DALY, HESS, WADATI and others.

GUTENBERG and RICHTER published a work entitled "Seismicity of the Earth, 1949" which summarized the earthquakes that had shaken the world for about 50 years dating from the early part of the 20th century. According to him, the stable Pacific mass where no earthquake occurs, is surrounded with the three belts of seismicity closely arranged along the Pacific margin, in the order of shallow, intermediate and deep. From the work of this author, it may be remarked that the intermediate and deep earthquake belts are always
associated with the trench that lies between the ocean basin and the continent, while in N. America, where there is no trench along the Pacific coast, there are no intermediate and deep earthquakes within the continent. From this fact we may infer that there is the closest connection between the trench and the two kinds of earthquake of the Pacific. In the Pacific proper are there found the following trenches: the Atacama Trench of South America, the Acapulco Trench of Middle America, the Aleutian Trench, the Nippon, Mariana, Yap and Palau Trenches on the Asiatic side, the Tonga and Kermadec Trench of the Australasia. These trenches may have some causality with the fracture of the earth crust that penetrates within the earth, through the Sima layers, dipping toward the continent and preventing the intermediate and deep earthquakes from the stable and non-quake layer.

On the one hand, however, the ocean basin distinguished by the Andesite Line from the continental mass has been studied thoroughly by Prof. VeninG Meinesz who measured gravity anomalies at the series of stations across both Atlantic and Pacific, where he has found these anomalies to be strongly positive. This means that the density of the rock below the oceanic ooze is considerably higher than that of the continental average rock, and that there cannot be any deficiency of matter under the ocean. Prof. VeninG Meinesz, however, has by submarine traversed the Nero Deep of the Mariana Trench, off Guam I, where he found that the anomalies suddenly decrease to the strongly negative which indicates only the local deficiency of attracting matter. Dr. Daly remarking this phenomenon observes thus: "This means that the long troughs seem to have been formed where the suboceanic crust has been bent down by the powerful force of mountain formation from the oceanic side; especially under the horizontal pressure of overriding Sima crust. Beneath each resulting trough the material of the substratum was forced away laterally, and sea water was accumulated in the trough itself. Manifestly the outflow of heavy rock-matter and inflow of much less dense water caused a net deficiency of matter under the trough. Here the upward pressure of the quasi-liquid substratum has increased, but its tendency to push up the crust toward the original level has been resisted by the strength of the crust. So long as this resistance is impaired, the crust under the deep carries a negative load. The new data suggest that the negative loads rival with the positive loads in stressing the sub-Pacific crust. From both sets of observation geologists have been led to assume for the crust an average strength about twice that of granite."

There are some interesting phenomena of the oceanic earthquake concerning the Nippon Trench. Dr. Wadati has once distinguished three kinds of earthquake; the inland earthquake, the deep earthquake and the oceanic earthquake. He has pointed out the oceanic earthquake whose depth may be so insignificant as to be perhaps 10 km. or so. According to him, the seismogram of the oceanic earthquake consists of very slow and long lasting undulations of fairly large amplitude; there appear three phases though very indistinctly, or rather,
there exists no S-phase at all. In the ordinary inland earthquake we have noticed that a great earthquake is followed always by many small after-shocks. But it is not so in the case of the oceanic earthquake, which usually takes place in groups, with the rare occurrence of the greatest one at the first shock. There are no fore- or after-shocks; the earthquake of nearly the same magnitude taking place one by one, in the same (but comparatively wide) region lasting about half a month. The oceanic earthquake from Jan. to Feb. 1925 that occurred about 250 km. to the SE. of Nemuro, Hokkaido, was the most striking example of such a phenomenon. This is part of the Kurile Trench. As for the oceanic earthquake we have only experienced in our country such as occurred in the Kurile Trench. But we may presume that the Aleutian, Ryukyu, Philippine, Tonga Deep, etc., are all regions suffering from frequent oceanic earthquakes.

Dr. WADATI made observation about the oceanic earthquake along the Nippon Trench and concludes thus;—"We can suppose that the crustal conditions must be somewhat different in the regions of oceanic earthquake, probably due to the plastic and absorptive material there.

"Moreover, the depth of these earthquakes is estimated to be very small from the fact that the surface waves are so predominant as if originated from some distant earthquake." According to him we may suppose that the material which forms the shallow wall of the trench may be the Simatic layers.

In the Shichito Trench, the writer notices an existence of lateral thrust which thrusts the Shichito submarine ridge at the foot of the steep slope whose height reaches 9 km. and stands on the bottom of the Shichito Trench. The thrust came from the oceanic side and pushed the ridge from E. to W., which is manifested in the geologic structure of the Shichito submarine ridge and the Fossa Magna; moreover, the pushing from the oceanic side, is represented by the raising of the land margins of southern coasts of the Boso Peninsula and the Miura Peninsula, which consist of the Miocene and the Pliocene deposits, dipping landward.

The Shichito submarine ridge and the Fuji volcanic zone

The directrix of the Shichito submarine ridge NNW.-SSE. may be defined as the trend of the Fuji volcanic zone which consists of basaltic and andesitic volcanoes on the ridge, as well as that of the Shichito batholith which forms the foundation of the same. It begins first from the Izu Peninsula lying to the south of Mt. Fuji, while maintaining the trend throughout the course to the south, and passing the west of the Ogasawara ridge, it reaches the Sulpher L., where it diverges in two branches, one of which is the North Mariana submarine ridge (the Pagan volcanic chain) forming a prominent crescentic Mariana arc with the South Mariana submarine ridge, while the other is the submarine ridge which lies on the directrix of the Shichito ridge and may well be called
the Fuji volcanic zone. The latter accords somewhat with the arc of Mariana and running almost along the former trend, approaches, however, the Yap I. of the Palau group and then disappears. There is a depressed basin between the Mariana arc and the submarine ridge, which is called "Inner Marianas trough" by Dr. Hess.

In Japanese, the Shichito means seven islands which consist of such volcanoes as Toshima, Niishima, Kōzushima, Ōshima, Miyakeshima, Inanbashima and Hachizyoshima. The Shichito submarine ridge, however, not only contains the seven volcanoes mentioned above, but also there are from N. to S. such islands as Aogasima, Beyoneseshima, Torishima, Sōfu rock, Nishinoshima, etc., which are arranged between the seven islands and the Sulpher I., while to the S. of the Sulpher I., volcanoes on the ridge are extremely rare but there are some submarine swells which may be attributed to the submarine volcanoes. The Fuji volcanic zone is not only limited to the Shichito ridge, but also extends through the Fossa Magna into the inland and reaches the Japan Sea coast. Dr. Tsuya who studied the Fuji volcanic zone had divided it into two subzones, the inland Fuji volcanic zone and the oceanic Ōshima volcanic zone, the latter of which is entirely contained in the Shichito submarine ridge.

The Shichito submarine ridge delimits the South Japan Sea from the Pacific, the latter containing the Shichito Trench along the foot of the ridge which faces the steep slope toward the trench whose average depth is 8 km. reaching above 10 km. at its deepest to the east of Torishima. On the South Japan Sea side the slope of the ridge is not so steep, while there is no trench at the foot.

In the sea gravity survey of 1934, Dr. Kumagai discovered a zone of strong positive anomaly along the Shichito submarine ridge, and of negative anomaly whose minimum zone coincides with the bottom of the Shichito Trench mentioned above. The positive isanomaly line forms an oblong whose apical portion of the major axis reaches the neck of the Izu Peninsula where the cities of Numazu and Atami are situated. As in the case of NE. Honshu the positive isanomaly line seems to indicate an occurrence of granodiorite batholith which, however, is not yet discovered in the ejected mass of the above-mentioned volcanoes. Many years ago, in Niishima volcanic I. Mr. Fukuti discovered the fragments of diabase porphyrite, diorite porphyrite and propylite in the liparitic tuffs, ejected from the volcano. They appear to have come from the batholith of the foundation under the volcano. The Propylite, however, resembles that of Misaka series which is younger than the batholith. The propylite near Atami is penetrated by the dykes of quartz-diorite and quartz-gabbro. So the above-mentioned rocks outside the Propylite might not be regarded as the foundation rock. As in the case of the Kurile, the writer believes, however, in the occurrence of the granitic batholith under the Shichito submarine ridge, which may be discovered in near future.
The Shichito batholith is subjected to the enormous pressure of the Shichito Trench which may have acted as an underthrust. The direction of the thrust runs from E. to W., obliquely to the trend of the batholith whose directrix may be NNW. to SSE. Accordingly it may be analyzed into two elements of stress; one parallel to the trend; the other, perpendicular to it. To former acts as shearing stress, while the other does as thrust. The volcanoes on the Shichito submarine ridge are arranged in a straight line which coincides both with the trend of the ridge and the trench; it may be the shearing zone, produced in the batholith, through which the volcanoes may have erupted out.

The directrix of the Shichito submarine ridge appears to predominate over the tectonics of the Shichito and Fossa Magna. The fault produced in the earthquake of North Izu in 1936, was NNW.-SSE, whose eastern portion shifted to the north, while the western did to the south. In the earthquake of Atami, the preliminary tremor usually felt is always NNW.-SSE. In Torishima I., the southern volcanic I. of Shichito, the composite volcanoes erupted in recent time are arranged in the trend of NNW.-SSE. In Yatugatake and Hakone, the volcanoes of the Fossa Magna, the composite cones are erupted also in the same trend.

Geotectonics of the Fossa Magna

In Southwestern Japan, there is the Median fault line which divides the outer Japan from the inner. Physiographically and geologically we should distinguish the boundary between the two zones, which coincides with the Median fault line. In Shikoku, where the fault line passes between the Izumi-sandstone group and Crystalline schist series, one may observe the fault plane dipping north, which had the milonitized sandstone at the contact, where the Izumi-sandstone may have given thrust to the Crystalline schist series from the north.

Fig. 2. The Geotectonic Map of the Fossa Magna.
I. The probable trend of the Median line, whose transformation and displacement in early Miocene time, are represented by II. and III.
II. The pushing of Shichito batholith, by which arcuate formation of the Median line from I to II.
III. The making of Itoigawa-Atami tectonic line and 60 km shifting of the right wing of the arc from II to III, by the lateral thrust of Shichito Trench. Concerning the shifting, the following movements may be remarked: the building up of the Echelon of Akaishi, Kiso and Hida alpine range on the western wall of the Fossa Magna; the drag of the mountain ranges (Mikuni and Ashio ranges, Nasu and Azuma volcanic ranges etc.) of NE. Honshu; the depression of the Fossa Magna region whose eastern wall is defined by the Chikumagawa fault line running NS.; the cutting of the Kwanto range by the Sagamigawa fault line running NS., and the subsidence of the detached block under Tokyo Bay, which is manifested by the gravity anomaly O.
IV. Repetition of the movement of Shichito batholith in early Pleistocene time, whence resulted the formation of the arcuate Miasa Mt. range and of the Nirazaki-Shizuoka fault line, as well as the folding of Neogene series in the Fossa Magna and the Miura-, Bōsō Peninsulas by the continual thrusting of Shichito Trench.
In Kyushu, the trend of the fault line is SW.-NE., which connects the cities of Yatsusiro and Usuki; in Shikoku, it runs WWS.-EEN.; in the Kinki district, however, it runs W.-E. and reaches the city of Uji-yamada. Though it might have been expected to keep the course to the east and to the Pacific, in crossing Ise Bay, however, it turns gradually to EEN. then to NE., along the Toyokawa where the city of Toyohasi lies, and the Tenryu gorge; and it finally swings to NS. and reaches Lake Suwa, where the transverse fracture "Fossa Magna" traverses Middle Honshu. The great arc of the Median fault line between Toyohasi and Lake Suwa, is the prominent tectonic structure of Middle Honshu. To the east of Lake Suwa is the Median line got out of sight; it is cut by the transverse fracture and the crossing is shifted 60 km. north to the town of Ōmati, where the continuation of the Median line may be found.

The Kwanto Range whose trend is from WWN. to EES. lies to the east of Lake Suwa; it is the continuation of the outer zone of Southwestern Japan. Though the connection between both of them is unknown, we may reconstruct the mutual relation in a geological map and determine the shifting of the Median line. In the town of Ōmati, it turns to the east and then, after a remarkable curving parallel to the course of the Saikawa, reaches the City of Nagano; then along the course of the Karasugawa it swings to the city of Takasaki where it reaches, the plain of Kwanto, a great depressed basin. Along the Tone river running through the Kwanto plain, with those towns of Iwatuki and Narito it passes into the Pacific, where it is cut by the Shichito Trench.

Regarding the unknown trend of the Median line which traverses the depressed Kwanto plain, there is the seismic study of Dr. Fukutomi who discovered the local characteristics of the epicentral groups manifested by the vertical elements (up and down) of the preliminary tremor of the shallow earthquakes that would several times shake the Kwanto district. Following him, let us draw a boundary line from NW. to SE. limiting A area from B, to the S. of the Tone river, which almost running along the river, passes at last into the Pacific (the beach of Kuju-kurihama). In A there are many epicenters obtained by measurement, the left side of whose axis N5°E is

Fig. 3. Distribution of the epicentral groups of the shallow earthquake in Kwanto district, specially in reference to the vertical elements (up and down) of the preliminary tremor (after Kunitomi). Epicenter and its axis, whose one side is shaded; in the observatories of the shaded side, the preliminary tremor is down, while in those of the non-shaded it is up. The figures indicate the number of the epicenters. A, B, C, D, E and F denote the divisions of the epicentral groups.
always “up” in the preliminary tremor, while the right side is certainly “down”. This principle applies to those epicenters on the continental shelf of the Pacific. In B, however, the axis of the epicenter becomes N70°W, whose north side shows “down” in the preliminary tremor, while the south side does “up”. This applies also to those epicenters on the continental shelf of the Pacific.

The actual causes of the earthquakes whose depth are measured to be about 20 km. may be due to the local underground geologic structure. Dr. Fukutomi drew another boundary line in the Bōsō Peninsula and distinguished C area; but D to the east of the Nippon Trench; and E and F, to the Asigara mountainous land and Izu Peninsula. The boundary line between A and B coincides exactly with the Median line which may be drawn from the geologic structure of the Kwanto mountainous land whose north boundary indicates the existence of the Median line near by; while B coincides with the geologic trend of the Chichibu series and C with that of the Kobotoke series (Akigawa series in Shikoku, Jurassic).

The Kwanto mountain range is cut by the NS. fault of the Sagami river, to the west of Tokyo Bay, whose eastern prolongation appears to have been depressed deeply under the bottom of the same bay, where the gravity anomaly shows zero expressly; and its eastern extension across the continental shelf of the Pacific was proved by Dr. Fukutomi as mentioned above.

The great curving of the Median line along the Toyokawa and the Tenriugawa; the Echelon of the three high Alpine mountain range of Akaishi, Kiso and Hida along the transverse fracture and the 60 km. shifting of the Median line from Suwa to Ōmachi are the prominent tectonic features of the Fossa Magna, which may be divided into 3 phases: 1) The pushing of the Shichito batholith into the outer zone of Middle Honshu at the neck of the Izu Peninsula, by the lateral thrust of the Shichito Trench, and the consequent occurrence of the great curving of the Median line, which is manifested by the Toyohashi-Suwa-Bōsō arc. 2) The making of the Itoigawa-Nirazaki-Atami line, along which the occurrence of the 60 km. shifting of the eastern wing of the arc by the continual lateral thrust of the Shichito Trench. 3) On the western wall of the Fossa Magna, the building up of the Echelon of Akaisi, Kiso and Hida mountain ranges which are subjected to the shearing pressure of 60 km. shifting of the eastern wing.

The time of the tectonic movement is assigned to the beginning of the Miocene by the study of the volcanism and the Neogene deposits of the Fossa Magna. The orogenesis seems, however, to have twice occurred in history, the first, in the beginning of the Miocene; the second in the early Pleistocene. The early Pleistocene movement is considered to be the repetition of the movement of the Miocene, that is, the pushing of the Shichito batholith into the Misaka series containing Lepidocyclina, which formed the Misaka-Miura-Bōsō arc, while the eastern wing of the Fossa Magna is subjected to the lateral
thrust from the Shichito Trench, which is manifested by the geological structure of the Neogene series deposited in the Fossa Magna and the Bōsō Peninsula.

The volcanism of the oceanic Fuji volcanic zone may have dated from the first phase of the Miocene movement of the Fossa Magna, mentioned above, but that of the inland, from the second phase of the same movement. According to Dr. Tsuya who studied the Fuji volcanic zone,

"The lower Miocene volcanism in Izu, which occurred beneath the sea at that time, is represented by a thick series of highly altered volcanics (lava and pyroclastics), referred to as the Yugasima beds (or propylite series). This series consists for the most part of basaltic and andesitic rocks, although dacites and liparites are also represented, especially in the upper horizon of the series. Its actual duration is a question we have no means of solving as yet, its only precise datum being the faunal evidence (Lepidocyclus limestone from Simosiraiwa and Miogypsina limestone from Nasimoto), which assigns certain dacitic volcanics to be some distance above the base of the series to the Lower Miocene.

"The propylite series is invaded by numerous minor intrusives of various rock types—diabase porphyrite, basalt, andesite, dacite and liparite (quartz porphyry). Among them, basic intrusives are older, but acid younger. The lower Miocene volcanism was followed, probably during the Upper Miocene, by submarine eruption of liparite and dacites, with subordinate andesites, all of which are distributed mostly in Southern Izu and rather locally in Northern Izu. The foregoing phase of volcanism was succeeded most probably during the Lower Pliocene, by a subordinate phase of activity characterized by the minor intrusions and extrusions of andesites. Regarding volcanism during this period, however, we are largely in the dark.

"In the uppermost Pliocene, eruptions of basalts, dacites and andesites occurred only locally in Izu, which were again exclusively submarine. At the close of the Tertiary or the beginning of the Pleistocene the Izu Peninsula was subjected like the other regions in the Fossa Magna to crustal movement, generally in the sense of uplift, and raised so much of the Tertiary sea-floor into land, that the Pleistocene volcanism became vigorous. This volcanism was concentrated mainly in the northern part of the peninsula, while in the southern part, the Tertiary volcanism was succeeded by quiescence.

"The 1st phase of the Lower Pleistocene volcanism is represented by eruptions of basalts, andesites, and dacites, all occurring in the form of tuff and tuff-breccia that now occupy the bulk of the lacustrine deposits (Ono-beds, Simo-Hata beds and Simo-Tanna beds) accumulated during that period on the erosion reliefs of the Tertiary formation. The volcanoes Tenshi, Usami, Taga, Yugawara, Asitaka, Amagi, Hakone and others in the NW. part of the Izu Peninsula, as well as dacitic masses in the vicinity of Atami are all products of this phase. So far as its visible part is concerned, Fuji may date from a much later age, probably from a recent. That one of the earliest lava-flows
from the volcano is younger than the older somma of Hakone has been definitely proved by field evidences”.

The above-mentioned 1st phase of the Lower Pleistocene volcanism, so-called by Dr. Tsuya, might be just the time of the pushing of the Shichito batholith into the Misaka series, in which course of the time the Izu Peninsula had been raised from the sea bottom into land and then the volcanism was concentrated in the northern portion. Dr. Tsuya tells more minutely about the insular Quaternary volcanoes, thus:—

“All the insular volcanoes of the Seven Izu I. and the Southern I. are undoubtedly the products of the Quaternary volcanism, whatever may be the history of their foundation. Of these dissected basaltic volcanoes, Utone-Shima, Toshima, Mikura, Higashi-yama (Hachizyo), Torishima and Kita-Iwoshima date from the Pleistocene. Torishima gave records of eruption. Oshima, Miyake, Nishi-yama (Hachizyo) and Aogashima have been active recently. Niishima and Kōzushima gave the record of one eruption.”

Moreover Dr. Tsuya relates about the inland Fuji Volcanic zone which contains Fiji, Kayagatake, Iizunayama, Kurohime-yama, Myoko-zan, Yatsugatake, and about the difference of the volcanic rocks between the two subzones thus:—

“Although the rocks of the Fuji volcanic zone belong generally to a calcic series, the rocks in its northern inland part are stronger in alkalis, and weaker in lime than those in the south oceanic. But whether the chemical differences of these two subzones are in any way connected with those of the geotectonic structure and of the nature of rocks of their foundation is a question.”

Dr. Tsuya believes the directrix of Shichito NNW.-SSE. to be the trend of basaltic and andesitic volcanoes, and NE.-SW. trend of South I. to be liparitic (or dacitic) or trachyandesitic volcanoes, and says that it may be a surface manifestation of the underground structure of the region, the former representing a principal fracture (Daly’s abyssal fissure) connected with deep-seated reservoirs of a regional basaltic magma, and the latter a subsidiary fracture connected with shallow-seated reservoir of local differentiation, either liparitic or trachyandesitic, from the basaltic magma.

To the south of the Fossa Magna region, there is the mountain range of Misaka series containing Lepidocyclina, which forms an arc surrounding the Fuji volcano. The arc faces the convex side toward N., forming an Echelon with the above-mentioned arc of the Median line, while the arc of the Yamato submarine banks, raised from the bottom of the Japan Sea, incloses the Noto Peninsula and forms an outer arc facing the convex side toward N. They form an Echelon which may suggest the pushing of the Shichito batholith into Middle Honshu, the influences upon the bottom of the Japan Sea.

The Shichito batholith may have been overlaid first by the Misaka series, whose stratigraphical and faunal order was studied by Dr. Yabe. According to him, the Misaka series consists at the base of thick series of propylite, of
agglomerate and tuff, in whose upper horizon are contained *Comptoniphylllum* and *Liquidambar* zones, while *Lepidocyclina* and *Miogypsinia* zones in the limestone occupy the upper horizon than the basal series. Moreover, those faunal horizons of *Miogypsinia* and *Opercunda*, *Desmostylus japonicus* and *Stegolophodon latidens* zones are described in the upper series of the sandstone and shale in the ascending order. The Misaka series is distributed from the Fossa Magna to the western portion of NE. Honshu and Hokkaido, as well as to the Boso Peninsula.

**The Tertiary Mountain Ranges of the Ogasawara and the South Mariana-Islands**

In 1901, the Ogasawara submarine ridge was distinguished from the Shichito ridge by Dr. Tokunaga who studied the geology of these islands. According to Mr. Akagi, the Ogasawara ridge consists of small islets which have undergone the erosion and orogenetic movement since the Oligocene time. It is the remains of oceanic volcanoes, erupted on the old tectonic lines, whose relief of mature stage contrasts that of Shichito, and there are no earthquake, solfatara and mineral springs, whose absence indicates the greater stability of these islands than that of the Shichito ridges. The stratigraphy of the Ogasawara islands was studied by Dr. Hanawa, and then some years later, that of the Saipan Islands by Dr. TAYAMA who clarified the geological connection between both groups of those islands. These inquiries have aroused within us an emotion as if we had met with the kindly light from a lighthouse in a lonely sea.

Dr. Hanawa who studied Hahazima of the Ogasawara L., discovered the *Nummulite* horizon at the base of the Tertiary tuff and breccia which overly the andesite rock. The series contains two or more horizons of foraminifera in the upper portion, whose uppermost consists of *Pellatispira* limestone, which indicates the middle or upper Eocene age. He also studied the geology of Chichizima of the Ogasawara ridge, which consists of tuffaceous sandstone and shale overlying the Boninite rock (hypersthen andesite), in which he discovered *Lepidocyclina* limestone on the west coast of the same island, indicating Oligocene. In Hahazima there are many faults whose trends are NNW.-SSE. which cut the island into many blocks, of which one along the western coast, and another along the eastern penetrating a cape are most prominent. In Chichizima there is also a fault which runs to NS. through the inland along the western coast.

Dr. Tayama divided the Tertiary limestone of the Saipan I. of the South Mariana submarine ridge into three series,—lower, middle and upper. The lower (*Camerina* limestone) contains *Pellatispira*, *Camerina* and *Dicocyclina* which indicate Upper Eocene. The middle (*Eulepidina* limestone) contains *Lepidocyclina* and *Spiroclupeus* which indicate Oligocene, while the upper (*Nephrolepidina* limestone) contains bulk of *Lepidocyclina*, some of which com-
mon to the middle limestone, go up to the Miocene age. In the Palau group, there is no Tertiary limestone in the Yap I; while in the Palau I, no limestone, but some fossils are contained in the limestone nodule in the volcanic agglomerate, which may be correlated to the middle and upper limestones of the Saipan 1.

The South Mariana submarine ridge may be connected faunistically to the Ogasawara ridge, the former of which consists of Medinila, Saipan, Tinian, Aguian, Rota and Guam, and forms the Tertiary mountain ranges lying closest by the Mariana Trench. The Ogasawara ridge is separated by a trough of 4 km. deep from the Shichito ridge, whose trough may be due to the NS. fault line produced by the overthrust from the east. In Mariana the Tertiary mountain range forms a crescentic arc lying parallel and closely in contact with the North Mariana submarine ridge which consists of the volcanoes dipping steeply to the east. They unite so closely that they are taken for one ridge, which is pushed out to the east by the depression of the Philippine Sea; formally, however, their relation may have been the same as is seen between the Ogasawara and the Shichito ridges. Once the eastern side of the North- and South-submarine ridges seems to have been occupied by the Mariana Trench whose downward warping is supposed to have been the cause of the eruption of the volcanoes of the North Mariana submarine ridge (the Pagan volcanic chain).

The Tertiary of the Saipan I. contains blocks of granite and Palaeozoic which indicate the existence of the foundation rocks. According to Dr. Reed, in the Tonga ridge are there raised coral limestone along the trench; to the west of which lies the zone of tuffs, and then that of volcanics respectively. In a portion of the ridge, there is Eua I. whose foundation is granite overlaid by the volcanic extrusives containing many horizons of foraminifera, in the uppermost, however, a thick limestone bed. Messrs. E. HOFFMEISTER and Leslie WHIPPLE had discovered the Eocene fossils in a portion of the limestone, *Pellatispira*, *Discocyclina* and *Asterocyclina*. The Eua, the Saipan and the Ogasawara not only stand in contact with the margin of the trench of the Pacific, and their Tertiary faunae have closest relationship to each other, but also the former two islands have the foundation of plutonic rocks, while in the last none is yet reported to have been found. Many years ago, the gravity anomaly of the Ogasawara I. had been measured by Dr. TANAKADE to be high positive anomalies; in the same I., lately, however, by Dr. MATUYAMA to be in Chichizima, +363 mgal, and in Mukozima +233 mgal which might indicate the existence of the basic plutonic rocks in the foundation.

**The Andesite Line or Marshall Line**

Dr. G. E. MACDONALD, a geologist of U.S. Geological Survey who studied lately the Hawaiian volcanoes came to the conclusion that the parent magma
of the Hawaiian volcanoes was the olivine basalt from which other basic rocks were derived, and the comparison of the types of igneous rocks in the Hawaiian province with those recorded from other Pacific islands shows that the rocks throughout the true Pacific basin are, for the most part, closely similar, and suggests the essential uniformity of the parent magma and petrogenic processes throughout the Pacific basin. From this viewpoint he included those volcanic islands of the Pacific in the same Hawaiian petrographic province, such as the Marquesas, the Tuamotu, the Tubulai, the Society, the Cook, the Samoa and the Caroline islands; and defined the boundary between the Pacific which consists of Simatic and the continent of Sialic. His hypothetical boundary which may be Andesite line is drawn along the Pacific coast—to the east, from California to Peru; but to the west, along the coast of the border-land of the Asiaticaustal continent to the Chatham I. of the east of New Zealand. Dr. Macdonald distinguished a submarine plateau containing the Easter I. which protrudes to SW., between the Galapagos I. and the San Felix I. with San Ambrosio I. lying off the coast of Peru; and from the reflection of the seismic wave he considered the submarine plateau as a Sial crust.

On the Asiatic side the Andesite Line swings from Japan along Shichito, Ogasawara, Volcanic I. (Sulpher I), Marianas, and Palau groups to the border of the Neithlands Indies, where it turns eastward, then southeastward along New Guinea, New Ireland, the Solomon and New Hebrides groups. After including the Fiji Islands, the line swings sharply southward, including among the continental islands, Horne, Tafahi, Niuatobutabu, the Tonga and Kermadec groups, and New Zealand, but excluding Wallis, Niuafou, and Samoan Islands. This defines the border of the true Pacific basin and has been called the "girdle of fire" because of the extent of volcanic activity which it includes. These islands are peaks of major mountain ranges towering above the ocean floor, contorting with manifestations of youth.

The most striking features of the Asiatic Andesite Line is the protrusion of the Sima crust of the Pacific bottom into the area between the Marianas-Palau group and New Guinea, where it reaches the Tobi submarine ridge which lies to the east of Halmahera. The Echelon of Palau I. and Yap I.; the remarkable turning to the west of the Mariana

Fig. 4. Asymmetric Echelon (after Tokuda). The above coulisses of the Echelon correspond to Marianas, Yap and Palau submarine ridges; the lower to New Guinea, and the apex to Halmahera.
Trench; the NW-SE. trend of the Solomon Is.; the apparent drag of the east end of New Britain I. by the New Ireland I., etc., are like the asymmetric Echelon of Dr. TokuDa who tried the mechanism with a sheet of Japanese paper mounted on some paste shown in Figure 4. If the writer’s supposition is correct, a portion of the Sima crust of the Pacific may have thrust into the area from the east toward Halmahera, which movement might well be called as “Halmahera Thrusting”.

In the submarine gravity survey, Prof. Vening Meinesz has defined the axis of strip of negative anomalies along the Java Trench, whose eastern prolongation bounds the Asiatic continent from the Indian ocean and Australasia. It forms a curve along the south side of Java and Lesser Sunda I. and turns to the north along the Banda Sea and reaches the Ceram I., then passing between the strait of Sula and Obi I., swings to the north along Molluka strait toward the Philippine Trench. To the west of Halmahera it forms an arc between the Ceram I. and the Philippine Trench, whose convex side faces to SW. and accords with the Halmahera thrusting. The Halmahera thrusting may have given influence upon the Banda basin where the wind of Timor-east-Celebes zone (UMBgroVE’s Banda Geosyncline) appears to accord with the thrusting.

On this occasion, it may be necessary to introduce the work of Dr. Fujiwara who studied the mechanism of Echelon cracks. According to him, shear stresses produce shear cracks whose normal type is Echelon cracks which contain two types, the type of tension and that of compression. The two types are produced respectively according to the hardness, thickness, etc. of experimental material.

Tension cracks are produced in such a way as to approach perpendicularly in the direction of stress. On the contrary, the compression cracks are formed so as to conform to the direction of stress. When a portion of a plate is pulled in a certain direction, there is produced Echelon cracks on both sides of it which are a kind of shear crack, whether they be the tension or compression crack. But when the plate is strongly pulled, the head of the Echelon cracks of both sides approaches and unites each other forming a symmetrical Echelon crack. The mechanism may be applied to the folding instead of the crack, which is represented by the anticline and the syncline.

According to Dr. Fujiwara’s principle the Echelon of the Yap and the Palau I. should be compression crack or folding, while the central ranges of New Guinea may have undergone thrusting from the NE.
Summary and Conclusion

The foregoing statement might be summarized as follows:

1) As to the distribution of the deep-focus earthquake of Japanese Is, Dr. Hess expressed the following adequate and precious opinion: "It has been postulated that the moderate and deep-focus earthquakes are located along approximately a 45-degree shear plane extending downward from the base of the trench. In regard to moderate-depth earthquakes, this appears to be a valid working hypothesis. These at least lie roughly in such a position with regard to the base of the trench. The very deep-focus earthquakes do not appear to satisfy the postulate, though many of them do occur in such a position that they may be attributed to a continuation of the 45-degree shear from those of moderate depth to 600 or 700 kilometers. But so far as the deep groups are concerned, there are some exceptions that may throw some doubts on the hypothesis."

"The deep-focus earthquakes of the Kamchatka-Kurile arc lie parallel to, and 400 to 60 km. west of, the axis of its associated trench. At the southern end of the Kurile arc, the trench, the volcanic activity, the shallow and moderate-depth earthquakes, and the exposed geologic structures all bend abruptly southward following the east coast of Honshu. But the deep-focus earthquakes continue the curve of the Kurile arc to the southwestward into the continent of Asia in complete disregard of the shallower structures and activities. Similarly the deep-focus earthquake trend below and west of the Shichito arc, south of Honshu, continues, to the northwestward, disregarding the fact that the shallower structures turn northward to meet those coming down from the Kuriles off Honshu. The junction of the two deep-focus trends at a point in Manchuria just north of Korea results in an area of exceptionally intense deep-seated activity."

From these facts, in reanalysing Gutenberg's and Richter's data, Dr. Hess came to the conclusion that the distribution of deep-focus earthquake seems to offer some independent support for a discontinuity or a transition zone at the depth of near 475 km.

According to the writer's investigation, the deep-focus earthquake associated with Shichito and Kurile seems to have the closest connection to the tectonic movements of the batholith. After the forming of Echelon structure in the Fossa Magna, by the pushing of the Shichito batholith into the outer zone of Honshu, the geologic force advanced farther to NNW. and may have raised the Noto Peninsula along the Japan Sea coast, and again have thrust up the Yamato Banks in the center of the Japan Sea bottom. Moreover, the pushing of the Shichito batholith into the outer zone of Honshu has caused the bending of the outer zone and the inner of Honshu, which is manifested by the great curving of the Toyohashi-Suwa arc of the Median line. At the starting point of the bending, where the upheaving begins eastward and reaches the culmi-
nation at the Nippon Alps, there occur the depressed basins of Ise Bay, Lake Biwa and Wakasa Bay, and under the bottom of which the deep-focus 'earthquake zone of Shichito passes to NNW. Then after crossing the Japan Sea at the same trend, and passing the west of the Yamato banks, the deep-focus earthquake zone reaches the Asiatic continent where it meets the other zone coming from the NE, which is the deep-focus earthquake zone of Kurile Trench.

Thus in the case of the Fossa Magna, the deep-focus earthquake zone appears to occur along the outer tectonic margin of the Shichito batholith, which may be the same in the case of the Kurile.

2) Geotectonically the Nippon Trench may supply something to Dr. Bemmelen's undation theory, who considers the Foredeep or Geosyncline as the resultant effect of the differentiation of Salsima urmagma. The lateral pushing away of the substratum was caused by the bending down of the Sima crust of the trough, by which the upward pressure of the quasiliquid substratum has been increased under the submarine ridge. Manifestly the outflow of heavy rock-matter and inflow of much less dense water caused a net deficiency of matter under the trough. But as to the range of outflow of the heavy rock-matter under the continent and the penetration of Salsima urmagma between Sial and Sima, we have no good proof besides some uplift of the land and the eruption of igneous mass.

On the one hand, about the pushing out of the Sial crust toward the the Nippon Trench, which may be considered as the manifestation of the adjustment of equilibrium, we have a typical instance of Kitakami mountainland, which may belong to the Mesoundation of Dr. Bemmelen's theory. The deep earthquake occurs in the substratum below the tectonosphere proper at depths of 300-700 km. According to Dr. Bemmelen these deep-focus earthquakes are possibly caused by the adjustment of equilibrium between the silicate mantle of the earth and the geotectonic processes going on in its outer layers. According to Dr. Honda the preliminary tremor of the deep earthquake is in the direction of the overthrust to the fault plane dipping, between the substratum liable to deep and intermediate earthquakes and that of nonquake stable layer. In this sense the Meso-undation phase of movement appears to accord rather with the deep earthquake.

On the other hand, the compression of the Nippon Trench from the oceanic side may be explained by the contraction of the ocean bottom, the contracting rate of which is 1.5 times greater than the continent, owing to the lesser quantity of radium and lesser heating than the latter. The contraction of the ocean bottom is manifested by reducing the the surface area, which compresses the margin of the continent and warps down along the fracture associated with the trench.

3) Close to the N. of the Fossa Magna, there is the S. part of the NE. Honshu which consists of the ruined Palaeozoic ranges of Tsukuba, Ashio, Taishaku, Komagatake and Mikuni together with the volcanic ranges of Nasu
and Azuma. They stand in an Echelon, and their trends are NE-SW, then EW, being considered to have changed the course from NS. as they approach the right wing of the Fossa Magna.

It may be due to the dragging of the right wing of the Fossa Magna, which shifted to NW. by the lateral thrust come from the Nippon Trench, though there is an influence of the lateral thrust from the Japan Sea (Japan Sea Movement), which pushed the Neogene Tertiary of the Echigo oil field from NW. to SE., and may have pushed out the Ashio range toward the Kwanto plain.

4) As to the age of the Japan Sea depression there is the theory of Dr. Okamura, a botanist, who studies the Japanese algae. According to him the algae in the Japan Sea are almost of the same species as those in the Pacific, but their kinds are less in number than those in the Pacific. The migration of the flora from the Pacific into the Japan Sea may have occurred in a later geologic age. In this sense the Japan Sea is younger than the Pacific proper.

Regarding the origin of the Japan Sea, however, there is no theory established on a valid foundation. The tectonic movement of the Shichito batholith may be a manifestation of the plutogenesis, occurring in the depth, and brought about by the underthrust of the Shichito Trench. Here at this place it may be necessary to quote the statement mentioned above, refered to the tectonic movement that occurred in the Fossa Magna in the early Miocene and the early Pleistocene time.

"After the formation of the Echelon structure in the Fossa Magna, by the pushing of the Shichito batholith into the outer zone of Honshu, the geologic force advanced further to NNW. and may have raised the Noto Peninsula along the Japan Sea coast, and again have thrust up the Yamato Banks in the center of the bottom of the Japan Sea.

Moreover, the pushing of the Shichito batholith into the outer zone of Honshu has caused the bending of the outer zone and the inner of Honshu, which is manifested by the great curving of the Toyohashi-Suwa arc of the Median line. At the starting point of the bending, where the upheaving begins eastward and reaches the culmination at the Nippon Alps, there occurs the the depressed basins of Ise Bay, Lake Biwa and Wakasa Bay, and under the bottom of which the deep-focus earthquake zone of Shichito passes to NNW. Then, after crossing the Japan Sea at the same trend, and passing through the west of the Yamato Banks, the deep-focus earthquake zone reaches the Asiatic continent where it meets the other zone coming from the NE., which is the deep-focus earthquake zone of the Kurile batholith.

As stated above, in the case of the Fossa Magna, the deep-focus earthquake zone appears to lie along the outer tectonic margin of the Shichito batholith which may be the same in the case of the Kurile batholith."

The pushing of the Shichito batholith into the Fossa Magna at the early
Miocene time must have influenced the continent which once occupied the Japan Sea basin, and caused the depression whose limit is manifested by the distribution of the deep seated earthquake. Thus the Japan Sea depression may be the same in the age as the revolution of the Fossa Magna which occurred at the early Miocene.

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