原著論文

Geotectonics of the Pacific concerning the Asiatic-austral Continental Islands: Geotectonics of the Yap-Palau Echelon brought about by the Pacific Movement

by

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Introduction

In the study of the Shichito-Ogasawara and Northeast Japan we have noticed the occurrence of geotectonic structures subjected to the Pacific movement, which represent on the one hand the geotectonic history of the Pacific movement, but on the other the transverse rift and the longitudinal tectonic line accompanying the deep earthquake zones. In this respect the Japanese Is. may be one of the most important places of the circum-Pacific where the geotectonic structures due to the Pacific movement are well preserved. But the southern Is. which here are composed of the Marianas, Yap, the Palaus, Halmahera, the Carolines and the Marshalls where Japanese geologists have spent years on geologic study, offer the best materials as to the Yap-Palau echelon, brought about by the Pacific movement, which is to be stated in this paper.

Commencing with an account of the Asiatic andesite line, the structural features of the margin of the Yap-Palau echelon would be elucidate in order.

The Andesite- or Marshall-Line

The andesite line was defined first by P. MARSHALL of Otago University in New Zealand. Lately G. A. MACDONALD of the U. S. Geological survey, who remarked the olivine basalt as the parent magma of the Hawaiian volcanoes compared the types of igneous rocks in the Hawaiian province with those recorded from other Pacific islands, and came to the conclusion that the rocks throughout the true Pacific basin are closely similar and suggests the essential uniformity of the parent magma. From this view point he included those volcanic islands of the Pacific in the same Hawaiian petrographic province, such as the Marquesas, the Tubuai, 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 the andesite line is drawn along the Pacific coast to the east, from California to Peru, but to the west, along the coast of the borderland of the Asiaticaustral continents to the Chatham Is. to the east of New Zealand.

On the Asiatic side the andesite line swings from Japan along the Shichito, Ogasawaras, Volcanics (Sulpher Is.), Marianas, and Palau groups to the border of the Netherlands Indies, where it turns eastward, then south-eastward 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 the Samoa Islands.

The most striking feature of Asiatic andesite line is the protrusion of the Pacific bottom into the area between the Marianas-Palau group and New Guinea, where it reaches the Tobi submarine plateau which lies to the east of Halmahera. The remarkable westward turning of the Marianas trench; the echelon of 8 rows of the Palau islands group; the Halmahera orogenesis subjected to the lateral thrust from the east; the northern coast of New Guinea running west-west-north to east-east-south; the apparent drag of the east end of New Britain Is. by New Ireland Is.; the north-west to south-east trend of the Solomon Is. etc.–these are like the asymmetric echelon of T. TOKUDA who experimenting with a sheet of Japanese paper mounted on some paste, pushed it obliquely with the top of a finger (the result is shown in Fig. 1.). If the writer's supposition is valid, a portion of simatic bottom of the Pacific may have thrust into the area from the east toward Halmahera, whose movement might have brought the asymmetric echelon around the Caroline Sea basin.

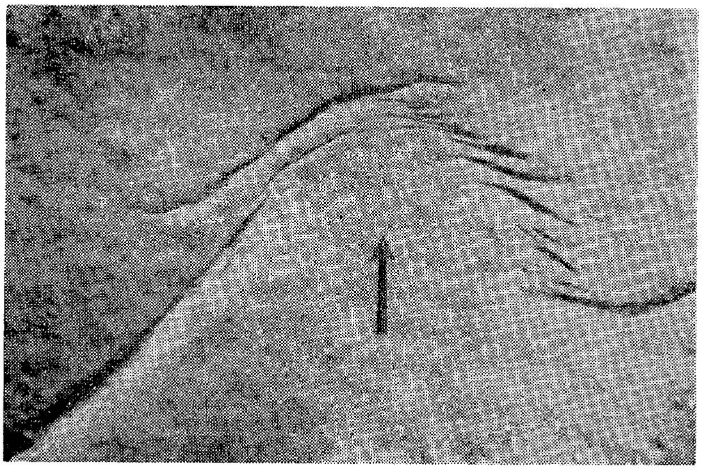

Fig. 1. Asymmetric Echelon, after T. TOKUDA

Marianas Trench

The Marianas trench starts in the south of the terminal of the Nippon trench, which is the east of the Volcanic Is. At first, the trend of the north portion of the trench is from northwest to southeast, but in the middle it becomes north-south, and south-west to north-east in the south. It is crescentic, standing due and facing the convex side toward east. The average breadth reaches 60 sea miles and the depth is great in the southern half where the Nero deep whose depth reaches 10,000 meters lies to the south of the Guam Is. Lately, however, the Challenger deep lying near the western end has been discovered, whose depth reaches 10,863 meters, the deepest in the world.

The Shichito trench (Nippon trench) is subjected to the lateral thrust of the

Pacific, which may extend enclosing the Ogasawara ridge toward the volcanic Is. and the northern part of the Pagan volcanic chain. For the Uracas, Medinila and Maug volcanoes belonging to the Pagan volcanic chain are dipping steeply toward the west, which reveals the direction of the lateral thrust coming from the Pacific. On the one hand, however, the southern portion of the Marianas trench is subjected to the tremendous compression of the western end of the West Caroline submarine ridges running west-east, and bended it strikingly toward the west. Consequently, the crescentic of the Marianas trench may be due to the lateral thrust coming from both the sides of the Pacific and the Philippine Sea; that is, the north and south ends of the Marianas trench are supported from the east by the Pacific movement while it is pushed out in the middle toward the east by depression of the Philippine Sea. On the same occasion with the Marianas trench the north and south Marianas submarine ridges, and the elongation of the submarine ridge of Shichito may have pushed out toward the east simultaneously.

The Tertiary submarine ridges of the Ogasawaras and the South Marianas

In 1901, the Ogasawara submarine ridge was separated from the Shichito ridge by S. TOKUNAGA who studied the geology of these islands. According to K. AKAGI, the Ogasawara ridge consists of small islets which have undergone the erosion and orogenic movement since the Oligocene times.

It is the remains of oceanic volcanoes, erupted on the old tectonic lines, whose relief of the mature stage contrasts with that of the Shichitos, 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 S. HANZAWA, and then some years later, that of the Saipan Islands by R. TAYAMA who clarified the geological connection between both groups of those islands. These inquiries aroused within us an emotion as if we had caught a glimpse of kindly light from a lighthouse in the lonely sea.

S. HANZAWA who studied Hahazima of the Ogasawara Is. discovered the *Nummulite* horizon at the base of the Tertiary tuff and breccia which overlie the andesite rock. The series contains two or more horizons of foraminifera in the upper portion, whose uppermost is composed of *Pellatispira* limestone, which indicated 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 (hypersthene andesite), in which he discovered *Lepidocyclina* limestone on the west coast of the same island, indicating the Oligocene. In Hahazima there are many faults whose trends are north-north-west to south-south-east 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 north-south through the inland parallel to the western coast.

R. TAYAMA divided the Tertiary limestone of Saipan Is. of the South Marianas submarine ridge into three series, -lower, middle and upper. The lower (*Camerina* limestone) contains *Pellatispira*, *Camerina* and *Discocyclina* which indicate the Upper Eocene. The middle (*Eulepidina* limestone) contains *Lepidocyclina* and

Spiroclypeus which indicate the Oligocene, while the upper (*Nephrolepidina* limestone) contains a bulk of *Lepidocyclina* going up to the Miocene age, but some of it is commixed with the middle limestone. In the Palau group, there is *Miogypsina* bed in the Yap Is., which may be related to the upper series of Saipan Is. while in the Palau Is. there is no fossil contained in the volcanic agglomerate and other series, which may enable us to determine the geologic ages.

The South Marianas submarine ridge may be connected faunistically to the Ogasawara ridge, the former consisting of Medinila, Saipan, Tinian, Aguian, Rota and Guam Islands forms the Tertiary submarine ridges lying closest by the Mariana Trench. The Ogasawara ridge is separated by a trough of 4 kilometers depth from the Shichito ridge. In the Marianas the Tertiary submarine ridge forms a crescentic arc lying parallel to and closely in contact with, the North Marianas submarine ridge which consists of the volcanoes dipping steeply to the east. They are so closely united that they are taken for one ridge, which is pushed out to the east by the depression of the Philippine Sea; formerly however, their relation may have been the same as what is seen between the Ogasawara and the Shichito ridges.

The Tertiary of Saipan Is. contains some rare blocks of granite and the Palaeozoic which may indicate the existence of foundation rocks. According to F. R. C. REED, in the Tonga ridge is there raised coral limestone along the trench; in the west of which lies the zone of tuffs, and then that of volcanics respectively. In a portion of the ridge, there is Eua Is. whose foundation is granite overlaid by the volcanic extrusive rocks containing many horizons of foraminifera, but in the uppermost, there is however, a thick limestone bed.

E. HOFFMEISTER and Leslie WHIPPLE had discovered Eocene in a portion of the limestone, represented by fossils as *Pellatispira*, *Discocyclina* and *Asterocyclina*. Eua, Saipan and the Ogasawara not only stand in contact with the margin of the trench of the Pacific, and their Tertiary faunae have the 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 Is. had been measured by A. TANAKADATE and to be high positive anomalies; of the same islands lately, however, by M. MATUYAMA to be in Chichizima, +363 mgal, and in Mukozima +233 mgal which might indicate the existence of basic plutonic rocks in the foundation.

The Volcanic Zones of the Shichito- and the North Marianas-Submarine ridge

The directrix of the Shichito submarine ridge north-north-west to south-south-east may be defined as the trend of basaltic and andesite volcanoes on the ridge (the Fuji volcanic zone), as well as of the Shichito batholith which forms the foundation of the ridge. It starts first in 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 Sulpher Is. where it diverges in two branches, one of which is the North Marianas submarine ridge (the Pagan volcanic chain) forming a prominent crescentic Marianas arc with the South Marianas submarine ridge, while the other is the submarine ridge which lies on the directrix of the Shichito ridge and may be considered to contain some rise of submarine volcanoes. The latter accords somewhat with the arc of Marianas and running almost along the former trend, approaches Yap Is. in the Palau group and disappears. There is a depressed basin between the Marianas arc and the submarine ridge, comparable with the trough between the Ogasawara and Shichito which is called "Inner Marianas trough" by H. HESS.

Most of the volcanoes of the north Marianas submarine ridge lie on the sea level but others under the sea. They are from north to south-Uracas Is., Supply reef, Maug Is., Assongsong Is., Agrigan Is., Pagan Is., Alamagan Is., Guguan Is., Zealandia bank, Sarigan I., Anathahan Is. and Esmeralda bank; of which Uracas is active, but Assongsong, the north and south volcanoes of Pagan Is., and Guguan preserve the remaining activity, while others are extinct, but were once active in the historical times. Most of volcanic rocks belong to the andesite and basalt. In the Pagan volcanoes, olivine basalt from the north volcano and augite andesite from the south are erupted simultaneously.

According to R. TAYAMA who studied Tinian Is. of the south Marianas submarine ridge, the first volcanic eruption of the Marianas arc appears to have begun in the middle of the Tertiary and have built up the base on which the coral grows. If so the volcanic period of the Marianas might have been at the same time as that of the Shichito.

The young volcano, when born, may be symmetrical in shape. But it must since then have become asymmetrical by the tilting movement of the ground on which the volcano stands. If the east side is raised and the west sunk the inclination of the east side of the volcano becomes slow and that of the west acute. On the contrary, if the east side is sunk and the west raised, the inclination of the east becomes acute, and that of the west slow. With regard to the inclination of the volcano the above illustration may be most adequate. In this sense the diastrophic movement of the Mariana is different between the north and the south, where 3 volcanoes of the north belong to the former case, while those of the south do to the latter. This movement has a close relation with those of the Marianas trench mentioned above.

The Yap Islands

The Yap Is. group forms an arcuate submarine ridge whose trend is north-north-east to south-south-west facing the convex side toward east and lying on the western side of the Yap Trench. It belonges to the northern member of the Palau Is. group, forming an echelon with the latter. On the ridge there are 3 blocks from north to south, Hanter, Yap and Nglu, of which Hanter may belong to the submerged table reef, and Yap forms an island enclosed in the fringing reef while Nglu is a block on which the Nglu atoll lies, but to the north, on the same block there is the so-called north Nglu rise. The breadth of the foundation of the Yap submarine ridge reaches 20~30 sea miles, while the height, from the sea bottom, does 4,000 meters.

In the southwest of the Yap Is. group there closely lies a submarine ridge which runs straight from northeast to southwest. It may be called the West Yap submarine ridge.

The Yap Trench: The Yap trench lies between both the submarine ridges of Yap and the West Caroline, whose geologic structures are entirely different. The trend of the former is north-east to south-west, parallel to the trench but that of the latter east-west, oblique to the trench.

The northern half of the trench has many indentations on both the sides, west and east. An indentation on the western side, lying between both the blocks, Hanter and Yap, may be noticed, while there are two on the eastern, manifesting the end of the Caroline ridge. The southern half is more simple than the north; the eastern side of the trench comes into contact with the end of the Caroline plateau. In the north, to the east-south-east of Yap Is. the depth of the trench reaches 7,533 meters while in the south to the east of Nglu it does 5,495 meters.

In the east-west section of the trench, the following facts may be remarked. 1) Both the walls are asymmetric; the western side steep, whose average dip angles reach 20°, but the eastern slow, and the average dip angle 6°. The western walls consist of many parts of both the steep and slow which alternate each other and form steps, but the eastern, monotonous and continuous slope. 2) Wall inclination of the trench increases with its approach to the bottom and shows the aspect of the valley in valley, commonly met with on land and the sudden enlargement of the inclination angle lies in the sphere of above 5,000 meters which may be defined as the deep. In the east of Yap Is. the breadth of the Yap trench reaches 55 kilometers while that of the deep does 25 kilometers at the same point.

Tectonic geology: The outline of Yap Is. is a right triangle, facing the shortest side toward northeast, and the longest one takes the trend of northeast to southwest, which coincides with the direction of the island axis, while another one occupies the remaining. The land is enclosed in the fringing reef, which consists of 4 blocks divided by faults, Rumong, Map, Tomil and Yap. The Geology of Yap Is. is studied by R. TAYAMA who has defined the order of geologic formations as follows:

Recent coral reef
Beach deposits
Unconformity
Terrace deposits
Garim limestone ....Riukiu limestone, Marianas & Palau limestone
Unconformity
Tomil agglomerate
Unconformity
Map formation
Miogypsina beds.........Miocene
Breccia
Unconformity
Yap formation

Of these, the Yap formation occupies the main portion of the island. It extends along the longest side from the southwest corner to Rumong Is. lying at the north corner, consisting of Crystalline schists which comprise amphibole schist, amphibolite, amphibolfels associated with gabbro, diallage-peridotite and norite.

The trend of the Yap formation is northeast to southwest and forms foldings except the southwest portion where the formation is disturbed. The Crystalline schist series of Yap Is. may have come from New Guinea where the same series is developed along the north coast of the island. But we have no convincing ground to probe so, since the geologic formation of the Tobi plateau is unknown.

Map formation consisting of Breccia and *Miogypsina* bed, is exposed in Map and Tomil areas. Tomil agglomerate shows the volcanic activity after the Miocene that occurred in this island. Garim limestone may be compared with Riukiu-, Marianas- and Palau limestone which may be allied to the Plio-Pleistocene, overlaid with the abundant mass of Tomil agglomerate. The *Miogypsina* bed which may be compared with the upper series of Saipan Is. is contained in the Breccia in small amount. It may be most important for the discussion of the period of the movement of the Halmahera orogenesis.

The Yap Is. forms a coulisse of the Yap-Palau echelon and may belong to the compression echelon folds and cracks of S. FUJIWARA. Consequently, it may have been subjected to the lateral thrusts coming from both the sides northwest and southeast. The foldings of the Yap formation may suit what he propounded. The Tomil agglomerate may have been extruded from the compression cracks, then formed.

The Palau Islands

The arcuate Palau Islands are composed of 3 blocks, north, middle and south, each of which is separated by the deep sea whose depth reaches 2,000 meters. The north submerged block lies in the depth of 700 meters and the south, 548 meters. The middle one may be subdivided into 5 blocks, of which Belasco submerged atoll, Garuangle and Kajangle atolls lie northward; while the barrier reef of the Palau occupies the middle, to the southwest of which there lies a submerged table reef whose depth reaches 16 meters; but the Angaur elevated atoll whose circumference is occupied by the fringing reef lies southward.

On the whole, the Palau Islands group is composed of 7 blocks, each of which has characteristic features. But above all the islands in the Palau barrier reef occupy the center, whose northern half is occupied by the volcanic Is. of Babeldaob, Alakabesan, Korror and Marakar, but the south by the limestone islands of Urukutabl, Oropshakel and Peleliu.

The Palau Trench: The Palau Trench lies between the submarine ridges of the Palau and the West Caroline basin. It starts in the east of the middle block, mentioned above and runs parallel to the island arcs toward the southwest to the terminal of the south block. Both the walls of the west and east are asymmetric, the western side being steep, but the eastern slow. The depth of the trench reaches 8,138 meters to the east of Babeldaob Is.

Babeldaob Island: In the Palau Islands group Babeldaob occupies the central. It is an island which is like a plateau extending to north-north-east to south-south-west, whose length reaches 40 kilometers while the breadth does 14 kilometers in the widest part of the midst. The height is not more than 240 meters, above the sea level but from the base of the island arcs at the bottom of the sea may be a great mountain whose height exceeds 4,000 meters. R. TAYAMA who studied the geology of the island defined the order of geologic formation as follows:

Recent limestone
Raised beach deposits
Palau limestone...........Riukiu- & Mariana limestone
Lignite bearing beds
Galdog beds
Babeldaob agglomerate

All the formation stands in the relation of unconformity. The Babeldaob agglomerate which occupies almost the whole of the island is a massive rock, but when tuffs intercalate it the stratification may be discerned from the distance, which dips usually to the west in the western slope of the island. It seems to be divisible into three horizons lower, middle and upper. The lower consists of the agglomerate of dark greenish augite andesite; the middle, of two pyroxene augite andesite; the upper, of hornblende andesite which resembles quartz-porphyry in outward appearance.

The age of the agglomerate appears to be older than the late-Tertiary, but in some places there are lava streams which seem to have erupted later. The trend of the Babeldaob agglomerate and Galdog beds is almost north-south which coincides with the island axis. It dips west in the western slope of the island and east in the eastern slope, forming an anticlinal. The dip angle is usually more or less than 30°.

Galdog beds consisting of the thick layers of tuffaceous sandstone and shale have some parts of them exposed along the Galdog River, and lie parallel to the eastern margin of Babeldaob Is. The strike is north-south and the dip 40°~80° to the east. In the layer any fossil has not yet been found. The dip angle of the lignite beds and the more younger series do not exceed 20°, and there may be a remarkable unconformity between the Babeldaob-Galdog and the lignite series.

The Palau Islands arcs are a coulisse of Yap-Palau echelon which may belong to the compression folds and cracks of S. FUJIWARA. Consequently the Palau Is. may have been subjected to the lateral thrust coming from both the sides, north-west and south-east. The Babeldaob agglomerate with its north-south trend forming an anticlinal may well be fit in this case. Probably the agglomerate may have erupted from the compression cracks, that happened in the basal complex which are not exposed.

In the southern limestone islands represented by Urukutabl, Oropshakel and Peleliu 6 terraces may be noticed, on the even plane of which up- and down-warping movements with the axis of northwest to southeast and the tilting movement toward the west are remarked.

The Tobi Submarine Plateau

Yap Is. is not more than 180 meters in height above the sea level, but as it lies on the top of the Yap submarine ridges rising up from the depth of 4,000 meters of the Caroline sea bottom it may represent a great cordillera. Between Yap and the Palau Is. there are 3 parallel, small and slender submarine ridges, on which lies neither island nor reef.

The center of the Palau barrier reef is occupied by the islands of Babeldaob, Korror and Alakabesan, consisting of andesite rocks. They are not more than 230 meters in height above the sea level but as they lie on the top of the Palau submarine ridge emerging from the depth of 4,000 meters of the Caroline sea bottom it may represent a great mountain range like Yap Is.

Seven coral islands on the Tobi submarine plateau form 3 rows of the islands running north-east to south-west, of which the western consists of the islands (from north) Sonsol, Banna, Bul and Tokobei, furthermore a crest lying to the northeast of Sonsol, whose depth reaches 1,609 meters -the row may be called as

"Sonsol row" and all of them belong to the table reef. The middle consists of two islands, of which the Merill table reef lies northward and the atoll of Helen southward- "Merill row." The eastern is composed of the Transit reef and two coral reefs of Asia and Aiu which lie outside the Tobi submarine plateau, belonging to the Dutch dominion- "Transit row."

These 8 rows mentioned above-from east to west, Yap Is., 3 small parallel submarine ridges, the Palau Is., 3 rows of coral islands Sonsol, Merill and Transit-form en echelon, characteristic of the Caroline Sea. Between the submarine Tobi plateau and the continental shelf surrounding the northwest of New Guinea, there lies a hollow like a graben, the depth of which is more than 4,000 meters. It may extend to the Philippine Trench running north-south, crossing between the submarine Tobi plateau and Halmahera Is. the existence of which may be an obstacle to the geologic connection between the Tobi submarine plateau and New Guinea. H. BROUWER connected Helen reef via Morotai Is. to the northern segment of Halmahera whose eastern may have a close geologic relation to New Guinea, and made out the geologic connection between Asia and Australasia.

The protruding apex of the Caroline sea basin which is manifested by the andesite line has been pushed between both the continents of Asia and Australasia by the Pacific movement and has reached the eastern foot of the Tobi submarine plateau, pressing the formations, by which the plateau may have been formed. But whether the plateau is made by the series of Crystalline schist, the Cretaceous and Tertiary which are developed on the north coast of New Guinea or the formations of the Solomon Is. chain which may have come westward we have no means to prove at present.

Halmahera Is. lies to the west-west-south of the Tobi submarine plateau, but it may be certain that it has been subjected to the lateral thrust coming from the Tobi plateau, which caused the so-called Halmahera orogenesis by B. BESSHO.

The Halmahera Island (Fig. 2.)

Halmahera Exploration by B. BESSHO (1942): The geologic study of Halmahera Island began as late as in 1908, 50 years ago. The rock specimens from several localities of Halmahera were collected and described by VERBEEK; and in 1913 the central depressed zone of the island was traversed from Ekor to Weda by WERNER while in 1918 the Tertiary of the North segment was studied by GOGARTEN, and in the same year the volcano of Djailolo was researched by GEORGIYADES. In 1923, BROUWER traversed both the segments of the northeast and the east, of the island. But with regard to its through study, we had to await the exploration of the island made by B. BESSHO in 1942.

At the time of the great war, when it was raging in Eastern Asia in 1942, B. BESSHO was requested by the Japanese Navy for the researches of Halmahera Is. He organized a group composed of 14 men and 100 coolies, and made geological researches there above 100 days. The K-typed Halmahera Is. composed of segments of the north, the south, the northeast and the east lies near the equator, covered by the jungle sea, which made the work serious. But B. BESSHO, chief of staff, brought the enterprise to completion by the co-operation of the firmly combined group.

In the first scheme B. BESSHO who tried to grasp the geotectonic essence of Halmahera Is. selected the area on the map, which occupies the central part of

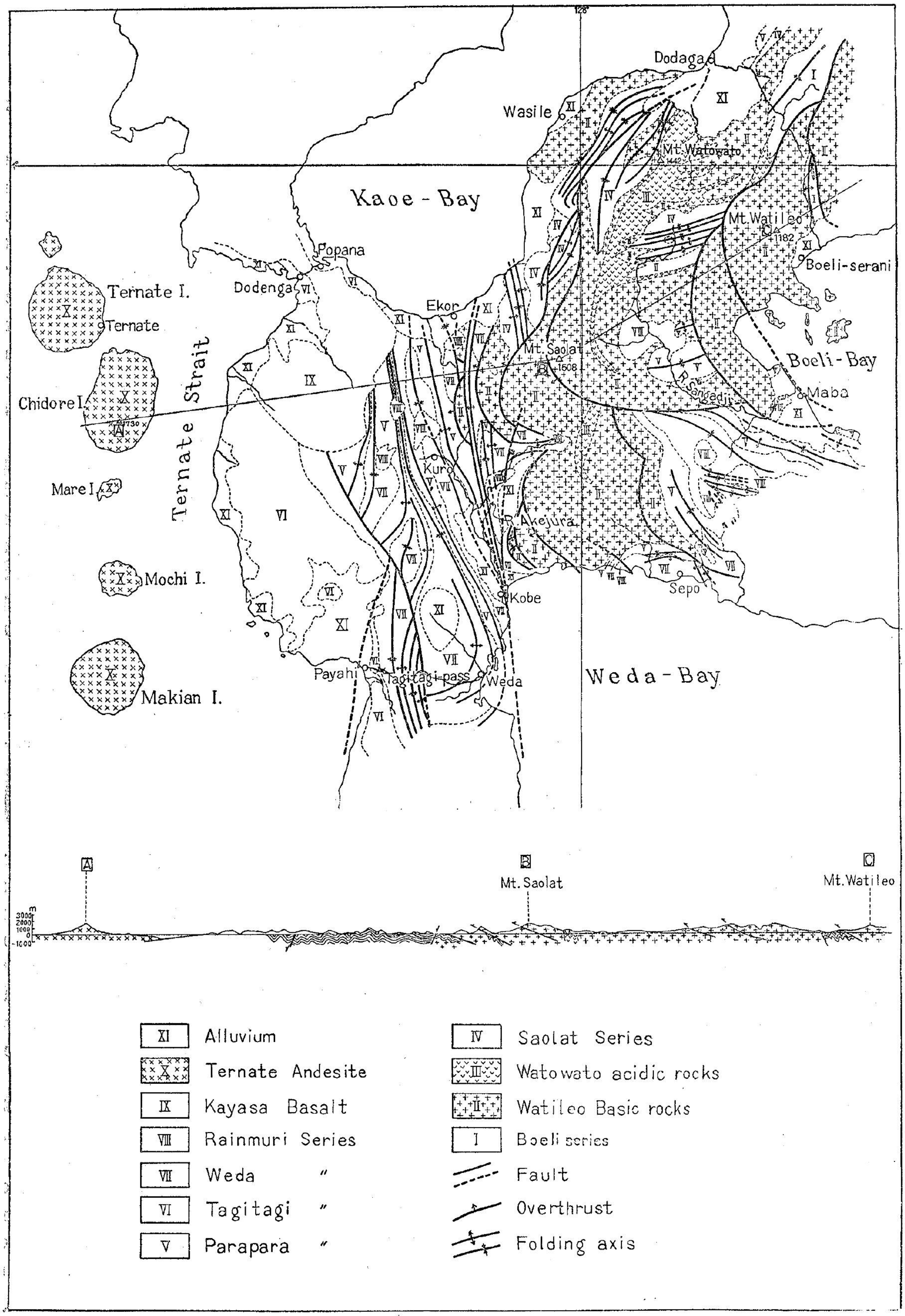

Fig. 2. Tectonic Map of the Central part of the Halmahera Island, after B. BESSHO (1944)
Scale: 1/500,000

the island and avoided places where we are apt to fall easygoing.

After a sufficient preparation at Ternate he first landed at Dodenga and passed the isthmus for Kaoe Bay where he selected as his bases Ekor and Wasile, the villages lying on the southern coast of Kaoe Bay, whence his heavy attack was made against the mid-mountainous land. He traversed the pass from Dodaga to Boeli-Serani, which is the crossing of the northeast segment and reached Boeli Bay whence he went to Maba. After the geological researches of the R. Sangadji he traversed the pass of Rainmuri from Maba to Sepo, which is the crossing of the east segment and reached the coast of Weda Bay. He went to Kobe and along the R. Akejura his attack was again made against the mid-mountainous land from the south. Lastly he traversed the pass of Tagi-Tagi from Weda to Payahi, which is the crossing of the south segment, and returned to Ternate.

B. BESSHO who discovered nickel ore and asbestos in the olivine rocks which are commonly met with in the island, noticed the overthrust or decken stucture of the olivine rocks, associated with the limestone, exposed along the north coast of Weda Bay. The direction of the overthrust is decidedly from east to west.

On an occasion he climbed up the small hill of Seseo which stands in the midst of the plain of the Akejura R., casting his eyes eastwards upon the ranges. The aspect of that time is described by him with deep emotion, as follows:— "From the hill the mountain ranges of the hinterland of the Akejura may be seen eastwards, clearly close at hand. The 2 or 3 parallel spurs start from Saolat Mt. (1,508 meters), running from north to south toward Weda Bay. They are piled up, one above another and appears as if tumbled down toward the Akejura plain. The overthrusts coming from both segments of the northeast and the east are repeated several times; they are clashed against one another and some tectonic basins are formed between them. The topography may be compared with that of Shikoku, seen northward from the Murotosaki. Under the deep shaded mountain folds there is seen the Imelo ridge which appears like long greenish black hair flowing. Far away north from the north end of the ridge, a white glittering mass is seen, which is nothing else but Mein Kotakota where granitic rocks are found.

After the strenouous efforts for hundred days the K-typed island has first had the door opened and the secret shown. The nature reveals the truth to one who loves and seeks it. Viewing from Seseo hill which commands the Akejura plain, he has discerned the geotectonic essence of Halmahera Is. which no one has remarked as yet.

Thus he has ascertained the existence of the Pacific movement in Halmahera Is. His geological researches and geotectonic ideas will be described after him as follows.

Geology of Halmahera Is.: The geology of the central part of Halmahera Is. was studied by B. BESSHO, according to whom the stratigraphical order, in ascending is as follows:—

Boeli series — Cretaceous or Pre-Cretaceous
intruded by the Watileo basic rocks which is penetrated
by the Watowato neutrous igneous rocks

Unconformity

Saolat series — Paleogene

Unconformity

Parapara series — Neogene

Para Unconformity
Tagitagi series
Weda series Neogene
Unconformity
Rainmuri series Pleistocene
Overflow
Kayasa basalt
Overflow
Ternate andesite
Alluvium

Boeli series: — The oldest formation, found in the northeast segment; from the outward appearance its geologic age may belong to the Cretaceous or even older; intruded and contact-metamorphosed by the Watileo basic and Watowato neutral igneous rocks; intensely folded by the crustal movements showing the dip angles greater than 60°. The thickness reaches above 200 meters consisting of the alternation of thin layers of phyllite, clay slate, shale, graywacke sandstone, crystalline limestone, hornstone and chert; developed between Dodaga and Boeli.

Watileo basic rock: — Intrusive into the Boeli series, but penetrated by the Watowato neutral rocks, they are overlaid unconformably by the Saolat-, Parapara-, Weda- and Rainmuri-series. The age of the intrusion may be the late Cretaceous and most of them changing into serpentine; it consists of serpentine, peridotite, augite peridotite, hornblende peridotite, metamorphosed gabbro, metamorphosed hypersthene gabbro, two pyroxene gabbro, metamorphosed actinolite- peridotite-gabbro. Indeed the eastern mountainous land of Halmahera Is. is composed of Watileo basic rocks. To the east of the middle course of the Akejura River, a small amount of the captured rocks of scharlstein and chert by the Watileo basic rocks are discovered.

Watowato neutral rock: — Intrusive into both the Watileo basic rocks and Boeli series; overlaid by the Saolat series. The age of the intrusion may be just posterior to that of the Watileo basic rock. It is composed of quartz diorite, gabbro, granodiorite and gneiss, all of which have more or less a gneissic structure; sometimes there is an eye structure in the gneiss. In the intrusion it diverges in many apophyses, large or small, eastward, but westward comes in contact with the serpentine rocks by the straight line extending northsouth, but producing many fractures in the latter, which have an important meaning to the ore deposit.

Saolat series: — consisting of fine wavy foldings; the thickness reaches 200~300 meters. It consists mainly of dark-greenish shale, sandstone, limestone, conglomerate (consisting of the gravels of Watileo basic and Watowato neutral rocks) and andesitic brecciated tuff. Speaking generally, the conglomerate, occupying the lower horizon; the sandstone which is tuffaceous or accompanies limestone, the middle; and the shale, the upper. The Saolat series occupies two or three small basins lying to the eastern or in the northeastern segment. It may belong to the Paleogene.

Parapara series: — may belong to the Neogene; it overlies unconformably both the Watileo basic rocks and the Saolat series while it is overlaid conformably but partly para-unconformably by the Weda series. It forms a slow wavy foldings but in the Mid-strip zone is severely folded by the lateral thrust coming from the east, making either overturning or reversed faults.

The thickness reaches almost 300 meters, consisting mainly of limestone, and small amount of marl, with sandy shale intercalated. In the area occupied by the series there is found the Karst topography, such as the doline of the Parapara R., and the limestone cave of Sagea.

Tagitagi series: — intercalated between the series of Parapara and Weda; developed locally; there is para-unconformity between the series and the Parapara series but conformity between the Weda series.

The thickness reaches almost 300 meters and consists mainly of tuff, brecciated tuff, augite andesite, biotite-hornblende-augite-andesite, hornblende-andesite, brecciated andesite, trachyte, sandstone intercalating the thin layers of tuff, sandy shale and limestone. The series is locally developed along the strait of Ternate.

Weda series:—Conformably or partly para-unconformably for the Parapara series, but conformably for the Tagitagi series; folded together with the above mentioned series.

The thickness reaches almost 200 meters. It consists mainly of coarse grained light yellowish sandstone, and intercalates sandstone on the lower horizon.

Rainmuri series: — It may be deposits of the Pleistocene or late-Neogene. It overlies unconformably the above mentioned series with no trace of foldings. The thickness reaches about 100 meters; consisting of the grabels of serpentinized sandstone. It may be distinguished from the fault breccia of the Watileo basic rocks by hardness and the occurrence of round grabels in the conglomerate. The series occurs spottedly in the eastern mountainous land.

Kayasa Basalt: — Consisting of basalt, olivine basalt and basic augite andesite; the lava flow covers the Parapara, the Tagitagi and the Weda series; it may belong to the eruption in the beginning of the Pleistocene; forming the plateau, extending to the isthmus of Dodenga.

Ternate andesite: — It consists of the augite andesite erupted from the new conide volcanoes, spottedly arranged in the direction of the north-south in the Molucca Sea.

Alluvium: — consisting of mud and sandy soil; the deposits occupy a small area of the lower course of those rivers, Tonik, Palama, Dodaga, Sangadji, Kobe, Akejura, and of the middle course of the R. Fuji. There are the growing coral reefs in Maba Bay, Weda Bay and the strait of Ternate.

Geotectonics of Halmahera Is.: E. Suess has taken a serious notice of Halmahera Is. considering what an important role it may play as a link between Australasia and Asia, while H. Brouwer connects the island on the one hand to Palau Is. but on the other to Vogel Kopf of New Guinea via Waigeo Is. Lately the central part of the island was thoroughly studied by B. Bessho, where he discovered the Halmahera orogenesis which might have been caused by the Pacific movement.

The trends of foldings of the Boeli, Saolat and Parapara series of the north-east segment of Halmahera Is. are east-west, north-east-east to south-west-west, north-east to south-west and north-south, but at the junction with the Mid strip zone which is represented by the river course of the Waiyameru R. and the Kuro-Kobe R., they follow the same general trend of north-north-west to south-south-east. The trends of the Parapara and Weda series of the east segment are east-west, and north-west to south-east, but at the junction they also take up the general trend of north-north-west to south-south-east.

The blocks of both the segments, northeast and east, composed of the older basic rocks in whose small basins the above mentioned folded Tertiary deposits are contained, have been thrust over the Tertiary of the Mid strip zone consisting of the Parapara and Weda series, from east to west forming the scaly structure in themselves. The blocks, bounded by the eleven arcuate faults face the convex side westward, and have been thrusted over the Mid-strip zone.

This is the most important characteristic of Halmahera Is. B. BESSHO calls the movement, as the "Halmahera Orogenesis". The Tertiary land which was thrust over by the Halmahera orogenesis has intensely been folded toward the north-south but in the front there are seen overturning and reversed faults. But in recent times the great faults of Halmahera are occupied by the normal faults running north-south, which may be due to the retrogressive action by B. KOTO. The volcanoes of Ternate Is. may have erupted from the faults, running parallel to the normal faults of Halmahera which are active at present.

The strip of negative anomalies along the Java trench has been defined by Vening MEINESZ. It forms a curve along the south side of Java and Lesser Sunda Is. and turns northward along the Banda Sea, while it swings further to the north along the strait of Molucca toward the Philippine trench forming an arc between Ceram Is. and the Philippine trench, whose convex side faces to south-west which accords with the direction of Halmahera orogenesis. The Halmahera orogenesis may have given influence to both the sprawling Celebes Is. whose shape is analogous to the Halmahera Is., and the Banda basin where the wind of Timor-east-Celebes zone (Umbgrove's Banda Geosyncline) is noticeable. There may be some probability of the existence of the same structure in central Celebes as in the Halmahera.

Geotectonics of New Guinea and the Solomon Is. with reference to the Yap-Palau Echelon

New Guinea is a great island running west-west-north to east-east-south. Geologically it may be divided into 3 zones: the south the middle and the north. The south zone is a marshy low land occupied by the granitic series, closely allied to the northern Austral continent, overlaid by the Tertiary. The middle is the great mountain land forming the back bone of the island, which thrusts over the south zone. It consists of Crystalline schists, Paleozoic, Mesozoic and Cainozoic. *Alveolina* limestone of the Eocene age is discovered from the Carstenz and Wilhelmina Tops which rise to 15,000 feet in height.

The middle zone is separated from the north by a great tectonic line. It commences in the Gulf of MacCluer is continued by the valley of the Waiponga stream draining westwards into Geelvinck Bay, and thence eastward by the Rouffaer and Idenburg Rivers. Then traversing the river system of the Sepik River it passes the valley of the Ramu and the Markham River, both of whose sides are bounded by the Finisterre and Bismarck ranges rising to the heights of over 10,000 feet and penetrates into the Gulf of Huon.

In regard to the trend lines of the north coast and the Finisterre Ranges, STANLEY does not consider them as a portion of the same tectonic zone as the main ranges of the island, but views them as a separate geanticline "of smaller dimension, with a probable Asiatic structure, and thereby related to Halmahera, Philippines, and Japan. This coastal feature is modified by faults or step folds, which cut obliquely the geanticlinal axis".

This axis bends eastwards in the Huon Peninsula, and extends into New

Britain, while parallel to it runs a line of active volcanic Is. (the Schouten group), which is continued by the great series of volcanoes along the northern coast of New Britain.

The Solomon Is. belong to the outer zone of the First Australian arc of SUESS, which consists of two rows of the islands running northwest to south-east. They manifest the remains of old cordillera composed of rocks of the olden times. New Ireland belongs to the inner row of the two, whose trend is north-west to south-east but changes to the due south at the south end, where the east end of New Britain Is. comes near by. This may be due to the fact that New Ireland, has once dragged New Britain Is. when the Pacific movement has pushed the Caroline Sea basin toward the west.

According to GUTENBERG and RICHTER, the great tectonic line between the north and middle zones of New Guinea coincides with the shallow seismic zones, but with a greater approach to the Gulf of Huon it undergoes a more change into the intermediate earthquake, and in the Gulf runs parallel to the east-west axis of New Britain Is. through the Planet deep. It may be considered that in the simultaneous dragging of the New Britain and Finisterre Ranges by New Ireland, the eastern half of the great tectonic line might have been split in the great depth.

Submarine Geotectonics of the Caroline Sea basin with reference to the Mid-Pacific orogenesis

The east-west nine parallel rows of the submarine ridges crowned by coral reefs, whose height reaches 3,000 meters from the bottom of the Caroline Sea, which may manifest the tectonic lines are defined by R. TAYAMA. The rows are separated into the eastern and the western by a trough running north-south along the East long. 150°, of which the western row whose terminals reach the Yap trench forms the eastern side of the trench while the eastern row is not so closely arranged as the former and forms an arc which faces the convex side toward the northeast.

To the east of the Caroline group, there are 6 rows of the submarine ridges of Marshall group running from north-west to south-east, whose outer ones merge into those of Gilbert group. The Marshall and Gilbert groups form an arc parallel to the outer rows of the Caroline group, and face the convex side toward the northeast, while to the northeast of the latter, the Marshall group is cut abruptly by a fault running from northeast to south-west.

Once the Caroline submarine ridges and the sea bottom containing the submarine plateau may have thrust themselves from east to west between the continents of Australasia and Asia and brought about the western bending of the south Marianas trench, together with the south Marianas submarine ridge, the Pagan volcanic chain and the south elongation of Shichito submarine ridges. The echelon of Yap and the Palau Is.; the drag of the eastern end of New Britain Is. by New Ireland Is.; the northwest to south-east trend of the Solomon Is. may have taken place at the same time with this thrusting.

To the southeast of the Caroline, Marshall and Gilbert there are Elice and the Samoa Is., the former of which may have come in the same trend of Marshall and Gilbert. To the east of the Samoa Is. the Mid-Pacific is occupied by those islands of the Paumotu and Society which may consist of many rows of submarine ridges running from northwest to southeast, while to the south-west of the Paumotu there are the Cook and Tubuai Is. whose trend is almost parallel to the former, and consist of lesser rows of submarine ridges. L. KOBER who believes in the existence of the Alpine orogen which transverses the Pacific parallel to the equator has defined both the Kratogens occupying the North and South Pacific. According to him, the Paumotu and Society Is. belong to the north stamm of the Alpine orogen while Tubuai and Cook to the south stamm of the same. The North and the South Pacific represent the depressed block of Kratogen which squeezes the orogen from both the sides north and south. If the Kratogen of the North and the South Pacific sinks, it may well illustrate the theory of B. WILLIS; and the squeezing of the Alpine orogen in the Mid-Pacific may have driven the east-west submarine ridges and sea basin of the Caroline and Marshall between the continents of Australasia and Asia.

Summary and Conclusion

1) The formative period of the Yap-Palau echelon may be inferred to have been in the beginning of the Miocene, when the volcanic eruption of the North Marianas submarine ridge might have taken place. B. BESSHO who studied the Halmahera orogenesis has defined the orogenic times to be posterior to the Neogene; but there may be suspected two times of the orogenesis, the first in the beginning of the Miocene, the second to be posterior to the Pliocene. The overthrusts that occurred in the Halmahera basic rocks (Watileo series) remarked by BESSHO may be the resultant waves of two kinds of orogenesis. According to W. N. BENSON the orogenesis of New Guinea took place the twice-in the Oligocene-Miocene and in the Post Tertiary, which represents the unity of the orogenic period between Australasia and Asia.

2) We have no good convincing ground for proving the tectonic relation between both the trenches of the Marianas and Philippines, which are running parallel though far apart.

The lateral thrust of the Pacific, that bends the Marianas trench and makes the Yap-Palau echelon, appears to have influenced the Phillippine trench which has lain in this place since long before. The Phillippine trench may be older than the Yap Palau echelon, but there is no good proof to ascertain the original time of the two trenches, whether they have occurred at the same or at a different time.

3) On the Pacific coast of Japan and her far southern Is. there are three regions undergoing the lateral thrust from the Pacific, of which from north to south, the first is the region of Chishima and Hokkaido including the Chishima trench; the second lying between Cape Inubo and Ogasawaras containing the Shichito Is. and the Shichito trench., the third manifested by the andesite line of the Caroline Sea, protruding to the west between Australasia and Asia.

About the first, it is reported by the writer in the former paper, thus:— "The Chishima trench begins to the east of the Peninsula of Kamchatka and runs from northeast to southwest along the Chishima Is. toward the south of Hokkaido. The existence of a tectonic line may be supposed running in parallel with the trench and through its bottom which is found to be 9,000 meters in depth to the south of Uruppu Is. The lateral thrust from the Pacific may have come from south-east to north-west which is analysed into two components against the plane of the tectonic line, one of which is perpendicular, and the other in parallel with it and by the latter, the outer zone of the Chishima Is. chain my be pulled toward the southwest.

The tectonic movements of the Chishima and Hokkaido may be due to the Pacific movement whereby the outer zone of the Chishima was made to pull the inner in the beginning of the Miocene and the Diluvial, and in consequence the compression echelon cracks and folds have been produced in the inner zone, through which the volcanic eruption took place. The Chishima batholith which contains the outer and inner zones has pushed the Hidaka range from northeast and thrust up the metamorphic zones of the range toward southwest."

About the 2nd the writer has also described in the former paper as follows: — "The Shichito trench, a south portion of the Nippon trench, which appears to be a portion of the suboceanic bent-down crust by the orogenic force of the Pacific, may once have extended north-south from Cape Inubo, to the east of the Ogasawara Is. By being subjected to the orogenic pressure originated in the profound depth of the western Pacific, however, it has faced the convex side toward the west and come to press the Shichito submarine ridge. Consequently, the north-south abyssal basin of 4,000 meters in depth between the Ogasawara Is. and the Shichito submarine ridge was cut by the trench, to the north-west of the Ogasawara Is. while to the south of the Cape of Inubo, the trend of the trench has turned strikingly to the west, and come to approach the Shichito submarine ridge. Prior to the movement, the Ogasawara ridge, the Tertiary moutain range in the Pacific, may have extended to the north farther than now; but how far it is, is not clear.

The Shichito submarine ridge makes a boundary with the Shichito trench whose distance is above 500 kilometers from north to south extending between the east of Ôshima and Sôfu rock; beyond which both of them diverge from each other. In the above-mentioned distance, however, one may recognize the remarkable influences which the trench gives to the submarine ridge and the outer zone of Southwestern Japan, on the tectonic structures, of the sea floor and land. ......"

The lateral thrust from the trench has brought about not only the pushing of the apex of the Shichito batholith underlying the Shichito Submarine ridge, into the outer zone of the Japanese Is.; and the making of Transverse rift accompanying the deep earth-quake zone; but also the shearing zone running north-north-west to south-south-east into the Shichito batholith, through which the Fuji volcanic zone erupts.

With regard to the third it is stated in this paper as the andesite line of the Caroline Sea protruding to the west from the Pacific between Australasia and Asia. In this case the lateral thrust from the Pacific has brought about the Yap-Palau Echelon and the Halmahera orogenesis, the latter of which has influenced upon the Banda Sea.

Against the Pacific movement mentioned above two regions subjected to the lateral thrust from the continent may here be noticed; the one is the region of Northeastern Honshu of the Japanese Is. while the other, the Marianas Is. With regard to the former it is reported by the writer in the former paper as follows: — "In the beginning of the Miocene the Japan Sea movement appears to have overwhelmed the Pacific movement and pushed out the Kitakami range toward the Pacific, while at that time the formations of Inner Japan where the volcanoes erupt, have almost been depressed away except the Paleozoic lying in the south of Northeastern Honshu. The pushing out toward the Pacific may be verified by the following facts:

I) The arc of the eastern coast of the Kitakami range whose convex side faces toward the east, and whose center lies at the city of Kamaishi.

II) The present position of the Nippon trench is pushed out from the former toward the east, and the traces of the trench whose portion is buried by materials of the continental slope, pushed out at the same time with the Kitakami range. The 6,000 meters isobath of the traces shows the outline of the trench, which delineated an incised, wide-flattened area running parallel with the foot of the continental slope.

III) The axis of negative anomaly, which ought to be identical with that of the trench, but is detached from and lies under the continental slope, whereabout the hypocenters of shallow earthquakes lie. The instability along the Sanriku trench is verified by frequent shallow earthquakes, which may be due to the pushing out of Northeastern Honshu toward the Nippon trench."

The pushing out of the Kitakami range toward the Pacific may be due to the depression of the Japan Sea which occurred both in the times of the Miocene and the late-Pliocene.

The other region mentioned above, which might have been subjected to the lateral thrust from the continent is the Marianas. The due crescentic of the Marianas trench and the North-and South-Marianas submarine ridges may be attributed also to the pushing out of the Philippine Sea toward the Pacific, whose depresion might have occurred both in the times of Miocene and the late-Pliocene.

4) With regard to the seismicity of the Marianas, three seismic zones are described by GUTENBERG and RICHTER. On the whole they are regulary arranged from the trench toward the west in the order of Shallow earthquake, Intermadiate and Deep, of which Shallow and Intermediate are remarkable, but Deep rare. The tectonic line along and penetrating the bottom of the Marianas trench, whose fault plane dipping west may extend into the depth. As in the case of the Transverse Rift of Japan, in depth 250 kilometers it may diverge the fault plane of Intermediate earthquake upwards; then it may bend acutely toward west and form that of Deep earthquake. The fault plane of the Transverse Rift is subjected to the underthrust from the Pacific, while in Marianas, partly the upper portion from 250 kilometers is done to the overthrust from the continent.

As B. WILLIS had once stated that the force acting from the continent has pushed the surface block toward the ocean while that from the ocean is acting in a sort of undertow, the lateral thrust from the continent may act near the upper surface, making island arcs while that from the ocean does not often represent so remarkable a topography on the upper surface, but instead develops the great tectonic line and orogenesis of the profound nature. Many of the Asiatic festoon islands may belong to the former.

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亜濠海諸島の太平洋地体構造論: Yap-Palau 雁行と太平洋運動

江 原 真 伍

(摘 要)

かつて，本邦の領有下にあつた南方諸島は太平洋運動に対する好箇の資料を有する所であり Yap-Palau 雁行がそれである.

本文は Mariana, Yap, Palau, Halmahera, New Guinea, New Britain, New Ireland に依て囲まれた Caroline 海域が，太平洋より圧縮を受けて一大雁行を形成すること，及び Halmahera 造山運動が Banda 海に影響することを述べている.