50. *Reciprocal Development of Radiolarian Rocks as between Asiatic and Australian Sides.*

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While marine formations of neritic facies in Nippon have been thoroughly studied with a mass of facts, stratigraphical and palaeontological, our knowledge on their bathyal facies still remains chaotic. Two important groups among these little known formations are the Shimanto and Sambosan groups forming two broad belts through West Nippon. Yehara was the first to pay special attention to the radiolarian rocks contained in them in the Island of Shikoku. His studies were followed by Huzimoto's on the rocks in the Kwantō Mountain-land. Age-determinations made by them, however, were either incorrect, inadequate or ambiguous. Because they are contained in preorogenic sediments of the Flysch type, the role which they played in the tectonic development of the Japanese islands is evidently of prime importance.

Some fifteen years ago I began a stratigraphic study on them which has lately been given great impetus by cooperation from my students. As demonstrated on a previous occasion¹⁾ it is now quite warranted to conclude that radiolarian rocks formerly taken for the members of the Upper Jurassic Torinosu series all belong, or at least almost all of them belong, to the Sambosan group lying beneath the Torinosu.

As revealed in my synthetic study on the origin of the Japanese islands²⁾ radiolarians are most common in the cherts of the Yamaguchi, Sambosan, Shimanto and Naegawa groups aside from some inclusions in the Nakamura group, Neogene and younger diatomaceous earths and in the Upper Gotlandian rocks, this last being the oldest of the radiolarian rocks found in Nippon.

It is noteworthy that the distribution of these radiolarian rocks shifted from the inner or the continental side to the other in perfect accordance with the migration of geosynclines through orogenic cycles. More precisely, the Chichibu group of the Yamaguchi facies in the in-

* This and the next paper give summary notes on a paper on the radiolarian rocks the manuscript of which has now been nearly completed. Because a long bibliography is annexed to it, most of the references are omitted here. The field work for this research was carried out in cooperation with my students during the three years beginning in 1939 with a grant given to me from the Department of Education. Later the study was continued in my laboratory with Mr. Toshio Kimura, the cost for this part of research being defrayed by the grant for Scientific Research given to my section from the Department. These two short papers are presented in advance to the Academy by Prof. T. Kato to whom I here wish to express my indebtedness.

1) T. Kobayashi (1941), Some Facts on the Distribution of Radiolarian Cherts in Nippon. *Jour. Geol. Soc. Japan*, vol. 48.

2) T. Kobayashi (1941), The Sakawa Orogenic Cycle and its Bearing on the Origin of the Japanese Islands. *Jour. Fac. Sci. Imp. Univ. Tokyo*, sect. 2, vol. 5, pt. 7.

ner zone of West Japan which is rich in radiolarian cherts is a thick sediment within the Chichibu geosyncline later disturbed by the Ladinic Akiyoshi orogenesis. It is overlain by the Upper Triassic Mine and later formations with distinctly marked unconformity between them.

The Sambosan and Shimanto groups are similarly rich in radiolarian cherts and slates. The Sambosan on the inner side of the Butsuzo line comprises the Upper Palaeozoic Chichibu and the Togano of the

Map showing the Distribution of radiolarian rocks in the Western Pacific Regions.

Triassic as well possibly as of the Lower Jurassic age, the two formations being conformable and the latter being overlain by the Torinosu series. The upper or Nishigawa and the lower or Higashigawa series of the Shimanto group on the outer side of the line, roughly speaking, is the correlative of the Torinosu and Togano series respectively. The Sakawa orogenesis caused the Sambosan group to form a *Deckengebirge* together with Upper Jurassic and Lower Cretaceous formations while the Shimanto formed a *Faltengebirge*.

The Onizashi and Nakamura groups are also sediments of younger geosynclines folded later by Middle Tertiary orogeneses. According to Otatsume¹⁾ the Onizashi group in Hokkaido is mostly composed of schalstein. Cherts are especially common in its upper part and some lenses of limestone yield fossils known from the Torinosu and Lower Cretaceous Monobegawa series. It lies conformably beneath the Albio-Aptian Lower Ammonites beds, but its relation to the Upper Palaeozoic Hidaka formation is as yet undetermined.

The Nakamura group in the outer zone of West Nippon is almost barren of fossils. Exceptional occurrences of Senonian *Inoceramus* at Kunimi near Nakamura in Western Tosa and of some molluscan shells of the Oligocene Ashiya fauna in Hyuga show that it consists of Upper Cretaceous Kunimi and Palaeogene Nichinan divisions.

Because it has been well established that intimate relationship exists in our country between radiolarian rocks and geosynclines, and accordingly also between the rocks and orogenic zones, I looked into the literature on the subject to see if the same relation holds in other western Pacific regions. Available data which I have unearthed are compiled in the map inserted here.

The following facts emerge from a glance at the map:—

- 1) The Older Palaeozoic radiolarian rocks for which a new name, *Heathcotian suite*, is proposed here, exist in southeastern Australia. Though they have not yet been thoroughly studied, they are known to be mostly Cambro-Ordovician²⁾ and partly Gotlandian. Radiolarian slate in the Upper Gotlandian Takainari series is a sole representative on the Asiatic side that I know.
- 2) The Devonian *Tamworthian suite*, also a new term, is well represented in Eastern Australia and has been studied by Hinde while the Permo-Carboniferous *Yamaguchi suite* is distributed from the inner zone of West Nippon to the environs of Chabarowsk in the Mongolian geosyncline³⁾. Lydites of the Annamian facies contained in the Devonian and Carboniferous formations in Indochina is intermediate in age between the preceding two. It is interesting to see that the orogenesis of the Uralian Sakamoto phase was

1) T. Otatsume (1940), Stratigraphic Relation of the Schalstein Formation with the Lower Ammonite Beds in Central Hokkaido. *Rep. Geol. Comm. Hokkaido*, no. 10.

2) T. Kobayashi (1941), On the Ordovician Shelly Faunas in Southwestern Pacific Province. *Japan. Jour. Geol. Geogr.* vol. 17.

3) T. Kobayashi (1942), The Akiyoshi Orogenic Cycle in the Mongolian Geosyncline. *Proc.* **18** (1942), 306.

stronger in Indochina than in Nippon, in accord with the fact that the chert-bearing formation is older in the former than in the latter.

- 3) The *Sambosan* and the *Higashigawa* suites, the former of which is mostly Permo-Triassic or at least in a range from Carboniferous to Lower Jurassic, and the latter of which is of the Triassic age or thereabout, is extensive in the Sakawa orogenic zone. In the inner Malayan zone the suites are well represented in the chert series in the Malayan peninsula, the Tuhur in Sumatra, and the Danau in Borneo. This last was at first suggested by Hinde to be Jurassic, but it is now thought to be mostly Permo-Triassic. Krekeler's observation that the Danau lies between the *Monotis salinaria* horizon and the Fusulinid limestone in the Upper Sekajam river district is the important basis of that opinion.

The facies of Danau appears to enter, by way of the Palawan and Jolo or Sulu arcs, into the Philippines where the formation containing radiolarian cherts is called Babuyan. No fossil evidence has for long been obtained in the islands, at least not sufficiently to enable the determination of the age of pre-Tertiary formations, until Villa's recent discovery of the fossils of various ages from Liassic to Malm in a sandstone and shale formation in Mindro. While this fact is seen in conjunction with the similarity of facies between the Babuyan and Danau formations, it can be said that the Babuyan most probably lies below rather than above this Jurassic formation.

Although the Sambosan suite is not well represented in Australasia, a limestone containing radiolarians together with *Globigerina* was found lately in Otago, New Zealand and considered to be either Triassic or Permo-Triassic by Benson and Chapman.

- 4) The best display of the Jurassic-Cretaceous *Naegawa* suite is found in the central range of Hokkaido; its occurrence in Northern Kamchatka is reported by Chabadow. The radiolarians are uncommon in the Cretaceous-Tertiary Nakamura group, though contained in a few limestones in the Kobotoke and Setogawa series which are members of the group.

To the South of Nippon radiolarian rocks are reported to occur in many islands of the outer Malayan zone in the sediments mostly Mesozoic but partly Tertiary among which the Ladinian one is the oldest. In Lampong district, Eastern Sumatra, as well as at Loh Oelo in Central Java they are found together with *Orbitolina* limestone in the same formation or complex. In the Indian peninsula Cretaceous radiolarians were lately found in cherts of the Niniyur stage in the Trichinopoly district and also in some limestones beneath the Deccan trap.

The Cretaceous-Palaeogene radiolarians are known from various places in Westlarian geosyncline, as boulders in the northwestern basin of Australia, in the coastal regions of Northern Australia and Papua of New Guinea among which Fanny Bay, Port Darwin, is the most famous locality. The so-called *Callaisses* in the

Eocene formation in New Caledonia may suggest their extension further to the southeast.

- 5) The limestones containing radiolarians and coccolithes in the Moluccan islands are Neogene or probably Pliocene; radiolarians are sometimes found contained in diatomaceous earths in Nippon and other countries.

In summarizing the salient facts known at present it can be concluded that the Heathcotean suite is confined almost exclusively to southeastern Australia where orogenesis took place at the time of transition from Gotlandian to Devonian while the Tamworth and Yamaguchi suites are distributed in the zones of Eastern Australia and Eastern Asia where the Akiyoshi cycle attained its spasmodic phase earlier in the former than in the latter. The Sambosan-Higashigawa suite is not well represented on the Australian side while a good display is found in the Japanese islands and the inner Malayan zone which reveal respectively the northern and southern wings of the *Sakawaiden*. The latter wing was oronized before the deposition of the *Orbitolina*-bearing Seberuang formation. For the history of the former the reader is referred to my memoir on the Sakawa cycle. It is a remarkable fact indeed that the ages when radiolarian rocks developed greatly on the Asiatic side are those in which they did not show much development on the Australian side, and vice versa.

The Onizashi, Nakamura and younger suites are mostly distributed outside of the Mesozoic and older orogenic zones of Asia and Australia, although a part of them are found on the ancient continental masses. The geosynclines where the radiolarian rocks of these suites had deposited, were disturbed in the late Cretaceous, Middle Tertiary or Plio-Pleistocene phases.

Though not wholly, the major parts of these radiolarian rocks are contained in bathyal sediments of the Flysch type. The shifting of distribution of the radiolarian rocks in these pre-orogenic sediments in the geosynclines from the continental to the oceanic side, caused by orogenic cycles, indicates the advance of oronization toward the Pacific basin.