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Geologic Structure of the Riukiu (Loochoo) Curve, and its Relation to the Northern Part of Formosa.

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With 5 Plates.

CONTENTS.

PART I.—Introduction.

The Riukiu Curve,† consisting of all the islands lying between Kyūshū and Formosa, belongs partly to the Riukiu Islands and partly to the Province of Ōsumi; and is in all respects very little known. As for the geology of these islands, no reconnaissance survey of them had been made prior to the trip, the results of which this paper embodies. On the other hand, Formosa, our new territory, has been studied by many geologists, and the results of their studies have been partly published. Our Imperial University has sent in the last five years several naturalists to Formosa. Among them were Profs. B. Kotô and M. Yokoyama, who made geological observation, the former in 1897 and the latter in 1898. I was sent to visit Riukiu and Formosa, for the purpose of ascertaining their geological connection. After a trip of about one month in the northern part of Formosa, I spent nearly half a year (from July to December 1899) in travelling through the Riukiu Islands. With the kind assistance of the officers of the Okinawa Prefecture (the local government of Riukiu), I was able to visit nearly all the islands, which are about 65 in number. Only Kume-jima, Aguni-jima, Tonaki-jima, Tori-shima, the Iheya subgroup, the very small uninhabited islands, and some islands in the Kerama subgroup have not been studied. All of these, however, have been visited by others, who have furnished me

† This name has been proposed by Prof. B. Kotô. (*The Journal of the Geol. Society of Tōkyō* Vol. V, No. 49, 1897.)

with geological specimens and information, either published or in manuscript. Mr. T. Kuroiwa visited the islands of Kume, Aguni, Tonaki, and the Iheya subgroup, and his notes in part appear in "*The Journal of the Geological Society of Tōkyō.*" The uninhabited islands lying at a distance from other islands of the Riukiu Curve have been examined, formerly by the Prefectural officers, and also by Japanese and foreign naval officers, and recently by Messrs. M. Miyajima and Kuroiwa. In travelling through Okinawa-jima, I was with Prof. Yokoyama, who gave me many kind suggestions respecting my investigations. After having furnished my observations in the Riukiu Islands, I spent about three months in crossing through the Ōshima group, visiting all members of the group except a few islets. The geology of the islands lying between the Ōshima group and Kyūshū has been treated in Mr. K. Nishiwada's work on Yaku-shima and Tanega-shima, which was published in "*The Journal of Geography, Tōkyō*" (1895). The Tokara group has been visited by Mr. M. Yamagami; while the structure of a few remaining islands can be seen in the General Geological Map of Japan (1:1.000.000) published in 1900 by the Imperial Geological Survey.

As to the northern part of Formosa, Gordon, Jones, Richthofen, Swinhoe and Tyzack have written geological notes. Messrs. Y. Ishii, K. Inoue and Y. Saitō have successively worked as chief geologists to the local government of Formosa. The valuable reports of these three observers have been published in Japanese.

The present paper will treat of the geology of the northern part of Formosa and of the islands lying between Formosa and Kyūshū. The results of my study of the raised coral reefs in Riukiu and Ōsumi is embodied in another note.

My sincere thanks are due to Prof. Jimbō who has with great kindness given me his help in the revision of this paper.

PART II.—Literature.

Our first knowledge of the natural history of the Riukiu Curve is due to the expedition of an American squadron in the years 1852, 1853 and 1854, under the command of Commodore M. C. Perry. The topographical survey was limited to Okinawa-jima, and the geological descriptions were made chiefly by R. G. Jones (Report made to Commodore Perry of a Geological Exploration &c. of the Island of Great Lewchew.——*Narrative of the Exp. of an Am. Squadron to the China Seas and Japan &c.* Vol. I p. 184 & Vol. II p. 53). He states: "Commencing at the southern end, we have uniformly an aluminous rock, sometimes pretty compact, and sometimes running into shale; from it comes all the clay or common soil of this part of Lew Chew. This rock or clay is pierced and overlaid by limestone running N about 60°E, and rising to pinnacled ridges, so as to deceive the eye at the distance of only a few hundred feet. About 17 miles north of Napha, a very coarse gneiss begins to make its appearance, and soon becomes the prevalent rock, overhanging the sea-shore in bluffs of most contorted stratification, or running out in great ledges of jagged forms. The limestone is, however, seen yet occasionally, running slantingly across the island, in broken ridges, as before. At the village of Nacumma, on the west side of the island, say 42 miles north of Napha, we come to a small extent of granite hills, piercing through the gneiss. It is the only granite that I have seen on the island..... Beyond this, the gneiss begins to be mixed up with strata of clay-slate, to which it at length entirely gives place; and at Farnigi, 45 miles north of Napha, on the promontory of Fort Melville, we come to a coarse conglomerate, which gives us the first promise of a possibility of coal. The conglomerate soon passes into a coarse, and then into a finer sandstone. The slate and sandstone continue as we

advance northwardly, and at 7 miles from Farnigi, or 62 miles from Napha, we come to some outcroppings of the black bituminous slate, &c."

Furet has studied the fossils in the limestone and clay in the southern part of Okinawa-jima (Die Physikalischen Verhältnisse der Lutschu-Inseln.—*Petermanns Mittheilungen*, 1860, p. 156) and found in the limestone near Napha (Naha) and Tkiatung (?) the following eleven species:

Hemicidaris sp,
Pecten sp,
Pholadomia sp,
Perna sp ?,
Avicula sp ?,
Fusus sp.
Pecten aequivalvis,
Pecten quinquicostatus ?,
Isocardium sp,
Terebratula obovata,
Cerithium nudum,

He also mentions the following nine species as taken from the clay in the south of Napha:

Oliva clavula,
Pectunculus aequivalvis,
Arca sp,
Spondylus sp,
Ostrea marshii.
Natica cepacea,
Ostrea flabelloides,
Fusus neocomiensis,
Plicatula sp,

He seems therefore to have regarded the formation as belonging to the upper part of the Mesozoic group.

A long time after the publication of the above two works, Prof. Döderlein* in 1880 made a two-weeks trip to Ōshima (in the Ōshima group). He started from Nase on the west coast on August 16th, and first travelled on foot through the island over Yuwan, Nagara and Kují, following the shortest route. He then passed over to the next island,

* Die Liukiu-Inseln Amami Ōshima.—*Mittheilungen der deutschen Gesellschaft für Natur—und Völkerkunde Ostasiens*. Bd. III, 1880—1884, p. 103.

Kakeroma-jima, where he stayed a week on account of bad weather, and returned to Koniya in Ōshima. Then he went through Akina, Ichi, Gusuku and Asato, and returned to Nase on August 30th. According to his observations, the island consists of Archean rocks, which are chiefly granulite and gneiss. Only a small exposure of granite was found. There was also a bluish black clay slate at Cape Isisaki near Ichi, and a thin horizontal bed of recent (?) conglomerate at the harbour of Nase. He also explained the double-row structure of the islands in the *northern part* of the sea between Formosa and Kyūshū. The outer row including Tanega-shima, Yaku-shima, Amami-Oshima, Tokuno-shima and Okinawa-jima is sedimentary, while the inner row consisting of Kume-jima, Tori-shima, Linschoten, Erabu-jima, Kose-jima, Yuo-jima and Tage-shima is entirely volcanic. This was mentioned by E. Suess in his "Antlitz der Erde, Bd. II., 1888, p. 219;" and he remarked that the Riukiu Group might possess the same structure as the Antilles, Banda, Nicobar and Andamān.

With the exception of the above mentioned authors, I have failed to find any foreign geological observers, who have studied the geology of the Riukiu Curve. The islands have not been much visited on account of their lack of facilities for travel in their interiors, and also because of the presence of dangerous snakes and fevers. A very rough geological note with a map of the two groups, Okinawa and Saki-shima, was published by Mr. T. Kada in "*The Journal of the Tōkio Geographical Society*, 7th year, No. 5, 1885." A brief topography of the same islands has been written by Messrs. Kuroiwa and Nakayoshi. Mr. Kuroiwa's "General Geological Observations in Kume-jima and Ishigaki-jima" is found in "*The Journal of the Geological Society of Tōkyō*, Vol. V. No. 59, 1898 and Vol. VII, No. 71, 1899"; that of Tanega-shima and Yakushima by Mr. Nishiwada in "*The Journal of Geography, published by the Tōkyō Geographical Society*, Vol VII, No. 81,

1895." Summarizing the results of the above mentioned works together with several others, Prof. Kotô made a description of the geotectonics in his "Geological Structure of the Riukiu Curve" (*Journ. Geol. Soc. Tōkyō*, Vol V. No. 49, 1897). He found in this curve *three* parallel rows of islands. The inner row, being the same as that of Döderlein consists entirely of neovolcanic rocks. In the middle row, of Palæozoic or older rocks, are found Yaku-shima, Ōshima, Okinawa-jima, Ishigaki-jima and Iriomote-jima, besides other small islands. The outer row, of Tertiary and Quaternary sediments, is found by the following islands, viz., Tanega-shima, Mage-shima, the southern part of Okinawa-jima, the islands lying east of Okinawa, and finally Iriomote-jima and Yonaguni-jima. According to Prof. Kotô, the characteristic arrangement of the rocks is probably due to the great depression of Tunghai (the "Eastern Sea" of China), and a curved fissure extending for several hundred miles between Kyūshū and Formosa.

On the north of Formosa and far to the north-west of the Yae-yama subgroup, there lie a few small, barren and uninhabited islands. Among them the Pinnacle group, consisting of Waheizan or Chō-gyotō* (Hoa-pin-su), Kōbitō (Chia-u-su), Pinnacle and Raleigh rocks, belongs to the Okinawa Prefecture. The hydrographical as well as topographical survey of these islands has been made by many foreign and Japanese ships. Recently Messrs. M. Miyajima and T. Kuroiwa have reported respecting their situation, topographical features, &c. in "*The Journal of Geography, Tōkyō*, Vol. XII, No. 141, 1900 and Vol. XII, No. 144, 1900." Other islands lying nearer to Formosa are Agincourt Is., Crag Is. and Pinnacle Is. A rough geological and topographical note of these islands is found in "The China Sea Directory, Vol. III, 1894." Mr. Y. Saitō has visited the Crag and

* Among Japanese, the two names Hoa-pin-su and Chia-u-su have been confused and the Chinese characters 釣魚嶼 are incorrectly read Hoa-pin-su and 黃尾嶼 Chia-u-su.

Pinnacle islands† and found them to be entirely basaltic andesite. In Crag Is. the andesite is found in the form of lavas, dykes, ashes and breccias. According to the petrographic examination by Prof. Kotô, Agincourt Is. has hypersthene-basalt and hypersthene-andesite.

As to the geology of Formosa we have a number of notes. The coal-mines are mentioned in the following:—

Gordon, Observations on Coal in the N.E. part of the Island of Formosa—*Journal Roy. Geogr. Soc.*, Vol XIX, 1849, p. 22).

Jones, Report made to Commodore Perry of a visit to the Coal Regions of the Island of Formosa.—Narrative of the Exped. of an Amer. Squadron to the China Seas and Japan &c. Vol. II, 1856, p. 153.

Tyzack, Notes on the Coal-field and Coal-mining Operations in N. Formosa.—*Trans. North of Engl. Institute of Mining and Mechanical Engineering*, Vol. XXXIV, 1884, p. 67.

The geology of the neighborhood of Kōbi and Kiirun is in

Richthofen, Über den Gebirgsbau an der Nordküste von Formosa. —*Zeitschr. Deutsch. Gesell.*, XII Band, 1860, p. 532.

The determination of the age of the sediments of the neighborhood of Kiirun, by the fossils collected by Tyzack, is found in

Lebour, Notes on some Fossils from N. Formosa.—*Trans. North of Engl. Institute of Mining and Mechanical Engineering*, Vol. XXXIV, 1884, p. 67.

The principal facts gathered from these authors are as follows: There are, besides the Liassic deposit, two Tertiary formations, probably different in age. The older one with characteristic *Echinodiscus* is Miocene, and consists of a bluish shale, with clay and finegrained brownish sandstone. Coal-seams, especially those near Kiirun, appear to extend from east to west. Fossils found near Hokuto are *Ostrea*,

† 基隆沖無人島踏査報文 (Report on a Trip to the uninhabited Islands lying off the coast of Kiirun, 1900., *in Japanese*).

Lutraria (?), *Cardium* (?) and *Echinodiscus*. According to Richthofen, trachyte with its tuff and agglomerate, is found in the north-east and south-west of Kōbi, near Daiton-zan and Kwannon-zan ; and composes the foundation of the environs of Kōbi. Here a quite horizontal tuff predomates and forms the vast plateau onthe south-west of Kōbi. Porphyrite hills are found, according to Tyzack, at Daiton-zan and Kiirun-zan.

The more careful geological observations and microscopic studies by Japanese geologists, show these inferences to have been mostly incorrect. The igneous rocks of Daiton-zan, Kwannon-zan, Kiirun-zan and others, are proved to be not trachyte but andesite; and there has been found no trachyte tuff. The rocks of the vast plateau near Kōbi is nothing else than laterite.

Mr. Y. Ishii published in 1897 a reconnaisance map of Formosa with an explanatory text in Japanese.* Except the doubtful occurrence of gneiss, he found all the oldest rock to be crystalline schists, extending from the eastern side of Mount Sylvia up to the north-west of Pinan. A crystalline limestone, probably Palæozoic, is observed along the western side of this schistose belt, and extends from the east of Sessan to the north-west of Pinan. A clay slate of unknown age occupies a very wide area, between Tōi, north of Giran, and Bōryō near the southern end of Formosa. The main skeleton of the island, thus formed by the schists, limestone and clay slate, has been called the "Taiwan mountain system" by Mr. Ishii. The clay slate seems to surround the region of schists and limestone. The Tertiary sediments which overlie the clay slate without any discordance, are developed along the northern, western and southern sides of the principal range, as well as the middle of the eastern coast. Those in the northern part

*台灣島地質鑛產圖說明書 (Explanatory Text to the Map of Formosa, showing Geology and Mineral Resources).

are composed of coarse-grained sandstones with shales, and contain many coal-seams and limestone layers. Raised coral reefs are found only near the southern end of the island, and are rather limited in extent; their formation appear to have continued from the Tertiary up to the Recent time. Quaternary sediments usually without coral reefs compose the vast plateau along the whole western coast, which is about one-fourth as wide as the island itself. As to the igneous rocks, Mr. Ishii has found granite near Sessan, and diorite near Niitaka-yama (Mt. Morrison). The serpentine exposed on the north of Pinan and on the west coast of Kōtō island, is probably a metamorphosed Tertiary gabbro. Andesites are exposed: (1), on the northern end of Formosa, as at Daiton-zan, Kwannon-zan, Kiirun-zan and the adjacent hills; (2), on the eastern coast, near Shūkorankei and on the north of Pinan; and (3), on the islands of Kōtō and Kwashō, off the south-east coast. The numerous islands of the Hōko group are almost all basalt. In Formosa, all the strata, older than Quaternary, are steeply inclined, but the strike is almost always parallel to the longitudinal axis of the island. There have probably existed great fissures along the eastern side, running parallel to this axis; as is partly indicated by the occurrence of volcanic rocks on the islands of Kōtō and Kwashō and on the north of Pinan. Besides the general geological note, above summarized, Mr. Ishii has given in the same note many valuable descriptions of the mining products of the island.

Messrs. K. Inoue and S. Yokoyama have also written about the geology of Formosa. Recently Mr. Saitō has published his geological sketches of the Zuihō and Kinkwaseki mines, in which he mentiones that the two hills Kiirun-zan and Kinkwaseki-zan are formed of andesite dykes erupted through Tertiary sediments. Mr. R. Yamashita † has, under the direction of Mr. Saitō, examined a number of

† 台灣北部煤田 (Coal-seams in the north of Formosa, 1900; *in Japanese*).

coal-seams, their relations, and various profiles of Tertiary rocks.

All the above works have been specially consulted in writing this paper. There are, besides, notes by the foreign writers. Corner, Guppy, Beazeley and Kleinwächter, giving the results of their observations chiefly in the region south of Takao; also the reports by the Japanese geologists, Prof. Kotô, and Messrs. Ishii, Inoue and Saitō. In Prof. Kotô's work,* there are very valuable petrographical notes on the Hōkō group and the Kwashō and Kōtō islands. Mr. S. Yamasaki, who has travelled with Prof. Kotô, has also written about our present knowledge of the island in "*Petermann's Mittheilungen*, XLVI Band, 1900, X, p. 22." § Prof. J. Rein also spoke ‡ upon the same subject at the 'Niederrheinischen Gesellschaft für Naturkunde zu Bonn.'

PART III.—Geology of the Islands in the Riukiu Curve.

The Riukiu Curve consists of many groups of islands. Counting from the southern end, we have those of Saki-shima, Okinawa and Ōshima; then a row of small islands, collectively called Tokara and lying on the north-west of Ōshima; and finally the Ōsumi group with a few islands (such as Yaku-shima and Tanega-shima) between Tokara and Kyūshū.

I. THE ŌSHIMA GROUP.

This group includes Ōshima, with its numerous dependent islets, Kakeroma-jima, Edato-jima, Ikeji-jima, Yoro-jima, Sukomo-banare,

* Notes on the Geology of the dependent Isles of Taiwan.—*Jour. Coll. Sci. Imp. Unv., Tōkyō*, Vol. XIII, Part. I, 1899, p. 1.

§ Ueber geographischen Kenntnisse von der Insel Taiwan (Formosa).

‡ Die physische Geographie von Taiwan (Formosa).—*Sitzungsberichte der Niederrheinischen Gessell. für Natur-und Heilkunde zu Bonn*, 1900, I Heft, p. A. 21.

Yū-banare, Eniya-banare, Kerama-jima and Hashiya-jima, and also Kikaiga-shima, Tokuno-shima, Okinoerabu-jima and Yoron-jima.

Ōshima and its Dependent Islets. Ōshima, one of the largest islands in the Riukiu Curve, has a great many indentations in its coast which is about two hundred miles in length. The interior is entirely mountainous except on the small northern peninsula. There are inhabitants only on this flat part and on the small plains at the openings of river valleys. The highest peak, Yuwan-dake is near Yuwan in the southern part and has an elevation of 2300 ft. The northern half of the island is elongated parallel to the trend of its principal hill-range which runs NE to SW. But in the southern half, the ranges are transverse to the length of the island. There are two remarkable parallel ridges in the western part running eastward, one from Sokkō-zaki, and the other from Edato-jima. They are separated by a very narrow inlet opening toward the west. The island of Kakeroma, on the south of the island of Ōshima, is also elongated parallel to these two ranges. The narrow channel between the last two islands is called Ōshima-kaikyō or Setouchi. The sea around Ōshima and the adjacent islands is very deep and there are many good anchorages.

All these islands are almost wholly composed of Palæozoic sediments, with very limited occurrences of old eruptives. Raised coral reefs, with intervening sandy layers, occupy only small areas in the northern corner of Ōshima.* The Palæozoic rocks are chiefly clay slate and sandstone, while slaty sandstone is also common. Tuff-pyroxenite with amphibolite was rarely observed in the island of Ōshima. Compared with the island of Ōkinawa, which also consists chiefly of Palæozoic rocks, we find a great resemblance in tectonic and petrography; but in the latter the pyroxenite

* Yoshiwara, Notes on the Raised Coral Reefs in the Islands of the Riukiu Curve.—*Journ. Coll. Sci. Imp. Univ., Tōkyō*, Vol. XVI, Art 1, 1901.

or amphibolite is more extensive, though it is only next to clay slate and sandstone in distribution. The sandstone of the island of Ōshima is often highly siliceous, thus taking the appearance of quartzite. A very compact, white or red quartzite occupies large areas in the island, though restricted to the western part. Schalstein, associated either with compact quartzite or with other rocks, is found on the road form Toen to Naon, Konase to Atetsu, Shodon to Nomi-san, Akitoku to Osai, Setake to Kuji, Naze to Aira, Yanyū to Akaoki, Aira to Ikuzato, and south of Yamatohama; it is of very small extent and is always destitute of fossils. Palæozoic limestone is not rare; it is found in thick layers between Imazato and Uken, and in small lenticular masses in other rocks at Yui, Sokkō-zaki, Adachi and Sukomo, and near Setake and Yamma. The limestone is all crystalline and without fossils. The following is an abstract of my field note, showing the general stratification of the Palæozoic rocks :

Ōshima.

	Strike.	Dip.	Kinds of rocks.
From Naze to Koshiku.			
Naze—Asani	N—S	W 25	Slaty sandstone.
	N 20 E	N W 30	,,
	N 30 E	N W 35	Quartzose sandstone with a little slate.
	N 40 E	N W 50	,,
	N 40 E	N W 20	,,
Asani—Koshiku	N 40 E	N W 20	Chiefly sandstone.
From Koshiku to Yamatohama.			
Koshiku—Chinase	N—S	W 30	Slate.
	N 40 E	N W 45	Sandstone.
Chinase—Yuwangama	N 20 W	S W 30	Chiefly slate.
	N—S	W 50	Slate and sandstone.
Yuwangama—Yamatohama	N 20 E	N W 45	,,
	N 20 E	N W 70	,,
From Yamatohama to Uken.			
	N 60 E	N W 25	Slate and quartzose sandstone.
Yamatohama—Ōdana	N 40 E	N W 25	,,
	N 60 E	N W 40	,,
Ōdana—Toen	variable, but never inclined toward E.		Slate and compact quartzite.
Toen—Naon	N—S	W 25	Schalstein.
	N 10 E	N W 40	Compact quartzite.
	N—S	W 40	,,
Naon—Shitokan	N 30 E	N W 40	,,
	N—S	W 30	,,
			Porphyrite dyke.
	N 30 E	N W 35–55	Compact quartzite with thin layers of slate.
Imazato—Uken	variable		Limestone with thin layers of slate and compact quartzite.
	N—S	W 30	Slate.
From Uken to Yuwan.			
Uken—Kuji	variable		Slate and sandstone.
	N 40 E	N W 50	Slate.
Kuji—Ikegachi	N—S	W 35	,,
Ikegachi—Ashiken	N 30 E	N W 45	,,
	variable		Compact quartzite.
	N 30 E	N W 30	Slate.
Ashiken—Taken	variable		Alternations of thin slate and sandstone.
Taken—Yuwan	variable		Sandstone.
	N 30 E	N W 40	Alternations of sandstone and slate.
From Yuwan to Yamatohama.	N—S	W 80	,,
	N 40 E	N W 30	,,
	N 30 E	N W 40	Compact quartzite with thin layers of slate and sandstone.
	N 40 E	NW 30	,,
	N—S	W 30	,,
	N 30 E	N W 40	,,
	N—S	W 40	,,
	N 50 E	N W 30	,,
From Yamatohama to Nishinakama.			
	N 35 E	N W 40	Slate and sandstone.
	N 10 E	N W 60	,,
	N—S	W 30	,,

	Strike.	Dip.	Kinds of rocks.
			Schalstein,
	N 10 E	N W 40	Slate and sandstone.
	N 20 E	N W 25	,,
	N 40 E	N W 30	,,
	N 50 E	N W 20	,,
	N—S	W 40	,,
	N 10 E	N W 40	,,
	N 25 E	N W 45	,,
From Nishinakama to Yuwan.			
Nishinakama—Yakkachi	N 10 E	N W 55	Slate.
	N 40 E	N W 65	,,
	N 20 E	N W 45	,,
Yakkachi—Suko	N 40 E	N W 70	Quartzose sandstone.
	N 10 E	N W 55	Slate.
	N 30 E	O W 55	,,
	N—S	W 30—65	,,
	N 30 E	N W 40	,,
Suko—Yuwan	N 40 E	S E 50	Alternations of thin slate and quartzose sandstone.
From Yuwan to Yadon.			
Suko—Buren	N—S	W 45	Sandstone and quartzose sandstone.
	N 20 E	S E 50	,,
Buren—Nagara	N 50 E	N W 35–65	,,
	N 50 E	S E 40	,,
	N 50 E	N W 45	,,
Nagara—Sanen	N 40 E	N W 55	Slaty sandstone.
Sunen—Heta	N 40 E	N W 30–45	Slate.
	variable		Compact quartzite.
	N 40 E	N W 60	Slate, quartzose sandstone and quartzite.
Heta—Amuro			Quartzose sandstone.
Amuro—Yadon	variable		Compact quartzite with very little limestone.
From Yadon to Nishikomi.	N 40 E	N W 40	Compact quartzite with a little slate.
From Nishikomi to Sokkō-zaki.	N—S	W 40	Quartzose sandstone and slate.
	variable		Compact quartzite with very little slate and quartzose sandstone.
From Nishikomi to Kuji.			Limestone.
Nishikomi—Kudadon	variable		Alternations of compact quartzite, slate and sandstone.
	N—S	W 40	Pyroxenite.
	N 40 W	S W 40	,,
Kudadon—Keten	N—S	W 40—45	Slate and quartzose sandstone.
Keten—Kuji	N—S	W 40	Sandstone.
From Kuji to Koniya.			
Kuji—Koshi	N—S	W 40	Sandstone.
	variable		Slate and bluish sandstone.
Koshi—Shinokawa	N 20 E	N W 50	Slate.
	N 40 E	N W 35	Alternations of thin slate and quartzose sandstone.
	N—S	W 30	,, ,, ,,
Shinokawa—Amurogama	N—S	W 35	,, ,, ,,
Amurogama—Konase	N 30 E	N W 40	Slate, quartzose sandstone and bluish sandstone.
	N 40 E	N W 40	,, ,, ,,
	N 30 E	N W 50	,, ,, ,,
Konase—Atetsu			Schalstein.
	N—S	E 40	Bluish sandstone.
	N—S	W 40	,,
	N—S	E 40	,,

	Strike.	Dip.	Kinds of rocks.
Atetsu—Yui	N 10 E	N W 45	Bluish sandstone.
	N 70 W	N E 35	Quartzose sandstone.
	N 60 W	N E 35	Alternations of sandstone and slate.
Yui—Kunezu	N 50 W	N E 50	Limestone with a little compact quartzite.
	N—S	W 50	Sandstone and slate.
	N 50 E	N W 30	,,
Kunezu—Tean	N 40 E	N W 30-45	Slate.
	N—S	W 70	,,
Tean—Koniya	N 30 E	N W 50	Slate, sandstone and quartzose sandstone.
	N 40 E	N W 40	,, ,, ,,
	N 10 E	N W 30	,, ,, ,,
	N—S	W 40	,, ,, ,,
	N 20 E	S E 20	,, ,, ,,
From Koniya to Akina (along the sea).			
Koniya—Seisu	N 40 E	S E 50	Sandstone.
	N 30 E	S E 55	Quartzose sandstone.
	N 60 E	vertical	Compact quartzite.
	N 10 E	S E 75	Sandstone and quartzose sandstone.
Seisu—Katetsu	N 50 W	S W 20	Sandstone and slaty sandstone.
Katetsu—Isu	N 10 E	N W 60	Quartzose sandstone.
			Sandstone.
Isu—Akina	N 30 E	N W 40	Sandstone, quartzose sandstone and slate.
	N 30 E	vertical	,, ,, ,,
	N 40 E	N W 80	,, ,, ,,
	N 30 E	N W 30	,, ,, ,,
From Akina to Sekko			
Akina—Katsuura	N 30 E	N W 45	Alternations of slate and quartzose sandstone.
Katsuura—Aminoko	N 20 E	N W 55	Slate with a little quartzose sandstone.
			Slate.
			Compact quartzite.
	N—S	W 45–80	Slate.
			Quartzose sandstone.
From Akina to Yamma			
Katsuura—Yakkachi	N 20 E	N W 40	Quartzose sandstone.
	N 10 E	N W 30	Alternations of slate and quartzose sandstone.
	N—S	W 30	Quartzose sandstone.
	N 30 E	N W 40	,,
	N—S	W 40	Slate.
Yakkachi—Yamma	N 30 E	N W 40	,,
	N—S	W 30	,,
	N 20 E	N W 50	Alternations of quartzose sandstone and slate.
From Yamma to Katoku			Quartzite and quartzose sandstone.
	N—S	W 55	Slate.
	N—S	W 70–80	Alternations of quartzose sandstone and slate.
From Katoku to Ichi			
Katoku—Ao	N—S	W 50	Slate.
			Quartzose sandstone.
	N—S	W 60	Slate.
	N 20 W	S W 55	,,
			Quartzose sandstone.
	N 20 E	N W 80	Slate.
	N 20 W	S W 50–60	,,
			Quartzose sandstone.

	Strike.	Dip.	Kinds of rocks.
Ao—Ichi	N 30 E	N W 35	Quartzose sandstone. Quartzite. Granite.
From Ichi to Yamma			
Ichi—Todama			Granite. Quartzose sandstone and quartzite.
Todama—Yamma	N 20-30 E	N|W 35-65	Quartzite. Alternations of slate and quartzose sandstone.
From Yamma to Nishinakama			
Yakkachi—Nishinakama	N 20 E	N W 40	Quartzose sandstone and slate.
From Nishinakama to Gusuku			
Nishinakama—Higanakama	N 10 E	N W 35	Alternations of slate and quartzose sandstone.
	N 40 E	N W 20	,,
	N—S	N W 35	,,
	N 10 E	N W 65	Bluish sandstone.
	N—S	W 25	,,
	N 30 E	N W 60	,,
	N—S	W 45	,,
Higanakama—Gusuku			Slate, quartzose sandstone and bluish sandstone.
From Gusuku to Kominato.			
Gusuku—Nishinakagachi	N 20-30 E	N W 20-55	Alternations of slate and quartzose sandstone.
Nishinakagachi—Kominato	N—S	W 35	Alternations of slate, quartzose sandstone and bluish sandstone.
From Kominato to Ōgachi.			
Kominato—Toguchi	N 30-40 E	N W 25	Alternations of slate, sandstone and bluish sandstone.
	E—W	N 40	
	N 70 E	N W 30	
	N 60 E	N W 60	
	N 40 E	N W 40	
	N 20 E	S E 20	
	N 30 W	N E 35	
	N 20 W	S W 5	
	E—W	N 30	
	N—S	W 50	
	N 30 W	S W 30	
Toguchi—Ōgachi	N 30 W	S W 60	Slate.
	N 20 E	N W 50	,,
From Ōgachi to Akaoki			
	N—S	E 35	Alternations of quartzose sandstone and slate.
	E—W	N 35	,, ,, ,,
	N 10-20 E	N W 35-50	,, ,, ,,
From Akaoki to Tekebu.			
Akaoki—Kise	N 30 E	N W 30	Alternations of slate, quartzose sandstone and bluish sandstone.
	N—S	W 35-80	,, ,, ,,
	N 10 E	N W 80	,, ,, ,,
	N—S	W 50	,, ,, ,,
Kise—Tekebu			Quartzose sandstone.
From Akakina to Kasari.			
Akakina—Kawakami	N 20 E	N W 55	Quartzose sandstone and slate.
	N 40 E	N W 50	,,
	N 20 E	N W 40	Slate.
	N—S	W 55	,,
			Schalstein.

	Strike.	Dip.	Kinds of rocks.
Kawakami—Yani	N 20 E	N W 25	Slate.
Yani—Kutsuno	N 30 E	N W 25	„
			Quartzose sandstone.
Kutsuno—Sani			„
	N 30 E	N W 30	Slate.
			„
Sani—Yō	N 70 E	N W 30	Alternations of slate and quartzose sandstone.
From Kasari to Akaoki.			
Kasari—Beru			Quartzose sandstone.
Beru—Suno	N 20 E	N W 65	„
Suno—Ushuku	N—S	W 55	Quartzose sandstone, slate and quartzite.
	N—S	E 60	Quartzose sandstone.
Banya—Setta	N 30 E	N W 70	„
	N 40 E	S E 40	„
Setta—Yoan	N 30 E	N W 40	Alternations of sandstone, quartzose sandstone and slate.
	N—S	W 70	Diorite.
			Slate.
Yoan—Akaoki	N 20 E	N W 60	Quartzose sandstone with a little slate.
	N 10 E	N W 50	„ „ „
From Akaoki to Tatsugō.			
Akaoki—Ashitoku			Slate.
Ashitoku-Yaniu	N—S	E 30	
	N 10 W	N E 30	„
			„
	N—S	E 35	Slate with sandstone and quartzose sandstone.
	N 20–30 W	S W 40	„ „ „
	N—S	W 40	
	N 20 E	N W 30–35	„ „ „
	N 20 W	S W 30	„ „ „
Yaniu—Sekerube	N 30 E	N W 50	Slate.
			Quartzose sandstone.
Sekerube—Kuba	N 40 E	N W 35	Slate with a little quartzose sandstone.
	N 20 E	N W 60	„ „ „
Kuba—Tatsugō			Quartzite with slate.
From Tatsugō to Akina			
	N 30 E	N W 40	Slate with quartzose sandstone.
	E—W	N 35	„
	N—S	W 45	„
	N 20 E	N W 30	„
	N 20 E	N W 30	Alternations of slate and quartzose sandstone.
From Akina to Daikuma			
Akina—Ashikebu			
			Slate.
			Schalstein.
	N 20 E	N W 30	Slate with a little quartzose sandstone.
			Quartzose sandstone.
			Slate.
Ashikebu—Aira	N—S	W 20	„
			Schalstein.
Aira—Daikuma	N—S	W 50	Slate.
			Alternations of slate and quartzose sandstone.
	N 40 E	N W 50	Slate.
			Schalstein.

	Strike.	Dip.	Kinds of rocks.
From Daikuma to Naze.			
			Schalstein.
			Alternations of thin slate and quartzose sandstone.
			Schalstein.
	N 20 E	N W 50	Slate.
			Bluish sandstone and quartzite.
	N 20 E	N W 50	Slate.

Kakeroma-jima.

	Strike.	Dip.	Kinds of rocks.
From Oshikaku to Shodon			
Oshikaku—Kachiyoki			Slate.
	N—S	W 65	Alternations of slate and quartzose sandstone.
	N 20 E	N W 70	Slate.
	N—S	W 40–45	,,
	N 40 E	N W 50	Alternations of thin slate and quartzite.
Kochiyoki—Shokazu	N 40 E	vertical	Slate.
	N 50 E	N W 80	Bluish sandstone.
	N 50 E	N W 30	Slate.
	N—S	W 55	,,
	N 70 E	N W 50	Quartzose sandstone.
Shokazu—Ikema	N 40 E	N W 40–45	Slate.
	N 40 E	N W 40	Alternations of thin slate and quartzose sandstone.
Ikema—Doren	N 20 E	N W 70	Slate and quartzose sandstone.
	N 20–40 E	S E 30–60	,,
	N 40 W	S W 10	,,
	N 30 W	N E 60	,,
Doren—Shodon			Slate.
			Sandstone.
	N 30 W	N E 40	Slate.
	N 60 E	N W 45	Sandstone.
	N—S	W 40	,,
From Shodon to Akitoku			
Shodon—Nomisan	N 20 E	vertical	Slate and quartzose sandstone.
	N 20 E	N W 70	,,
	N 20 E	vertical	,,
	N 20–30 E	N W 70	Schalstein.
	N 30 E	N W 55	Slate.
	N 20 E	N W 45	,,
	N—S	W 35	Sandstone.
	N 30 E	N W 50	Bluish sandstone.
Nomisan—Akitoku			Slate.
	N 40 E	N W 30	Bluish sandstone.
			Quartzose sandstone.
From Akitoku to Nishiamuro			
			Schalstein.
Akitoku—Sachiyoki	N 40 E	N W 30	Slate.
	N 30 E	N W 35	,,
	N 50 E	N W 25	Quartzose sandstone.

	Strike.	Dip.	Kinds of rocks.
Sachiyoki—Osai	N—S	W 40	,,
	N 40 E	N W40	Quartzose sandstone and slate.
	N 60 E	N W 35	Quartzose sandstone.
	N 30 E	N W 45	Schalstein.
			Slate and quartzose sandstone.
	N 20 E	N W 50	Slate.
	N—S	W 40	,,
	N 20 E	N W 45	,,
Osai—Ikomo			Quartzose sandstone.
Ikomo—Kedomi	N—S	W 55	Slate and quartzose sandstone.
			Compact quartzite.
Ikomo—Nishiamuro	N 20 E	N W 30	Slate and quartzose sandstone.
			Compact quartzite.
	N 30 E	N W 55	Slate and quartzose sandstone.
From Nishiamuro to Shiba.			
Nishiamuro—Kaniu	N 20 W	S W 30-45	Compact quartzite.
			Slate.
	N 30 E	N W 50	Compact quartzite.
			,,
Kaniu—Sukomo	N 20 E	N W 60	Slate.
			Compact quartzite.
			Slate
			Compact quartzite.
	N—S	W 25	Limestone.
			Slate.
Sukomo—Adachi			Compact quartzite.
	N—S	W 35	Slate.
			Compact quartzite.
			Limestone.
Adachi—Saneku			Compact quartzite.
			Quartzose sandstone and slate.
			Compact quartzite.
			Bluish sandstone.
			Compact quartzite.
			Slate and quartzose sandstone.
			Compact quartzite.
Saneku—Shiba	N—S	W 50	,,
			Bluish sandstone.
	N 20 E	N W 45	Compact quartzite.
	N—S	W 45	Slate.
From Shiba to Satsukawa.	N 20 E	N W 45	Quartzose sandstone and slate.
From Satsukawa to Setake.	N 40 W	S W 50	Slate.
			Compact quartzite.
	N 20 E	N W 60	
	N 10 W	S W 50	Slate.
	N 10 E	N W 40	,,
From Setake to Oshikaku.			
Setake—Kiji			Limestone.
			Slate.
			Schalstein.
			Quartzose sandstone.
			Slate.
	N 40 E	N W 50	Quartzose sandstone.
			Compact quartzite.
Kiji—Takena			Slate.
	N—S	W 45	Compact quartzite.
Takena—Miura	N—S	W 35-45	Slate.
Miura—Hyō	N 30 E	N W 60	Alternations of slate and quartzose sandstone.
			compact quartzite.
	N 20 E	N W 55	Slate and quartzite sandstone.

	Strike.	Dip.	Kinds of rocks.
			Compact quartzite.
Hyō—Sesō	N 20 E	N W 60	Quartzose sandstone and slate.
			Compact quartzite.
Sesō—Oshikaku	N 20 E	N W 20	Slate and quartzose sandstone.

As shown in the abstract of my field notes, all the rocks dip steeply westward and are never horizontal. The strike is NE to SW which is nearly parallel to the line connecting the island of Ōshima with Tokuno-shima and Yoron-jima. The whole interior of the first island is mountainous; there is a plateau only on the northern end, which has been denuded and partially covered with raised coral reefs. A long narrow inlet with deep water, lying on the south of Edato-jima, is probably due to the formation of a fissure, perpendicular to the axis of the Ōshima group. There are greatly contorted strata as well as porphyrite eruptions on both sides of the inlet. The narrow and deep channel between Ōshima and Kakeroma-jima, probably of a similar origin, extends in the same direction as this inlet, and there is another porphyrite dyke on the northern coast of the western part. Besides the above mentioned three parallel dykes, exposed at Uken, Kuji, Ikegachi, Ashiken, Buren, Nagara, Sanen, Kudadon and Keten, there are three other dykes of the same porphyrite running generally NE—SW. They are found in Kakeroma-jima and on the road from Nagara to Keten in Ōshima. That exposed on the south of Naon is properly hornblende-porphyrite. No volcanic rocks are found in the islands; pre-tertiary eruptives are exposed chiefly near the eastern coast. Biotite-granite is found to have been erupted through the Palæozoic rocks near Yamma, as at Ichi, Todama and other villages. Diorite with a little granite is found near Tekebu on the northern corner of Ōshima.

Tokuno-shima. This island is elongated from north to south.

The high mountains in the interior consisting of Palæozoic rocks and plutonics, are surrounded by a vast plateau of Diluvial reefs, which is especially extensive in the southern part. The highest peak is Inokawa-dake which rises 2207 ft. above the sea-level. The Palæozoic rocks are chiefly clay slate, the same as that in Ōshima. Sandstone and quartzose sandstone are not uncommon, but pyroxenite or amphibolite is rarely found. Compact quartzite was never observed even in the form of fragments. All these rocks are regularly folded, but show several disturbances in contact with the plutonics.

	Strike.	Dip.	Kinds of rocks.
From Sanmura to Ketoku			
	N 30 E	N W 25	Slate.
	N—S	W 30	,,
	N 30 E	N W 25	,,
	N 20 E	N W 40	,,
			Sandstone and pyroxenite.
	N 40 E	N W 30	Slate.
From Ketoku to Bumo			
			Slate.
			Quartzite.
	N 40 E	N W 60	Slate.
	N—S	W 30	,,
	N 20 E	N W 55	Slate with a little quartzose sandstone.
	N—S	W 45	,,
From Shimokushi to Inokawa			Slate and sandstone.
From Kamezu to Omonawa	N 40 W	S W 40	Slate, sandstone and quartzose sandstone.
	N 20 W	S W 30-50	,,
Intabu-dake	N—S	W 30	Qartzite with a little slate.
From Shirai to Kamezu	N—S	W 30	Bluish sandstone and slate.
From Kamezu to Mikyō	N 40 E	N W 35	Slate.
	N—S	W 30	Bluish quartzose sandstone.
	N 20 E	N W 20	Slate.
			Serpentine.
	N 50 E	N W 40	Quartzose sandstone.
			Granite.
	N 50 E	N W 50	Quartzose sandstone and slate.
From Tōbe to Ketoku	N—S	W 30	Quartzose sandstone.
From Matsubara to Sanmura			
	N 40 E	N W 80	Greywacke sandstone.
Matsubara—Yonama	N 30 E	N W 60	Slate.
			Quartzose sandstone.
	N 30 E	N W 40	Slate.
	N 40 E	N W 45	,,
Tete—Kanami	N 60 E	N W 55	Quartzose sandstone.
	N 40 E	N W 55	Slate and quartzose sandstone.

	Strike.	Dip.	Kinds of rocks.
Kanami—Sanmura	N 60 E	N W 40	Slate and quartzose sandstone.
	N 40 E	N W 45	,,
	N 50 E	N W 35	,,
	N 60 E	N W 55	,,
	N 70 E	N W 50	,,
Amekidake	N 40 E	N W 30	Slate and quartzite.

The above list shows that, the general dip is NW and the strike NE to SW, as in Ōshima.

In the plutonics, there are various granites in different places, *e.g.*, I found biotite-granite at San-mura, and hornblende-granite on the road from Mikyō to Kamezu. Diorite is exposed over large areas, together with granite in the vicinity of Buma. Serpentines are found in some places, *e.g.* near Mikyō. Dyke rocks are not uncommon; quartz-porphyry is found on the west of Buma, at Shimokushi and Inokawa, and between Inokawa and Shoda, Yaezao and Shirai, Mikyō and Setaki. On the north of Ketoku, there is a porphyrite dyke with a strike N45°E. These pre-tertiary igneous rocks have disturbed, only at the line of direct contact, the Palæozoic strata which usually show regular dips. Thus the last tectonic disturbances in Tokuno-shima, Ōshima and other islands seem to have taken place long after their eruption, and certainly before the elevation of the reefs which are quite horizontal.

Okinoerabu-jima. This island is a table-land of Diluvial coral reefs with two peaks of Palæozoic rocks in the interior. The highest peak Ōyama has a height of only 687ft. above the sea-level. The island extends from NE to SW, which is also the direction of the axis of folding of the Palæozoic rocks. In the bluish quartzose sandstone of Ōyama, I have found the following stratifications:—

N30°E NW20° N45°E NW30° N—S W30°

The Palæozoic on the north-east of Ōyama is chiefly clay slate. In the eastern part of this region, a Palæozoic sandstone is pierced by a porphyrite dyke with a NE strike.

Yoron-jima. Though I have not visited this island, I am informed that it is very low and plateau-like, consisting mainly of raised coral reefs. As judged from a collection of rocks, there are in the interior limited exposures of Palæozoics, such as pyroxenite, sandstone and limestone.

Kikaiga-shima. This small island with a coast line of about 20 miles lies far to the east of Ōshima and Tokuno-shima. The longitudinal axis runs NE to SW, parallel to a line joining Ōshima with Yoron-jima. The interior is a flat table-land, with a maximum height of 684 ft. above the sea-level. The coast is cliffy and fringed with recent coral reefs. The island consists of raised coral reefs with a foundation of Tertiary rocks which are exposed only in a cliff near the sea coast (Fig. 1). The Tertiary rocks on the eastern coast, traceable

Fig. 1.—A view of Kikaiga-shima, as seen from the south-east.

from Sōmachi to Kamikatetsu, are chiefly bluish sandy shale, often with intervening layers of marls and loose brownish sandstones and very rarely with thin pumice beds. The sandy shale on the road from Keraji to Urabaru shows a strike N20°W or N—S, and dip NE or E with an angle of 35°. In the western part of the island, there is found a marly sandstone, sometimes alternating with loose bluish sandstone, and always dipping due west 5°.

II. THE TOKARA GROUP.

This group lying on the north-west of Ōshima, consists of very small islands on a line NE to SW ; viz, Yoko-shima, Kaminone-sho, Tokara-jima, Shimako-jima, Akuseki-jima, Suwanose-jima, Nakano-shima, Kuchino-shima, Taira-jima, Gwaja-jima and Kogwaja-jima. According to Mr. Yamagami, all these islands consist of andesite. Solfataras are said to exist on Nakano-shima, Kogwaja-jima and Akuseki-jima. He also informs me that Suwanose-jima is even now sending forth lava and is considered as the only active volcano in the Riukiu Curve. Besides, distinct volcanic craters are seen in Nakano-shima and Akuseki-jima, and some traces of volcanic centres in Kuchino-shima and Gwaja-jima.

III. THE ŌSUMI GROUP.

This group contains only a few scattered islands near Kyūshū. The two largest islands, Tanega-shima and Yaku-shima, have already been described by Mr. Nishiwada.* According to him, Tanega-shima has the shape of a battery with the highest peak 1200 ft. above the sea-level, and consists of Tertiary rocks, such as sandstone, shale and conglomerate, with thin layers of impure limestone and brown coal-seams. The strata are greatly distorted with a strike NNE, which is parallel to the longer axis of the island. Diluvial rocks cover the Tertiary, but here the raised coral reefs, which are met with in the islands lying to the south, are never found. According to Mr. E. Sagawa, who visited this island in 1899, the interior seems to be composed of two different formations. The older one is greatly

* 種子島及屋久島探險記 (Report on Tanega-shima and Yaku-shima; *in Japanese*).—*The Journal of Geography, Tōkyō*, Vol. VII, No. 80, 1895.

distorted, hard and slate-like, and is Tertiary or even older ; while the other one is less distorted and has the aspect of a more recent Tertiary.

Yaku-shima is entirely destitute of flat land, and the highest peak has an elevation of 6345 ft. The central portion is entirely granite. Only around the coast do we find clay slate and sandstone, which are older than the granite, as in Ōshima, Tokuno-shima and other islands.

The island Make-jima lying near Tanega-shima is composed of Tertiary sediments. The four islands of neovolcanic rocks (andesites), Kuchinoerabu-jima, Kuro-shima, Iwō-jima and Take-shima, are situated on a line connecting the islands of the Tokara group with some volcanoes in Kyūshū, such as Kaimon-dake, Sakura-jima and Kirishima-yama. According to Mr. Yamagami Iwō-jima has a crater at the summit, which is now vigorously emitting sulphuretted hydrogen gas. Kuchinoerabu-jima has also a distinct crater which emits the same gas. In 1839, a great eruption took place in the latter island, and many persons were buried in the ejectamenta.

IV. THE OKINAWA GROUP.

Besides the main island, Okinawa, with its numerous dependent islets, such as Kudaka, Tsuken, Kouri, Miyagusuku, Ike, Ie, Sesoko, Minna, Yagaji, Ō, Shitomo and others, this group includes the islands of the Iheya subgroup (five in number), those of Kerama subgroup (more than twelve) and the islands of Kume, Tonaki, Aguni and Tori.

Okinawa-jima and its Dependent Islets. The principal part of Okinawajima trends from NE to SW, and the southern part from N to S. The former, being almost entirely Palæozoic, is mostly mountainous

especially near the northern part; the western coast is nearly straight, with the exception of the tongue-shaped projections of Motobu, Akamaruga-saki and Hedo. It is very interesting, that these regions which project out to sea are composed of Palæozoic sediments entirely different from those in other places. The highest peak Katsuo-dake, is found in the Motobu region and has an elevation of 1557 ft. above the sea-level. The southern part of Okinawa-jima is generally plateau-like, and belongs to the Tertiary and Post-tertiary formations.

The Palæozoic rocks are clay slate, sandstone, pyroxenite or amphibolite, and schalstein found in the main part of the island; and the overlying limestone with compact quartzite, found in the western part, viz. in the regions of Motobu, Akamaruga-saki, Hedo, and in the south of Shioya. In the region of Motobu the dip is variable, but most frequently west or south-west 20—70 degrees. Pl IV shows the kinds of rocks observed in my trip through this region. In the limestone with compact quartzite, belonging to the western part, there are thin layers of slate, sandstone and pyroxenite or amphibolite, all of which are also found in the main part. Moreover the limestone and compact quartzite are conformable with the same rocks in the main part and seem to represent only a later part of the same period as is shown by the dips. In the other islands of the Riukiu Curve, all of the Palæozoic rocks are also associated with one another. Thus in Ōshima, the two rocks showing generally a westward dip, are found in the western part and are often intercalated in the other Palæozoic rocks, just as in Okinawa-jima. Moreover the islands on the west of Okinawa, viz., Sesoko, Ie and Kouri, and those in the Iheya subgroup are almost all composed of limestone and compact quartzite and not of other rocks.

The following abstract of my note refers to the Palæozoic rocks lying outside of the Motobu region :

Okinawa-jima.

	Strike.	Dip.	Kinds of rocks.
From Kina to Onna.			
Kina—Yamada	N 50 E	N W 30	Slate.
	N 40 E	N W 50	,,
Yamada—Fuki	N 40 E	N W 50	,,
Fuki—Chatan	N 40 E	vertical	,,
Chatan—Onna			Quartzose sandstone and slate.
From Onna to Choda.			
Onna—Seragaki	N 50 E	N W 40	Pyroxenite with a little quartzose sandstone.
Seragaki—Afuso			Slate and quartzose sandstone.
Afuso—Nakama	N 30 E	N W 50	,,
			Porphyrite dyke.
	N 40 E	N W 50	Slate.
Nakama—Kise	N 40 E	N W 30	,,
Kise—Kōki	N 40 E	N W 40	,,
Kōki—Choda	N 40 E	N W 40	,,
From Choda to Nago.			
Choda—Sukuda			Slate.
			Porphyrite dyke.
			Hard sandstone.
	Distorted		Slate.
Sukuda—Semurokei	N 50 W	S W 30	,,
	N 10 W	S W 40	,,
	N 30 W	S W 30	,,
Semurokei—Nago	N 30 W	S W 45	Hard sandstone.
From Nago to Oyakawa.			
Nago—Izashigawa			Alternations of slate and sandstone.
From Oyakawa to Shioya.			
Inamine—Genga	N 40 E	N W 40	Quartzose sandstone.
Genga—Tsuwa	N—S	W 20	Pyroxenite.
			Porphyrite dyke.
Tsuwa—Tonujā			Slate.
Tonujā—Shioya			,,
From Shioya to Okuma.			
Shioya—Nejime			Quartzose sandstone.
Nejime—Ōgimi			,,
Ōgimi—Ōkaneku	E—W	S 20	Slate.
Ōkaneku—Nyōha	N 60 W	S W 30	,,
	N 40 E	N W 40	Limestone.
Nyōha—Hama	N 80 E	N W 20	,,
	N 20 W	S W 50	,,
Hama—Okuma	N 20 W	S W 20	,,
	N 20 E	N W 20	Slate.
	E—W	S 20	,,
From Okuma to Hetona.	N 50 W	S W 20	Quartzose sandstone with a little slate.
From Hetona to Yona.			
Hetona—Iji	N 60 W	S W 40	Quartzose sandstone.
Iji—Yona	N—S	W 40	Alternations of slate and sandstone.
From Yona to Shashiki.			Sandstone and porphyrite dyke.
From Shashiki to Henoki.	N 20 E	N W 20-50	Sandstone with very little slate.
From Henoki to Uka.	N 20 E	N W 30	Sandstone.
From Uka to Ginamabara.			
	N 30 W	S W 20	Sandstone with a little slate.
	N—S	W 40	,,
	N—S	W 45	Sandstone and slate.
Jachinbira	N 40 W	S W 45	,,
	N—S	W 30	,,

	Strike.	Dip.	Kinds of rocks.
Bumibira	N 40 E	N W 20–40	Quartzose sandstone with a little slate.
From Ginamabara to Hedō.	N 45 E	N W 40	Slate.
From Hedō to Oku.	N 40 E	N W 45	,,
	N—S	W 40	,,
From Oku to Sosu.			
	N 54 E	S E 30	Slate.
	N—S	W 50	Quartzose sandstone.
	N 40 E	N W 40	,,
	N 50 E	N W 40	,,
	N—S	W 30–70	,,
	Distorted		,,
	N—S	W 40–80	,,
From Sosu to Ada.			
	N 20 E	N W 60	Slate.
	N—S	W 50–60	,,
	N 20 W	S W 50	Quartzose sandstone.
	N 20 E	N W 50	Alternations of quartzose sandstone and slate.
	N—S	W 50	
	N—S	W 60	
	N 20 W	S W 50	
	N—S	W 50	
	N 10 W	S W 80	
	N—S	W 60	
	N 10 E	N W 80	
	N 10 E	N W 50	
From Ada to Awa.			
	N—S	W 50–70	Slate.
	N 10–20 E	N W 70	,,
	N 10 W	S W 70	Quartzose sandstone.
From Awa to Miyagusuku.			
Awa—Arakawara	N—S	W 50	Quartzose sandstone and slate.
	N 40 E	N W 40	,,
	N—S	W 40	,,
	N 40 E	N W 50	,,
	N—S	W 30	,,
	N 30 E	N W 50	,,
Arakawara—Miyagusuku	N—S	W 50	Slate.
	N 40 E	N W 50	,,
	N 20 E	N W 50	Sandstone.
	N 20 E	N W 40	,,
	N—S	W 50	,,
	N 40 E	N W 40	Slate with a little sandstone.
	N 10 E	N W 50	,,
	N 30 E	N W 50	,,
	N—S	W 45	,,
	N—S	W 60	,,
	N—S	W 70	Sandstone.
	N 30 E	N W 50	Slate
From Miyagusuku to Arume.			
Miyagusuku—Kawada	N20–40E	N W 40–60	Sandstone with a little slate.
	N—S	W 40–60	,,
Kawada—Tēra	N 30 E	N W 50	Slate.
Tēra—Kesaji	N 30 E	N W 20	Sandstone.
	N 40 E	N W 30–50	,,
	N 40 E	N W 40	Slate.
Kesaji—Arume	N—S	W 50	,,
	N 20 E	N W 70	,,
	N—S	W 50	,,
	N 30 E	N W 60	,,

	Strike.	Dip.	Kinds of rocks.
From Arume to Setake.			
Arume—Teniya	N 50 E	N W 60	Sandstone and conglomerate.
	N 50 E	N W 50	Slate.
	N 60 E	N W 40	,,
	N 70 E	N W 25	Sandstone.
	N 50 E	N W 30	,,
Teniya—Kayō	N 70 E	N W 50	Sandstone.
	N 60 E	N W 40	Slate.
	N 80 E	N W 50	,,
	N 60 E	N W 30	Sandstone.
	N 80 E	N W 40	,,
Kayō—Abu	N 40 E	N W 15	Sandstone.
	N 30 E	N W 30	,,
Abu—Tēma	E—W	N 50	Sandstone with a little slate.
	N 40 E	W 50	,,
	N—S	W 50	,,
	N 60 E	N W 50	,,
	N 80 E	N W 50	,,
Tēma—Setake	N 60 E	N W 60	Sandstone and slate.
From Setake to Ōura.	N 20 E	N W 50	Slate.
From Kushi to Kin.			
Kushi—Kochiya	N 60 E	N W 30	Slaty sandstone.
	N 50 E	N W 30	,,
Kochiya—Kanna	variable.		,,
Kanna—Kin	variable.		Slaty sandstone, schalstein, slate and sandstone.
From Kin to Ishikawa.			
Kin—Ige	N—S	W 50	Alternations of schalstein and quartzose sandstone.
	N 45 E	N W 70	Slate.
	N 30 E	N W 50	,,
	N 70 E	N W 70	,,
	N—S	W 30	,,
	N 20 E	N W 30	Alternations of pyroxenite, quartzose sandstone and slate.
	N—S	W 30	,, ,, ,,
Ige—Yaka	N 30 E	N W 40	Quartzose sandstone.
	N 50 E	N W 30	,,
	N 50 E	N W 40	Pyroxenite with thin alternations of slate and quartzite.
Yaka—Ishikawa	N 40 E	N W 40	,, ,, ,,

It is apparent, that Okinawa-jima is simply a continuation of Ōshima, which it closely resembles in tectonics and petrography. The Palæozoic rocks found in the former are never horizontal, and have the strike parallel to the longer axis of the island, and the dip almost always westward. There is observed no marked folding or faulting on the sea coast, nor in the interior. The principal Palæozoic rock is clay slate. Greywacke sandstone is also common. Pyroxenite or amphibolite is more extensive, and schalstein less so than in Ōshima.

Fossils are not found in these rocks. I was able to collect specimens of only a single species of coral from the limestone in Motobu, and of an indeterminable Mollusca from the same limestone bed in the neighbouring island of Sesoko.

The southern part of Okinawa-jima, which trends from N to S in contrast with the principal Palæozoic region, shows a foundation of Tertiary sediments. They were once entirely covered with raised coral reefs, but these now remain only in scattered patches. The Tertiary sediments are also exposed in the valleys of the Palæozoic regions near Oyakawa. The chief Tertiary rock is a loose sandy shale with thin layers of marl. Sandstones of a fine-grained brownish, and of a hard bluish calcareous variety are sometimes found at Toguchi near Ōse, and a bluish shale near Naha and Ōse. Fossil wood and a few species of small shells are found here and there in the sandy shale. I have collected at Kochinda *Leda*, *Drillia*, *Natica*, *Dentalium octogonum* Lamk. and one other species of the last mentioned genus. A number of Foraminifera, belonging to *Operculina*, which is small in size and not identical with the characteristic species found in Diluvial reefs in the Riukiu Curve, have been gathered from the loose sandstone in Okinaga near Itoman. The Tertiary rocks are either quite horizontal, or inclined in various directions in contrast with the regularly bedded Palæozoic; as

at Naha	E—W N10,° or N60°E NW50°
at Taira near Shuri	N30°E NW20°
at Nakanishi (north of Naha)	horizontal
on the road from Shuri to Konaha	N60°E NW40,° N60°E NW10°, N50°W SW50°
at Konaha	N40°E SE35°
on the west of Yonabaru	horizontal
at Ōse	N45°W NE5°
at Okinaga	N40°E NW20°

at Kochinda	N40°E	SE10°		
on the road from Kochinda to Hēbara	N60°W	SW25,°	N-S	W15,°
	N40°W	SW10°		
near Oyakawa	N40°E	SE20°		

The igneous rocks are all Pre-tertiary porphyrite forming eight dykes, all in the western part of the island. With a single exception at Nakama on the east of Onna, where it is N30°W, the strike of the dykes is parallel to the long axis of the island. The fifth dyke, counting from the west, runs exactly along the western coast on the north of the Motobu region. The dykes mostly belong to the mica-porphyrite, and there is no hornblende-porphyrite as in the vicinity of Naon in Ōshima. All the dykes pierce the Palæozoic rocks, but never come in contact with the Tertiary.

Yagaji-jima is merely a piece of land separated from Okinawa-jima by the action of the sea. The Palæozoic limestone with compact quartzite is nothing but a continuation of that in the Motobu region; and the clay slate and sandstone in the center of Yagaji-jima are the same as those in the principal part of the larger island. The remaining parts are almost wholly occupied by raised coral reefs. Only at the south-eastern corner there is a very small area of Tertiary sandstone with marl, exposed by the erosion of overlying reefs. This Tertiary rock contains fossil leaves, corals, *Dentalium*, *Tapes*, *Nassa*, and *Trochus*.

Kouri-jima, as well as Sesoko-jima, consists of Palæozoic limestone with a belt of raised coral reefs all around it. In the latter island, there is Palæozoic sandstone at the north-eastern and south-western ends of the limestone region. Some small exposures of compact quartzite are there found in different places. All these sediments incline to the west or north-west as in the case of the other islands. A dyke of porphyrite is traceable along the eastern side of

the limestone, and runs from NE to SW. Minna-jima lying near Sesoko-jima is a very flat island, composed wholly of coral reefs.

Ie-jima has a remarkable feature in a huge pointed rock called Gusuku which rises out of the surrounding hills in the eastern part of the island (Fig. 2). There is another point called Buppiji, but it is

Fig. 2.—View of Ie-jima seen from Tokuji.

only a little higher than the vast surrounding plateau, which is entirely made up of raised coral reefs. The rocks of these two prominences are compact quartzite and limestone, the same as those in the other islands of the Riukiu Curve. I collected a specimen of diabase exposed after the erosion of a reef. Blocks of Palæozoic sandstone and pyroxenite are found enclosed within the raised reefs. Though the latter are horizontal, the Palæozoic is always inclined with the strike NE and the dip NW, characteristic of the Riukiu Curve.

The above-mentioned small islands of the Okinawa group are all situated on the western side of Okinawa-jima. Those on the east of this island are arranged in a N—S line and are six in number; namely Ike, Miyagusuku, Hama (Fig. 3), Hianja (Fig. 4), Tsuken and Kudaka.

Fig. 3.—View of Hiama-jima seen from Yonagusuku-jima and Hianja-jima.

Fig. 4.—View of Hianja-jima seen from the western side of Yonagusuku-jima. (Tertiary rocks on the western [*i.e.* left] side).

They are all entirely capped with horizontal reefs. Only in Miyagusuku-jima and Hianja-jima, the foundation rock, raised above the sea-level, is loose brownish sandstone with intervening marly layers; bluish sandy shale also occurs. In Miyagusuku-jima they are inclined to SE on the south-eastern side; and to SW 10 degrees with the strike of S60°E, in the southern part. Fossils found from the Tertiary of this island are mostly small forms of shallow sea deposits. They are *Natica*, *Trochus*, *Guildfordia*, *Pectunculus*, *Limopsis*, *Pecten*, *Anomia* and *Dentalium*. There are also well preserved specimens of *Rhynchonella lucida* Gld., *Mergelia sanguinea* Chemn., *Terebratella mariae* A. Ad., *Terebratula japonica* Sow., *Dosinia exoleta* Linn'e and *Nucula mirabilis* Hinds. Besides these, I have collected unpetrified wood, fossil bones, corals and echinoids. The Tertiary rocks on the northern side of Hianja-jima, when traced from the western end of the island to the east, show a gradual change of dips, namely from an eastward to a southward and finally to a southwestward. Thus the structure, arrangement and kinds of the Tertiary rocks of the islands on the east of Okinawa-jima are just the same as those in the southern part of the large island itself, with which they are similar in origin.

Almost all of the *Kerama Subgroup* which contains the islands of Zamami, Aka, Geruma, Mokaraku, Yakashi, Kuba, Tokashiki, Kuro, Mae and others, as well as *Tonaki-jima* seems to consist of Palæozoic rocks. So far as I know, there is no trace of raised coral reefs; and the islands are mostly mountainous like the northern part of Okinawa-jima. Zamami-jima is especially mountainous and has the best anchorage of any of the Riukiu islands. Palæozoic slate, with a less extensive sandstone, generally dips toward the south, southwest or west, with an angle of 20°-45°, but never to the east, as in the other islands in Riukiu. A dyke of porphyrite is found in Akamura. Aka-jima, lying on the south of Zamami-jima, consists chiefly of greywacke

sandstone, often with slate. Pyroxenite or amphibolite is rarely found. These rocks show the same general dip as in Zamami-jima with an angle of 25°—45°. Geruma-jima and Mokaraku-jima are chiefly composed of sandstone and slate, showing the same dip as in the two islands above mentioned. Indeed the islands of the Kerama subgroup are nothing else than the mere continuation of the region of Palæozoic rocks, excluding compact quartzite and limestone, in Okinawa-jima, the evidence of which is assured by the kinds of rocks and the position of the islands on the map.

The *Iheya Subgroup* trending north and south, is composed of four small islands, Iheya, Gushichā, Izena and Yanaha. Mr. Kuroiwa has found most of these islands to be of compact quartzite, except Yanaha-jima and a part of Gushichā-jima, which consist of raised coral reefs.

The very small islets on the west of Naha, namely *Kei-jima Koisa-jima* and *Kisu-jima* consist essentially of fragments of recent reef corals. Only the western part of Kei-jima consists of undisturbed old reefs.

The three islands, *Kume*, *Aguni* and *Tori* are the only volcanic islands in the Okinawa group. Tori-shima, lying far to the northwest of Tokuno-shima, has a length of three miles, and is still emitting a great quantity of sulphuretted hydrogen gas. Mr. Kuroiwa has found Aguni-jima to be formed of neovolcanic rocks with raised coral reefs; and Kume-jima* to be almost entirely augite-andesite. Only between Janadō and Uemura on the eastern side of Kume-jima is there a little exposure of Tertiary (?) sandstone, dipping 45° to the northwest. A small mass of schalstein is found enclosed in the volcanic rock. Thick raised coral reefs are found also in this island, along its northern and on the middle of its western coast.

* 久米島 (Kume-jima; *in Japanese*).—*The Journ. Geol. Soc. Tōkyō*, Vol. V, No. 59, 1898.

V. THE SAKI-SHIMA GROUP.

The Saki-shima group is divisible into two subgroups, Miyako and Yaeyama, the former lying far to the east of the latter.

The Miyako Subgroup.

This subgroup contains the islands of Miyako, Shimoji, Irabu, Kurima, Ikema, Ōgami, Tarama and Minna (Fig. 5). Ōgami-jima alone consists of Tertiary calcareous sandstone with shale, surrounded by raised coral reefs; all the other islands are made up entirely of

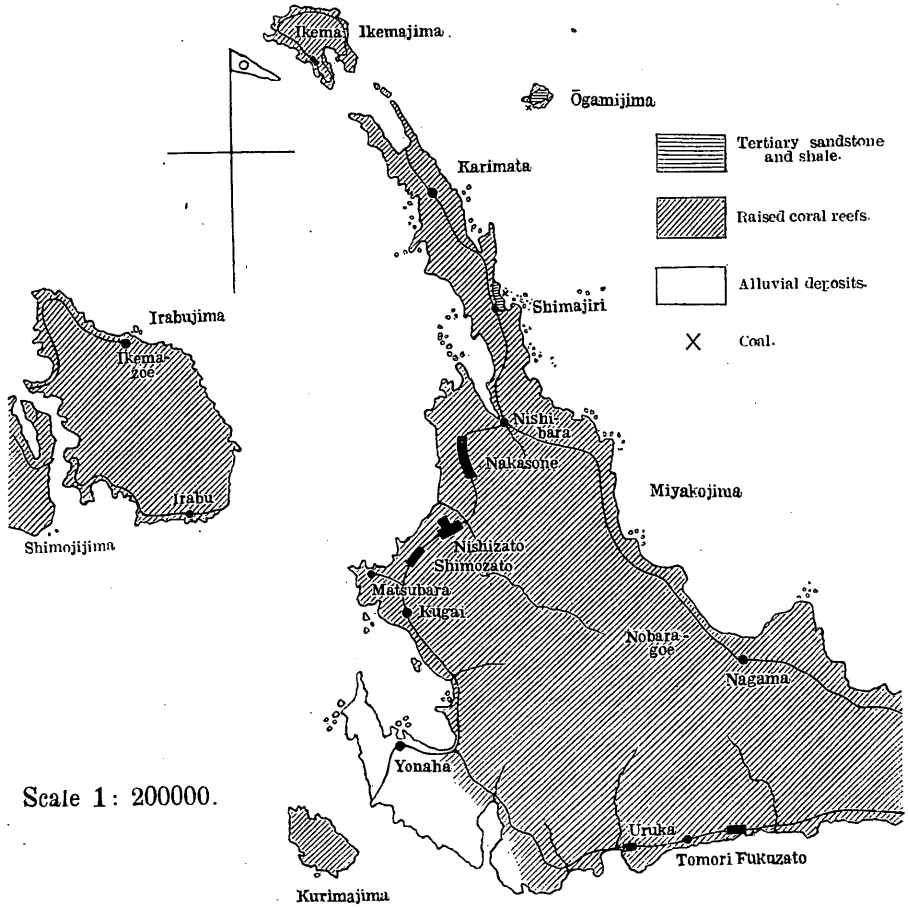


Fig. 5.—Geological Map of the Miyako Subgroup excluding Tarama-jima and Minna-jima.

raised reefs. Their Tertiary foundation is exposed only at Shimajiri on the north-eastern coast of Miyako-jima, and there the exposure is due to a fault. We find there a bluish shale conformably overlaid by a loose brownish sandstone with a dip SW 15° or W 7° and a strike N 20° W or N-S. I found the rocks to be very rich in fossils, among which *Pecten placunoides* Martin† and *Ranella elegans* Beck* are predominant. Both are in the Miocene of Java, and the former is also abundant in the Tertiary of Formosa. *Xenophora aff. dunkeri* Martin and *Conus aff. jenkinsi* Martin are also common. Besides these, *Natica*, *Oliva*, *Turritella*, *Macha*, *Corbula*, *Lutraria*, *Tapes*, *Dosinia*, *Cardium*, *Arca*, *Anomia* and *Ostrea* are not rare. Whale bones and crab-claws are also found. A thin black-coloured coal-seam in the strata appears not so late as the fossil wood in the Tertiary of Okinawa-jima. Another thin layer of coal-seam is found in Ōgami-jima.

The Yaeyama Subgroup.

This subgroup comprises, besides the two large islands of Ishigaki and Iriomote, ten smaller islands, viz., Yonaguni, Hatoma, Nakanogan, Taketomi, Kayama, Kobama, Kami-Kuro, Shimo-Kuro, Aragusuku and Hateruma. The last four are entirely built of raised coral reefs. Nakanogan-jima, Hatoma-jima and Yonaguni-jima are composed of Tertiary sediments and raised reefs. Taketomi-jima and Kayama-jima consist of Palæozoic rocks in addition to raised reefs. In the three islands, Ishigaki-jima, Iriomote-jima and Kobama-jima, there are Palæozoic and Tertiary sediments, igneous rocks and raised reefs.

Ishigaki-jima, showing the most complicated geological structure of any of the islands of the Riukiu Curve, has been visited by Messrs. Kada and Kuroiwa and afterwards by myself. We find in this island

† Martin, Nachträge zur Tertiärschichten auf Java.—*Samm. des Geol. Reichs-Museums*, I Ser., II Band, 1881—83.

* Martin, Tertiärschichten auf Java, 1880.

the Palæozoic rocks such as clay slate, sandstone, pyroxenite or amphibolite, compact quartzite and limestone, and the igneous rocks, granite, diorite, diabase, andesite, propylite, quartz-porphyry and liparite, besides less extensive Tertiary sediments and raised reefs. The interior, with the exception of the table-land composed of reefs, is mountainous. The highest peak, Omoto-dake, rises 1680 ft. above the sea-level. The greater part of Iriomote-jima, another large island in the Yaeyama subgroup, is composed of Tertiary sediments, with Palæozoic sediments only on the north-eastern corner, and raised reefs at various places. The whole island with the exception of the very limited occurrences of raised reefs is mountainous. The highest peak, Goza-dake, has an elevation of about 1500 ft. above the sea-levle. The interior is entirely uninhabited on account of the presence of a terrible fever and poisonous snakes. People are living on the coast, and maintain communication between their villages chiefly by means of small dug-out canoes. Only a few persons have succeeded in crossing the island from its northern to its southern coast. This is a journey of only fourteen miles, but it takes at least three or four days. The three islands, Kayama-jima, Kobama-jima and Taketomi-jima, lying between Iriomote-jima and Ishigaki-jima, have Palæozoic sediments in the interior and make the connecting link between these two large islands.

Palæozoic Rocks of Ishigaki-jima. This island trending in a NE direction, shows two very narrow isthmuses of recent formation in its northern part. Also the western peninsula (B in Pl. II) is connected by a plateau of raised reefs with the main body (A) of the island. Thus the island, at the time of the formation of the ancient reefs, was probably four separate islets, A, B, C and D. Clay slate, sandstone, and pyroxenite or amphibolite are found in B, C, D and in the eastern part of A. Compact quartzite, with very thin intercalations of other

Palæozoic rocks, is exposed in the central and western part of A, and shows a characteristic distribution in contrast with them. Though the Palæozoic frequently shows various distortions by the eruption of igneous rocks, yet there exists a certain regularity of inclination. The part C is made up of Palæozoic hills with a belt of reefs on the eastern and western coasts. The rocks at the northern end are chiefly pyroxene or amphibole rocks. Fūji-banare, which is a rock in the sea to the north of C, is composed also of these sediments with intervening thin layers of slate. They show a dip the same as that on the opposite coast, namely 35°—55° to SW or S and a strike from N 70°W to E—W. When we trace the Palæozoic rocks of the eastern coast of C, beginning from the northern end, we find numerous distortions of strata until we reach Yasura. The following shows the measurements of strikes and dips counted southwards from the place where a liparite dyke and a propylite sheet are found:

E—W S70°,	N20°E NW30°,	N50°E	NW40°,
N35°E NW30°,	N—S W20°,	N60°W	SW20°,
E—W S35°,	N40°W SW30°,	N—S	W20°,
N40°—45°W	SW30°		

The pyroxenite with some quartzose sandstone is greatly distorted, but as a whole shows a regular inclination. Rocks exposed between Yasura and Hirakubo are chiefly pyroxenite with the strike N30°—50°W and the dip SW 20°—30°. On the road from Yasura to the southern end of C, the dip is constant as is shown in the following list, no fault being observed:

N 30°W SW 40°,	N 20°W SW 25°,	N 30°W	SW 15°,
N 50°W SW 20°,	N 30°W SW 20°,	E—W S	20°.

We meet about midway on this road a liparite stock, in contact with Palæozoic rocks, with however no trace of disturbance. Thus

their present inclination seems to be due to a pressure exerted long after the eruption of the stock. Therefore the part C, though much disturbed in its northern part, still shows the constant dip of the Palæozoic sediments, namely 20°—40° to S or SW and the strike from E—W to N20°W. This strike is apparently transverse to the longer axis of Ishigaki-jima.

The part D lying on the south of C has hills of Palæozoic sediments surrounded by a plateau of raised reefs which are now almost entirely eroded on the eastern coast. The Palæozoic consists of pyroxenite or amphibolite with small layers of clay slate and quartzose sandstone. They are very regularly inclined, with no signs of faulting or folding. The following measurements have been made on the rocks of the eastern coast beginning from the north:

E—W	S 30°,	E 30°W	SW 30°,	N 50°W	SW 60°,
N 50°W	SW40°,	N 40°W	SW 50°.	N 45°W	SW 60°,

On the mainland A, pyroxenite or amphibolite, as well as clay slate and quartzose sandstone are limited to the eastern part, while large districts of igneous rocks and compact quartzite are observed on the west. Pyroxenite is common. Quartzose sandstone, clay slate, and alternations of clay slate and quartzite are also not rare. The inclination of these rocks is quite constant. I measured, in the northwestern part, the strike N40°—50°W and the dip NE 20°—60°. Even the small coast exposure of Palæozoic sediments, lying very close to the east of the Nosoko volcano, has the strike N 30°W and the dip NE45°. Also the southern Palæozoic regions have the strike N20°—70°W and the dip NE 20°—30°; the most common measurement is N40°W, NE25°. Thus the Palæozoic rocks of A, except the compact quartzite, have dips quite opposite to those of C and D, though the strike remains the same. This is perhaps due to the great andesite eruption of the Nosoko volcano.

In the part B, pyroxenite with some alternations of clay slate and quartzose sandstone compose the Palæozoic area. Tracing the strata of the southern coast from east to west, I made the following measurements :

N20°W SW30°,	N40°W SW35°,	N—S W30°,
N20°W SW25°,	N35°W SW20°,	N—S W10°.

Thus the inclination of rocks is quite similar to those in C and D, and in contrast to A. On the north-west of Kabira, a little Palæozoic exposure pierced by andesite, is also inclined towards the west.

Compact quartzite is found on the mainland A and extends from the southern foot of Omoto-dake to the neighborhood of Nagura and Shikamura. The same rock is also exposed along the sea coast from Nagura to Sakieda. Near Sakieda there is only an alternation of sandstone and compact quartzite ; and finally we find only sandstone at the northern end of the quartzite region. The strike of rocks in the former region is almost always E-W, but sometimes nearly N60°E to N70°W. The dip, which is generally constant, is very steep; the strata being sometimes vertical, and sometimes inclined to N or S with an angle of 60° or 70°, but never less than 40°. In the eastern part of this region, a thin layer of clay slate is found in compact quartzite, and has the strike E-W and the dip S70°. The Bannā hill, which lies on the north of Shikamura, is composed of an alternation of clay slate and compact quartzite with the strike N50°W and the dip NE 35°. Rocks on the coast between Nagura and Sakieda are in direct contact with granite which has disturbed their layers. The following dips and strikes have been measured northwards from Nagura:

N 40°W NE 60°	Compact quartzite.
N 60°W NE 60°	,,
N 50°W NE 20°	,,
N 80°W NE 50°	,,

E—W	N 30°	Slate and sandstone.
N—S	N 10°-30°	Compact quartzite.
N 70°E	NW 40°	,,
Granite.		
E—W	vertical	Compact quartzite.
N 70°E	NW 50°	,,
E—W	N 50°	,,
N 70°E	NW 60°	Alternations of compact quartzite and sandstone.
N 30°E	NW 55°	Sandstone.

Palæozoic limestone found at Ishizoko and its environs has the strike E-W, and is crystalline being identical with that of the Ōshima and Okinawa groups.

There are three small islands (Taketomi, Kobama and Kayama) making a connecting link between Ishigaki-jima and Iriomote-jima. The eastern island *Taketomi-jima* is a flat table-land; its northern half is compact quartzite with sandstone and clay slate, while the southern half is entirely built of raised reefs. The Palæozoic rocks have the strike E-W, N70°E or N80°E, and the dip N30°—65°, NW35°—40°, just as on the opposite coast of Ishigaki-jima.

The principal part of *Kobama-jima*, lying on the north-west of Taketomi-jima, is composed of Palæozoic pyroxenite, sandstone and clay slate with the same strike as in Taketomi-jima, but with the dip S or SW 20°—40°.

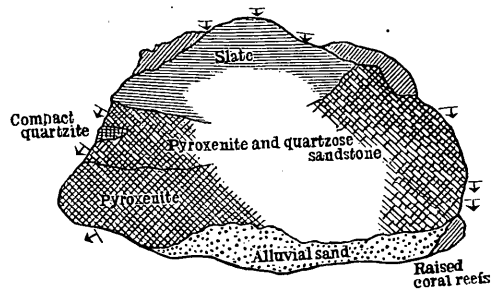


Fig. 6.—Goelogical Map of Kayama-jima.

The smallest island, *Kayama-jima*, whose tectonic condition is shown in Fig. 6, is chiefly composed of pyroxenite with a very limited occurrence of compact quartzite. These are inclined to SW only on the western

corner; in other parts we find a strike E-W, and a dip toward the south.

The Palæozoic rocks of *Iriomote-jima* are mostly pyroxenite-like and are exposed on the south of Takana, and show various distortions caused by andesite stocks.

Tertiary Rocks of Ishigaki-jima. Among these rocks which occupy very large areas in the Yaeyama subgroup, we find the following in Ishigaki-jima; namely fine-and coarse-grained brownish sandstones, compact quartzose sandstone, limestone and agglomerate tuff, all exposed in the form of patches rather near the coast. The strata are elevated hardly more than a hundred feet, except in the case of the tufaceous rocks. The most northern exposure extends from the north-western corner of Ibaruma to the cape called Ishizaki (Fig. 7). A continuation

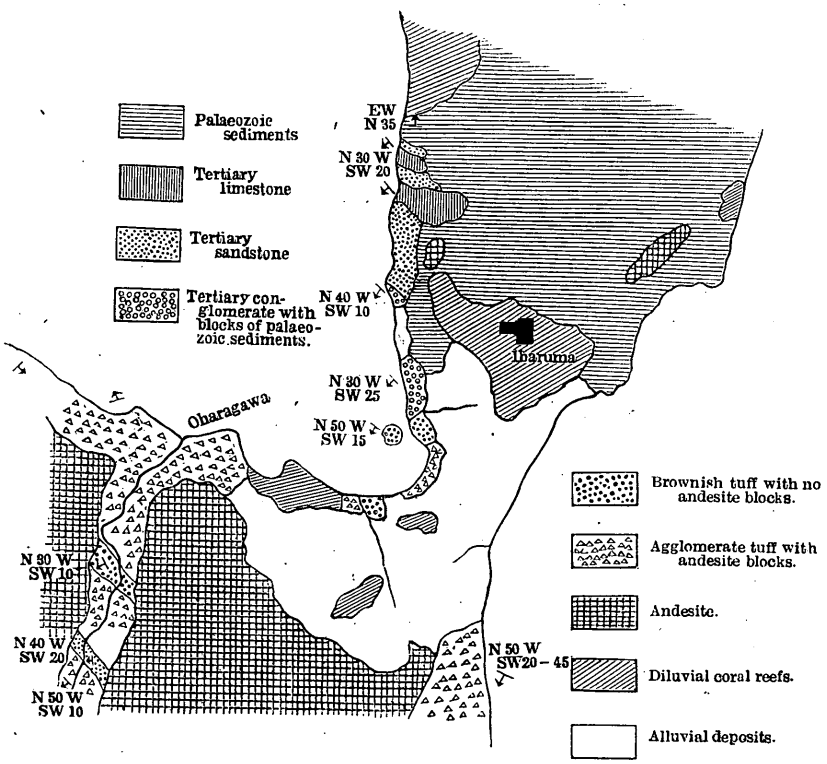


Fig. 7.—Geological Map of the Ibaruma Region.

of this Tertiary is found under the andesite in the valleys of the Ohara-gawa and other rivers. The order of succession of the Tertiary rocks in this part, counting from above downwards, is as follows :

Agglomerate-tuff of andesite, with thin layers of a non-tufaceous sandstone, shale and a tuff without andesite blocks.
Brownish tuff containing no blocks of andesite.
Conglomerate with pebbles of Palæozoic sediments.
Non-tufaceous sandstone.
Limestone.
Non-tufaceous sandstone.
Limestone.
Non-tufaceous sandstone.

The lowest sandstone bed discordantly overlies the Palæozoic rocks which show a northerly dip with an angle of 35°. The agglomerate-tuff encloses large blocks of andesite which are from the Nosoko volcano, and are deposited on its fringes ; and covers quite concordantly the limestone with alternating sandstone. The latter is the same as that in Iriomote-jima, and the agglomerate-tuff contains thin layers of this sandstone, besides shale and a very hard quartzose sandstone. Thus the above mentioned alternation of limestone and sandstone is probably similar in age to the agglomerate-tuff, which has been erupted from the Nosoko volcano. This tuff is not only found along the northern side of the volcano, but also composes the isolated hills near Tamatori-zaki, besides being exposed in small patches in the neighborhood of Inoda. In this rock there are intercalated, in some places, thin layers of bluish sandstone which show the strike N50° or E-W, and the dip SW 20°-45° or S 30°-45°. Small exposures of the limestone, together with Palæozoic rocks, are found on the coast near Inoda. A little to the south of these exposures, there is a small region of Tertiary sediments with andesite in contact, which forms a hill. These sediments are

separated from the limestone by Alluvial sand and raised reefs. The entire region of the cape Nobara-zaki is of Tertiary rocks showing the following order of superposition :—

Bluish sandstone.
Tuff without andesite blocks.
Agglomerate-tuff with andesite blocks.
Brownish tufaceous sandstone.

All the rocks lying on the northern and eastern sides of this andesite hill show the dip varying from S W 25° to S 30°, with the strike from N 60° W to E-W. Even at the line of contact with the andesite, there is no marked disturbance of bedding. On the south, limestone exposures along the coast are separated from these exposures by a narrow stripe of Alluvial sand. The limestone shows a regular southward dip with an angle of 20°, and consists almost entirely of the calcareous algæ, identical with *Lithothamnium rosenbergii* Martin* from the miocene of Timor. Besides these only one large Irregular Echinoid belonging to the *Spatanginae* has been collected. The limestone extends more than a thousand feet along the shore, and is covered at its southern extremity by sandstone containing pebbles of Palæozoic sediments. In the neighborhood of Karadake on the west of Tōzato and Moriyama, there is a small exposure of sandstone with pebbles of Palæozoic sediments. It shows a dip 31° south as in the other parts of Ishigaki-jima. Thick beds of limestone, with the same appearance and fossil contents as those above mentioned, are on the north of Miyara-mura. I found here two thin intervening layers of the pebbly sandstone, which, as in other places in the island, show the dip 25°-30° SW and the strike N 50° W. Sometimes the Tertiary rocks are in direct contact with andesite,

* Martin, Die versteinerungsführenden Sedimente Timor's. *Samm. des Geol. Reichs—Museums in Leiden*, I Serie, I Band, 1881.

probably a dyke through the Palæozoic, but are not disturbed. Sometimes the Tertiary sandstone is deposited over the andesite. The sandstone in two small regions, namely near Ōhama-mura, and on the north-east of Shikamura, is that exposed after the erosion of the overlying reefs; and shows a regular dip towards the south. That exposed near Ōhama-mura contains imperfect casts of fossil leaves. Another exposure of limestone in B has the same character and same inclination (N50° W, S W 40°) as those in the other parts. In the western portion of B, there are also exposures of agglomerate-tuff with intercalations of sandstone and shale, showing the strike varying from N 40° W to N-S, and the dip nearly westward with an angle 10°-25°. The bedding of the rocks has not been modified by the andesite, with which they are in direct contact in some places.

The characteristics of the Tertiary of Ishigaki-jima consist of the deposition of agglomerate-tuff near andesite masses, and of limestone at some distance from the andesite; the andesite showing no influence upon the bedding of the other two rocks. Except on the western side of the Yarabu peninsula, the various Tertiary sediments are all regularly inclined southwards with the strike varying from N 50° W to E-W. This direction of inclination is moreover general in the Palæozoic sediments. There may perhaps have taken place a single great folding, after the deposition of the Tertiary rocks and the contemporaneous eruption of andesite. The single limestone bed on the fringe of the island now appears in small separate tracks always with the same inclination.

The Tertiary of Kobama-jima, which is found only in its south-eastern part, consists chiefly of fine-grained brownish sandstone with thin layers of conglomerate containing pebbles of Palæozoic rocks; besides these there is a very small exposure of *Lithothamnium*-limestone, like that found in Ishigaki-jima. I found also a thin coal-bed at the

south-eastern corner. Inclination is variable, but generally towards the east or south. Beginning from the northern end of the Tertiary region I have found the following beddings:—N-S, E10°-20°; then N20°-50° E, SE 10°-25°; and lastly E-W, S 5°. An exceptional dip towards the north-east is sometimes found in small exposure, but there are no westward ones.

The Tertiary of Iriomote-jima. This island, which is principally composed of Tertiary rocks, has the Palæozoic only on the north-eastern corner, besides scattered exposures of the ancient fringing reefs. The Tertiary rocks are rather regularly inclined and are never horizontal; they are mostly fine-grained, bluish or brownish sandstones, the latter of which often shows a false bedding. Shale is sometimes intercalated in these rocks. Coarse-grained brownish sandstone and conglomerate are less developed. Several coal-seams are found in the western part, each dipping towards the west, and with a strike nearly N N E.

The uppermost bed of the Tertiary, which is exposed near the western coast, is a calcareous sandstone with fossil shells. The exposures are found on the western corner of Hoka- (Soto-) banare and the point projecting between Urauchi-zaki and Unari-zaki. The fine-grained brownish sandstone is found between the calcareous sandstone and the first or uppermost coal-seam, and has the strike N 30°-50° E and the dip N W 8°-10°, as measured in Uchi-banare. This first coal-seam, which is only 10 inches thick, is exposed on a curved line running from the south-eastern corner of Hoka-banare toward Uchi-banare. The second seam is the greatest having a thickness of 3—4.5 ft. in Uchi-banare, and of 1 ft. on the north of Hoshidate and on the south of Unari-zaki. Between the first and second seams there is fine-grained brownish sandstone with a little shale. In Uchi-banare, the Tertiary rocks show the strike N 45°-60° E

and the dip N W 10°-20°; a slight change of bedding is observed on the north of Hoshidate, where we find them N 30°-60° E and and N W 5°-10° respectively on the north-western edge of the island. A small strike-fault in Uchi-banare has raised the western part of the island about forty or fifty feet. The third seam about 1 ft. in thickness is exposed on the main island at a place opposite Uchi-banare, then on the south-east of Sonai, on the north of Hoshidate, on both banks of the Urauchi-gawa and finally on the west of Uebaru. At the first mentioned place the seam has been upheaved by a fault lying in the sea between Uchi-banare and the main island. Between the second and third seams there is chiefly brownish sandstone, which contains, near Sonai and on the west of Uebaru, bands of shale. The sandstone shows the strike N 30° E and the dip N W 5°-10° near Sonai. The measurement is however N 40° E and N W 10° in the neighborhood of Aka-saki on the south, and from N 40° E to N-S and N W 10° to W 5° near Hoshidate on the north. Then proceeding towards the north, I measured N 20°-60° E, N W 5°-10° on the north bank of the Urauchi-gawa and N 30°-60° E, N W 10° on the west of Uebaru. The fourth seam, about 6 inches in thickness, is exposed on the upper course of the Nakara-gawa, on the east of Sonai and on the south of Uebaru. Above this seam there is also found chiefly brownish sandstone with the usual westward dip. The most prevalent bedding is N 40° E, N W 30° in the upper part of the Nakara-gawa; from N-S to N 20° E, and from W5° to N W 10°, on both banks of the Urauchi-gawa. I have found, on the east of Sonai, a thin limestone layer full of *Orbitoides*, together with a few remains of *Lithothamnium* and *Amphistegina*. The fifth seam is found on the steep mountain-side far to the south-east of Uebaru. The strata above this seam, chiefly of sandstone, shows N 30° E and N W 10° on the upper course of the

Nakara-gawa; N-S, W 5°-20°, on the upper part of the Urauchi-gawa; and N 30°-40° E, N W 15° on the east of Uebaru. At a considerable distance from this seam, two other coal-seams, namely the sixth and seventh are said to exist near the summit of Goza-dake, the highest peak in this island. On the northern part of the island, the beds underlying the fifth seam show the same inclination as above stated, and consist of sandstone with thin layers of shale and conglomerate. Their general strikes and dips, observed on the route from the east of Uebaru to Takana are as follows. Until we reach Intaya we find sandstone showing the strike N 30°-50° E and the dip N W 5°-15°, then conglomerate from Intaya to Aka-banare, and sandstone with shale thence to Takana, the last mentioned rocks showing the strike N 40°-60° E and the dip N W 10°-15°, except in the case of some small folds.

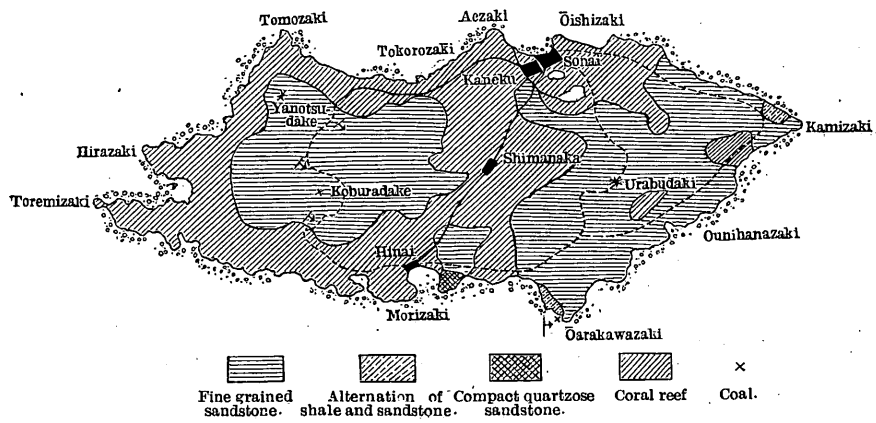
Then coming to the east coast, we find on the north of Komi quite different rocks with other inclinations. These are agglomerate-tuff with andesite blocks, and conglomerate with pebbles of Palæozoic rocks. They are inclined to S or S W 10°-40°, with the strike E-W or N 30° W, and are probably of the same age as the agglomerate-tuff in Ishigaki-jima. Rocks found a little to the south of Komi are sandstone with a little shale as in the northern and western parts of Iriomote-jima. On the route thither as far as to a region near Kuira-gawa, the inclination of the rocks is not as regular as that already mentioned for these parts. Near Komi the bedding is variable, being sometimes N 30° E, N W 15°, sometimes N-S, W 25°, in other cases N 60° E, S E 5.° Thence and until a short distance from Nakama, the rocks are regularly inclined to S E 5°-30°, with the strike N 30°-70° E. I found at Nakama-zaki a thin coal-seam, probably the lowest in the island. The stratification is N 70° W, S W 30° or E-W, S 30° at Nakama, and N 70°-80° E, S E 20°-40°

or E-W, S 30° in the vicinity of Haemi. Then along the southern coast from Haemi to Kanokawa, the inclination is different. After going about a mile to the west of Haemi, the rock observed is a fine-grained sandstone, which shows various inclinations, until finally the dip is due north. After this point and until Kanokawa is reached, we find the strike and dip N 70°-80° E, NW 5°-25°, N 80° W, NE 20°, or E-W, N 30°. From Kanokawa to the west of Ochimizu-zaki where a thin coal-seam occurs, I found the strike to be nearly the same, viz., E-W and the dip N 20.° At Ubiraishi there is a calcareous sandstone with fossil shells, closely resembling the rock on the north of Urauchi. Then we enter the northern and western parts of a tongue shaped region including the places called Yaeme-zaki, Nohama, Sakiyama, Amitori, Funauke and Kuira-gawa. Here the Tertiary rocks are very much disturbed, the dip and strike never remaining constant even for a short distance; the coast is very deeply indented as is shown in the plate. All these are perhaps due to a fault along the south-western coast of the islets Uchi-banare and Hoka-banare. In this region, which consists essentially of brownish sandstone, I have found four thin coal-seams which can not be identified with those in the main part of the island. The first seam is exposed at Nohama; the second runs from Sakiyama to the south of Amitori; the third is exposed on the south of Amitori; and the last is on the road from Ubiraishi to Ochimizu-zaki. In the brownish sandstone are sometimes found shale beds; a calareous shell-bearing sandstone, probably a continuation of that of Ubiraishi, is seen on the east of Funauke and in Saba-zaki.

Though the whole interior is almost entirely composed of Tertiary rocks, they contain very few fossils. Except *Lithothamnium* and *Orbitoides* and a few other Foraminifera found in the limestone, and some indeterminable shells in the calcareous sandstone, I have found

only the large Echinoids, *Echinodiscus* and *Astriclypeus* in the sandstone of Hoka-(Soto-)banare. The former has a diameter of 9 cm. and greatly resembles *E. placenta* Duncan and Sladen in the form of its lunules. It is interesting to note, that I found the same species in the Tertiary of northern Formosa, which contains numerous coal-seams and consists of rocks which are the same as those in Iriomoto-jima. The latter genus is now represented by one living species *A. manni* Verill. In 1899, I studied the *Astriclypeus* from the Tertiary of Mizuhomura, Prov. Kai (probably Miocene), and named them *A. integer*. The specimens from Iriomote-jima are rather ill-preserved, yet showing sufficient characters to identify them with the same species. Moreover the Tertiary near Mizuhomura incloses a thin limestone with *Orbitoides* very closely resembling that in Iriomote-jima.

The Tertiary of Yonaguni-jima. This island consisting of Tertiary rocks, is disposed in two hilly regions separated by raised reefs (Fig. 8.). The eastern half is called Urabu, and the western Kobura.



Scale 1:100000.

Fig. 8.—Geological Map of Yonaguni-jima.

Raised reefs are also observed along the margin of the hills, especially on the western and northern sides (Pl. V.). The Urabu region is elongated from N. to S, but Kobura is broad in shape. Between them,

there probably existed a fault line on both sides of which we observe a difference in petrography and tectonics. The western half is composed entirely of brownish sandstone dipping to SE 10°—30° with the strike N 30° E. But in the other part, brownish sandstone is seen only on a high level, and under it are found a hard bluish sandstone, compact quartzose sandstone and shale with a thin coal-seam. Fossil plants and Echinoids are found just above the coal-seam. The bedding of these rocks is N—S, E 20°. Though the island is elongated from east to west, yet the strike of rocks is not parallel to the longer axis of the island, but is really perpendicular to it.

Igneous Rocks in the Yaeyama Subgroup. Among the plutonics, granite, of which biotite-and hornblende-granite are the chief varieties, occupies large areas in Ishigaki-jima, forming elevation of 1680 ft. It has pierced compact quartzite on the south and west, and other Palæozoic sediment on the east. Olivine-diorite is found in the granitic region on the south of Omoto-dake, their mutual relations being still unknown. Besides, in Uchino-mura in the northern part of the part D, there are small exposures of diabase and quartz-porphyry. In the part C, a liparite dyke is found in the north-east, and a liparite stock in the south-east, both of which run from NE to SW. Andesite is predominant in Ishigaki-jima. Pyroxene-andesite is the principal lava from the Nosoko volcano, and extends even to the north-west and north-east of Ibaruma. Around the volcano we find agglomerate-tuff with angular blocks of andesite. The volcano is much eroded, showing no trace of its original form. Its highest part, Nosoko-māhē, has an elevation of 951 ft., and forms a sharp point standing out prominently from the surrounding hills (the remains of the Nosoko volcano), which again descend by perpendicular cliffs to the plateau on their northern side (Fig. 9). The two independent volcanic masses in the west of Nobara-zaki as well as in the part B con-

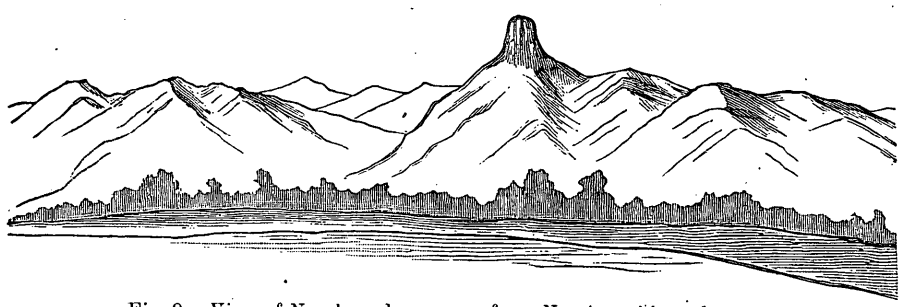


Fig. 9.—View of Nosoko volcano seen from Nosoko-zaki on the west.

sist of pyroxene-andesite. Stocks of the same rock are found on the north of Nosoko, in the south-western part of C and the north-west of Kabira, and extend from NE to SW. I found two dykes of pyroxene-andesite on the north of Miyara and another on the south of Omoto-dake. Dykes and stocks of the same rock are also found in the south-western and north-eastern corners of Kobama-jima and in the north-eastern corner of Iriomote-jima. Propylite sheet is exposed on the coast, north of Yasura in Ishigaki-jima.

The andesites of the Yaeyama subgroup pierce through the Palæozoic sediments but not through the Tertiary. Though some places in Ishigaki-jima show the Tertiary rocks in contact with the andesite, yet there is no contact change nor tectonic disturbance in the former. The agglomerate-tuff of andesite alternates with thin non-tufaceous sediments. This shows that the deposition of the Tertiary rocks of Ishigaki-jima took place either contemporary with, or else immediately before or after the andesite eruption. The regular bedding of the Tertiary, as well as that of the Palæozoic sediments of Ishigaki-jima is characteristic, showing a single folding pressure after the eruption of the volcanic rocks. In contrast with the Tertiary of Ishigaki-jima, that of Iriomote-jima has a very great thickness, contains several coal-seams, and is generally inclined to NW in the western, but not in the eastern part. Although this Tertiary is doubtless a

continuation of that of Formosa, as is explained hereafter, the strike of the western part thus differs from that of the latter region which is E—W. This is probably due to a fault running N—S, which direction is also taken by a line of andesite eruption in Ishigaki-jima. The strike of rocks in Yonaguni-jima again shows the existence of a fault of the same direction running through its central portion. Previous observers have assumed a great fault line parallel to it on the eastern side of Formosa. These lines of weakness all running N—S were probably caused by a pressure independent of that which folded the Riukiu Curve, and it is also probable that the former pressure preceded the latter. The "Mayon system" of Prof. Kotô* will perhaps show some relation to these lines.

VI. UNINHABITED ISLANDS IN RIUKIU.

Under this heading will be treated the Borodino and Pinnacle groups, both lying at a considerable distance from the other islands in the Riukiu Curve.

The very small islets scattered at a distance of about 155 miles to the south-east of the southern point of Okinawa-jima, and forming the *Borodino Group*, are named Rasa, South Borodino (Minami-ōagari) and North Borodino (Kita-ōagari). The first is in lat. 24° 32′ 30″ N and long. 131° 19′ E, the second in lat. 25° 55′ N and long. 131° 14′ 42″ E, and the third lies about $6\frac{3}{4}$ miles to the north-east of the second. Their length and width measure respectively 2.5 and 1 miles, 5 and 3 miles, and 3 and 2 miles. They are all composed of raised reefs which end in perpendicular cliffs on the shore.

Other small islets to the north-east of the Yaeyama subgroup,

* Kotô, On the Geologic Structure of the Malayan Archipelago—*Journ. Coll. Sci. Imp. Univ., Tôkyô*, Vol. XI, Part. II, 1899.

form the *Pinnacle Group* and are named Hoa-pin-su (Waheizan), Chia-u-su (Kōbitō or Kuba-shima), the Pinnacles and Raleigh (Sekibitō or Kume-aka-jima). These islands have been visited by Messrs. Miya-jima, Kuroiwa and others.† Hoa-pin-su, the largest island in the group, is in lat. 25° 47′ 7″ N and long. 123° 30′ 30″ E, at a distance of 90 miles from the western edge of Miyako-jima, 88 miles from Hoka-banare in Iriomoto-jima, and 100 miles from the north-eastern coast of Formosa. It is elongated from east to west, and is 4 miles long and 3 miles broad. The highest peak in the island has an elevation of 1180 ft. above the sea-level. The oldest rock is diorite, found on the southern coast. The greater part of the land is occupied by Tertiary sandstone, which is inclined to the north at an angle of 10°—20°, and becomes more coarse-grained toward its upper part, finally passing into a conglomerate. A thin coal-seam about 3 inches thick is found in the lower part. Raised reefs are found on the southern, western and eastern corners of the island. The Dinnacles lie a few miles to the north-east of Hoa-pin-su, and consist of several rocks such as Kita-and Minami-kojima and others, which are chiefly Tertiary sandstone. The sandstone is inclined to the north at 40° on the west of Minami-kojima. Raised reefs are also found on these two rocks, especially on the northern side of Minami-kojima. Chia-u-su lies 15 miles north-east of Hoa-pin-su (lat. 25° 58′ 30″ N and long. 123° 40′ E), and is about 2 miles long and a mile wide. The highest point measures 600 ft. above the sea-level. According to the petrographical examination by Prof. Kotô, the whole interior is a mass of basalt. The Raleigh rock, situated in lat. 25° 55′ N and long. 124° 34′ E, lies about 50 miles to the east of the above-mentioned islands,

† The China Sea Directory. Vol. III., 1894.

† Miya-jima, 黃尾嶼 (Kōbitō)—*The Journal of Geography, Tōkyō*, Vol. XII., No. 144., 1900.

† Kuroiwa, 尖閣列島探險記事 (Note on the Pinnacle Islands)—*The Journal of Geography, Tōkyō*, Vol. XII., No. 141, 1900.

and is 1½ miles long and a mile wide. The highest point rises 270 ft. above the sea-level. Mr. Kuroiwa has found the island to be of an agglomerate-tuff of andesite.

VII. UNINHABITED ISLANDS LYING TO THE NORTH OF FORMOSA.

There are three islands scattered at a distance from 20 to 30 miles north-east of Kelung (Kiirun) in Formosa. The most southern is called Agincourt (Hōkwatō) (lat. 25°38′N, long. 122°5′½ E), and has, according to "the China Sea Directory," a round summit, 540 ft. high, stretching out into high bold headlands on the north and south. All the eastern side is very steep, the western is less so. Pieces of rocks composing the island have been collected and sent to me by Mr. Ōsumi. By the determination of Prof. Kotô, they are found to be hypersthene-basalt and hypersthene-andesite. The Crag (Menkwatō) (lat. 25° 29′ N and long. 122°7′E) lies 9 miles SSE from Agincourt; and is, according to Mr. Saitō,* elongated N-S, with a length of 1640 ft. and a width of 984 ft. The coast generally has steep cliffs. The highest point is in the eastern part of the island and reaches the height of 180 ft. above the sea-level. The whole island is entirely composed of neovolcanic rocks. The volcanic centre is now invisible, but it was probably situated on the east of the highest peak. Basaltic andesite was first erupted, and then a small amount of volcanic ash and breccia deposited upon its sheet. Dykes of the same composition were finally erupted through these rocks. The southernmost island, the Pinnacle (Kwaheitō), lies NE by N of the entrance of Kelung harbour and at a distance of 19 miles from it, that is in lat. 25°26′N and long. 121° 57′E. It is a rugged mass of rock, 170 ft. high, with perpendicular

* 基隆沖無人島踏査報文 (Report on a Trip to the uninhabited Islands lying off the Coast of Kiirun, 1900., *in Japanese*).

sides. The outline is rectangular and the island is elevated 984 ft. above the sea-level. According to Mr. Saitō the rock of this island is also entirely basaltic andesite.

PART IV.—Geology of North Formosa and its Relation to the Riukiu Islands.

North Formosa consists of Tertiary sediments, pierced by andesite at the northern end. The Tertiary strata, which are never horizontal, are, on the whole, comparatively regularly folded. According to Mr. R. Yamashita eight parallel series of coal-seams are exposed in this district.

1st., (the uppermost), The Kusshaku series, with one seam, running through Ōkutsu, north of Kusshaku, Chōsōkei and Gyokō.

2nd., The Shinten series, with two seams, running through the west of Ōkutsu, Shintengai, Sekiteigai and Chōsōkei.

3rd., The Keibi series, with two seams, running through Ōkeikō, Shōsokō, east of Keibigai, Shinkogai, Fūshirin, Sekikan, Sōkei, and Banshikō, and south of Zuihō.

4th., The Shinkyakutei series, with two seams, running through Basozan, Chōhō, Reisuikō, Gyūhō, Nanseikaku, Jūgofun, Rokuchōri, Sanchōri, Nankōzan, Hakuhōshiko, Goto, Shikyakutei, and Shin-ō-kō and south of Hatto.

5th., The Denryōkō series, with four seams, running through Naikokōko, Parenkōkō, Hokukōkō, Yūrakōkō, Kōshinai, Sekikōkō (near Kelung), Denryōkō and Hatto.

6th., The Gwaibokuzan series, with two seams, running through Naikosankyaku (north-west of Shakkō), Jūshifun, Rokuryō, Daiburon, Daikanrin, Naibokuzan and Gwaibokuzan.

7th., The Kankyaku series, with two seams, running through Kentan (near Taihoku), Hasshirin (Pachinā), Kankyaku and Basokukōkei.

8th., The Intanshinai series with two seams, running through Kirigan, Sankakuhō, Intanshi (south of Kinpōri) and Hattoshi.

Mr. Yamashita has found two anticlinal and three synclinal foldings in the eastern part, and one anticlinal and two synclinals in the western part. All their axes run E-W, but most of them can not be traced from one end to the other of the district observed; the sole exception being a synclinal which runs through the south of Chōsōkei, the north of Heirinbi and the south of Shintengai. The Tertiary rocks, on the north of this axis, which show the above mentioned small folds, are *mostly* inclined to the south, while those in the southern half are *almost always* inclined to the north. Besides there are, in the north, all of the seams; but in the south, there was found only the uppermost seam near the synclinal axis. Though the greater part of the region in the south is now difficult to traverse on account of the wildness of the aborigines, yet it is probable that there are very scanty coal-deposits in that region. In the north, many limestone layers and several fossils are found. In the south, it is not yet reported that limestone exists, and fossils are moreover very rare. Rocks found in the north are mostly shale or fine-grained brownish sandstone, both being shallow-sea deposits. In the south, the uppermost strata are brownish shale, in which nodules are more abundant towards the lower part, which is irregularly split up into angular fragments. This part, which is slate-like, finally passes into clay slate which is in all exposures conformable with the shale. The annexed figure (Fig. 10) shows a profile, found in the northern half of the Tertiary region.

In these rocks there can not be distinguished any particular horizon either by fossil contents or by petrographical characters. The limestones which are found in Ajukō, Shakokō, Reisuikō, Yūra and between Sanchōri and Shinkōgai, are mostly more than 10 ft. in thickness, but at Yūra they are only a few feet thick. *Lithothamnium rosenbergii* Martin predominates as in the limestone of Ishigaki-jima. I found in the Tertiary rocks in several places in this northern portion the following fossils, which were partly determined by B. Newton and R. Holland* and partly by myself:

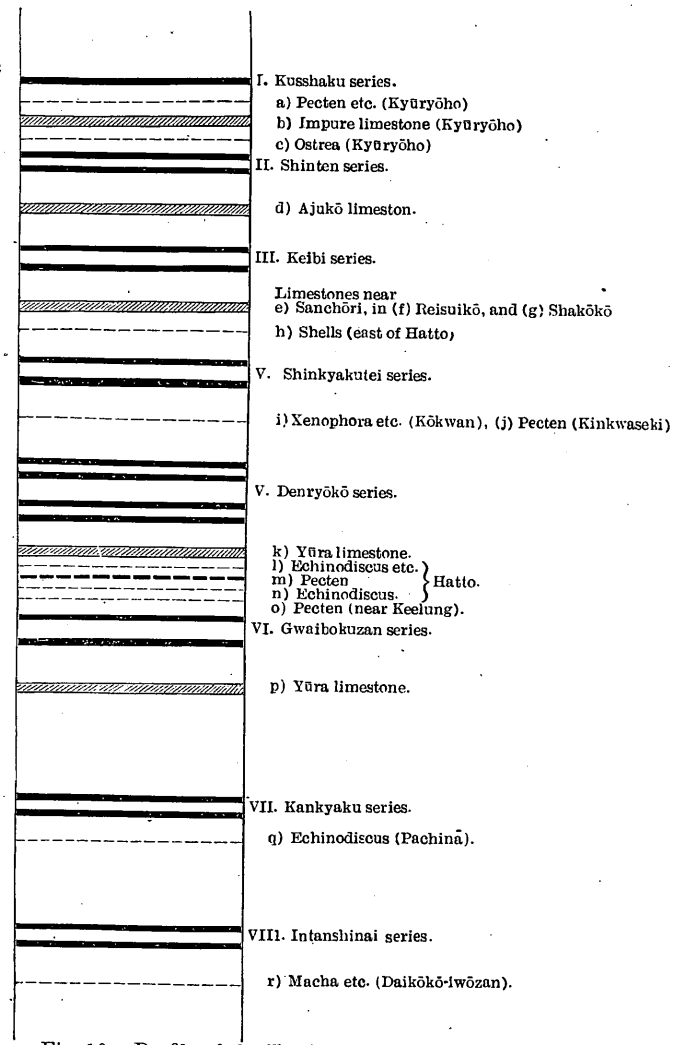


Fig. 10.—Profile of the Tertiary rocks on the northern side of their principal synclinal axis, with various limestone and coal beds and fossil horizons.

* Newton and Holland, Notes on microscopic Sections of Limestones from Formosa.—*The Journ. Geol. Soc. Tōkyō*, Vol VII., No. 81, 1900.

I collected peculiar large cone-shaped fossils from Sekiteigai and Shakōkō. Prof. Kotô sent them to Dr. R.B. Newton for determination, and has been recently informed that they belong to Cellepora in Bryozoa.

a) Kyūryōho (sandstone): *Pecten placunoides* Martin, *Ostrea sp.*, *Arca α sp.*, *Arca β sp.*, *Venus sp.*

b) Kyūryōho (impure limestone): indeterminable shells.

c) Kyūryōho (sandstone): *Ostrea sp.*

d) Ajukō (limestone): indeterminable shells.

e) Between Sanchōri and Shinkōgai (limestone): *Lithothamnium rosenbergii* Martin, *Globigerina bulloides*, *Bigenerina sp.*, *Textilaria sp.*, *Orbitoides verbeeki* New. and Hol., *Heterostegina sp ?*, *Valvulina sp ?*

f) Reisuikō (limestone): *Lithothamnium rosenbergii* Martin, *Gypsina inhoerens* Schultze (?), *Linderina sp* (?)., *Miliolina sp.*, *Pecten placunoides* Martin, *Ostrea sp.*, Coral, Echinoid.

g) Shakōkō (limestone): *Lithothamnium rosenbergii* Martin, *Gypsina inhoerens* Schultze (?), *Gypsina sp.*, *Linderina sp.*, *Textilaria sp.*, *Micheliniana sp.*, Sponge, Coral, Echinoid, *Pecten placunoides* Martin, *Ostrea sp.*

h) East of Hatto (sandstone): indeterminable shells.

i) Kōkwan (shale): *Xenophora sp.*, *Ranella elegans* Martin, *Yoldia sp.*

j) Kinkwaseki (sandstone): *Pecten placunoides* Martin.

k) Yūra (limestone): *Lithothamnium rosenbergii* Martin, *Linderina sp.*, Echinoid.

l) Hatto (sandstone and shale): *Echinodicus formosus* Yosh., *Astriclypeus integer* Yosh., *Dolium sp.*, *Voluta sp.*, *Cerithium sp.*, *Natica sp.*, *Dosinia sp.*, *Venus sp.*, *Pecten placunoides* Martin, *Arca sp.*

m) Hatto (calcareous sandstone): *Pecten placunoides* Martin.

n) Near Hatto (sandstone): *Echinodiscus formosus* Yosh.

o) Near Kelung (sandstone): *Pecten placunoides* Martin.

p) Yūra (limestone): *Pecten placunoides* Martin.

q) Pachinā (sandstone): *Echinodiscus formosus* Yosh.

r) Daikōkō-iwōzan (sandstone): *Macha sp.*, *Arca sp.*, Coral. In the southern half of the island I have found a tectonic different from that in the northern half. In the eastern part of the former we find a shale with a little sandstone as at the southern foot of Sōrei. Then toward Taikeishō, the rock is found to be chiefly bluish shale with nodules. Thence to Kōfunshō, it shows a fracture with spindle-shaped fragments. Bluish shale, with a few layers of quartzose sandstone and hard sandstone, is then exposed on the south of Kōfunshō. In this shale, whose exposures on the north of Giran have been described by Mr. Ishii as "Mesozoic slate," I have collected *Tellina* and *Schizaster* at Fukutokkō. The latter is a form found in all rocks from Tertiary to Recent. Thus the boundary between the Tertiary and older rocks must be found to the south of Giran.

The geology of North Formosa shows a connection with that of the Saki-shima group. (1) Many coal-seams of the same character are common to both. Though they are less in number and thickness in Iriomote-jima (Saki-shima group), yet they are all found in the same fine-grained brownish sandstone in Formosa as well as in Saki-shima. Yonaguni-jima lying between Formosa and Iriomote-jima, as well as Miyako-jima, have traces of the same coal-seams. (2) Though fossils are rather scanty in both regions, I found in Formosa and Iriomote-jima, the characteristic *Echinodicus* and *Astriclypeus* in a rock lying between the coal-seams. The Echinoid found close to the coal-seams in Yonaguni-jima is probably of the same species. (3) The typical species of *Pecten* occurring with *Echinodiscus* in Formosa, is also abundantly found in Miyako-jima. (4) The Tertiary of Formosa has the strike E-W, thus the strata running towards the Saki-shima group, whose western part is opposite to Formosa, are entirely Tertiary.

The *Echinodiscus* is a form found from Miocene to Recent, and

my specimens of it closely resemble *E. placenta* Duncan and Sladen* from the Miocene of India. But the latter species has broader lunules running in a line through the apical system to the tip of the petals; the petals are open and have less numerous ambulacral pores; and the tip of the petal is very distant from the lunule. Our species of *Echinodiscus*, as well as of *Astriclypeus* were erroneously described by Prof. Lebour as *E. bioculatus* Ag. and *E. bisperforatus* Leske.† The largest specimen of *Echinodiscus* in my collection has a diameter of 140mm. I propose for it the new specific name *E. formosus* with the following diagnose.

Test thin, flat, very slightly raised dorsally; broadly ovoid; widest posteriorly, not so strongly truncated as *E. bioculatus* Ag. Apical system nearly central, madreporite central, polygonal; four genital pores exsisting in the basal plates. Petals nearly closed; anterior longest. The length, breadth, and number of the pores in each petal in a specimen of about 100 mm. diameter are as follows:

	Length of petal. mm.	Width of petal. mm.	Number of pores.	Width of poriferous zone. mm.
Odd ambulacrum.	25.	11.5	75	4
Anterior paired ambulacra.	22.5	11.5	67	4
Posterior paired ambulacra.	22.5	11.5	67	4

Lunules two, one in each posterior ambulacral space; large and elliptical; 13.5 mm. in length and 9 mm. in width in the same specimen; these becoming more elongated in the older specimens: larger axis of lunule making about 30° with the median line of the ambulacrum. Distance from the tip of petal to the lunule only 5 mm. Peristome central, very small; groove single near peristome, and soon bifurcating.

* M. Duncan and W.P. Sladen, The fossil Echinoidea from the Gáj or miocene Series —*Mem. Geol. Survey. India*, Ser. XIV., Vol. I. 3., Fas. V. 1885.

† G.A. Labour, Note on some Fossils from North Formosa. &c.—*Trans. North Eng. Inst. of Mining and Mechanical Engineers.* Vol. XXXIV., Part. I., 1885.

Astriclypeus integer Yosh., found with *Echinodiscus* in Formosa and Iriomote-jima has been also found from the Miocene Tertiary near Mizuho-mura, Prov. Kai in Honshū. Near this place, there is found a limestone filled with *Orbitoides*. Nearly similar *Orbitoides* were collected by me in greater numbers from the limestone in Iriomote-jima. R. B. Newton and R. Holland have mentioned† that the *Lithothamnium* in the Tertiary of Formosa belongs to the same species as those in the Miocene of Timor. Thus the Tertiary sediments of the Saki-shima group and of the northern part of Formosa are of the same horizon belonging to the Miocene.

According to earlier investigations by many geologists, the main part of Formosa, consisting of slate, granite, Palæozoic limestone and Archean (?) rocks, is surrounded by Tertiary sediments mainly developed on the north, east and west coasts. The limestone and granite are no doubt the same as those in the Riukiu Curve. I found also many blocks of pyroxenite-like rocks from the neighborhood of Giran in Formosa. The greater part of Formosa is of clay slate, whose age is still unknown, but may be regarded as Mesozoic and Palæozoic. No indisputably Mesozoic rocks have yet been discovered in the island.

PART V.—Conclusion.

The Riukiu Curve consists of a number of islands, forming a long arc between Kyūshū and Formosa. The difference in longitude of the two extremities of this arc is about twice that measured in Kyūshū, while the difference of latitude is thrice that in Kyūshū. The sedimentary rocks in the Curve are never horizontal, showing usually a

† Newton and Holland, Note on microscopic Sections of Limestones from Formosa, &c.—*Jour. Geol. Soc. Tōkyō.*, Vol. VII., No. 81, 1900.

regular inclination, and are limited to definite zones. The raised reefs, which are found in various districts, are however quite horizontal. Only the Tertiary rocks in the northern half are rather irregularly inclined, sometimes being horizontal. The principal rocks of the Curve are the Palæozoic, in which limestone and compact quartzite show the occurrence different from slate, sandstone, and pyroxenite or amphibolite. The latter series of rocks are found in a zone running through Ōshima, Tokuno-shima, Okinoerabu-jima Yoron-jima, Okinawa-jima, the Kerama subgroup, Ishigaki-jima and Iriomote-jima. The former are found on the western side, namely in the western part of Ōshima, the Iheya subgroup, the tongue-shaped western region of Okinawa-jima, in its dependent isles, Ie, Sesoko, Yagaji and Kouri, besides in Ishigaki-jima and Taketomi-jima. Both series are all regularly inclined. Thus in Ōshima and Okinawa-jima, they have the strike parallel to the length of the island and the dip toward the west. In Tokuno-shima, Okinoerabu-jima and others, we find either the same strike of rocks or the longer axis of the island parallel to the Riukiu Curve. The islands of the Iheya subgroup are arranged parallel to the Curve. Though the rocks in the Yaeyama subgroup have been partly disturbed by volcanic eruptions, yet they show on the whole regular dips. A continuation of the above mentioned Palæozoic rocks is also found in Formosa, in the interior of which slate prevails and other rocks are of limited occurrence. The above-mentioned systems of rocks belong to the so-called *median row* of islands in the Riukiu Curve.

Erupted through these rocks, there are various Pre-tertiary igneous rocks, the chief of which are granite and diorite, found in Yaku-shima, Ōshima, Tokuno-shima, Ishigaki-jima and Hoa-pin-su. Similar granite is found near Giran in Formosa, and in the south-eastern part of Kyūshū.

The formation of the Curve has been explained by Prof. Kotô, as due to the depressions of the Tung-hai ("East Sea" of China), which took place mostly in the Tertiary period. Thus the greater part of the Palæozoic rocks in the above mentioned islands is inclined to the west. Sometimes the strike of the beds, and sometimes the longer axes of islands, are parallel to the direction of the Curve. The fissure of volcanic eruptions, which is continued to the series of Kyūshū volcanoes, such as Kiri-shima, Sakura-jima and Kaimon, is found on the *inner side* of the sedimentary zones of the Riukiu Curve, and is traceable through the islands, Take-shima, Iwō-jima, Kuro-shima, Kuchinoerabu-jima and the Tokara group, and further to Tori-shima on the west of Tokuno-shima, Aguni-jima and Kume-jima in Okinawa (Pl. II). The probable south-western prolongation of this great fissure is through the uninhabited islands on the north-east of Formosa, through Daiton-zan in the same island and the Hōko group (Pescadores). The volcanic rocks in Ishigaki-jima have an aspect different from those in this line of eruption and may perhaps be continuous with those in the southern Pacific Ocean. There must be some fissures, running from south to north, in the sea between Formosa and the Saki-shima group. They were probably caused by a pressure independent of that which folded the Riukiu Curve; and the volcanic rocks in the Yaeyama subgroup and those of the other islands in the Curve may belong to different periods, the former being older. The thick beds of Iriomote-jima were probably raised by a volcanic eruption in the Yaeyama subgroup. Limestone and sandstone, of the same age as this eruption, have been deposited in Ishigaki-jima, alternating with agglomerate-tuff. In Ishigaki-jima, the Tertiary as well as the Palæozoic rocks have not been disturbed by volcanic action, and remain equally inclined in the same direction with the strike nearly E–W, the direction of which does not coincide to the longer

axis of the island. The arrangement of islands in the subgroup and their stratification of rocks are probably due to the last folding of the Riukiu Curve.

The *outer* sedimentary zone of the Riukiu Curve is made up of Tertiary sediments, and extends through Tanega-shima, Kikaiga-shima, the islands lying on the east of Okinawa, and the southern part of Okinawa-jima. Some islands are elongated from north to south, and Tanega-shima, Kikaiga-shima and others have the strike of rocks coinciding with the direction of the Curve. Comparing the character and stratification of the Tertiary of the above regions on the one hand, with those of Formosa and the Yaeyama subgroup on the other, I have found the following differences. (1) The rocks are, in the former, loose sandy shale, without any hard rocks or limestones such as are found in the latter. (2) There are, in the former, very small fossils, mostly of existing forms, in contrast with those in the latter. (3) There are brown-coal seams in the latter, while in the former we find lately appearing remains of wood in Okinawa-jima and a few other islands. (4) The rocks in the former are very irregularly inclined, and sometimes are quite horizontal as in some places in Okinawa-jima. Thus the Tertiary of the northern half of the Riukiu Curve is probabry later than that of the southern half which belongs to Miocene. In this curve the deposits later than the Tertiaries are only the raised coral reefs, with Recent coral-reefs, sand &c. As mentioned in my "note on the raised coral reefs in the Riukiu Curve" (1901), the raised reefs are horizontally bedded, but quite irregularly distributed, thus showing that the folding of the Curve had taken place before the building of the reefs. The distinct zones of rocks, (namely, the inner neovolcanic, the median Palæozoic, and the outer Tertiary,) coincide with those in the Peninsula of Malacca, the Andaman Isles and the Nicobar Isles in the Indian Ocean, with the Banda Isles, in

the East Indies, and with the Lesser Antilles in the West Indies. Though our islands have been only slightly disturbed by volcanic action in the southern part, yet they show the type of folded mountain with parallel structure, as already treated in the preliminary note of Prof. Kotô, and ascertained by my own observations in nearly all the islands of the interesting Riukiu Curve.

March 1901.

PLATE I.

Plate I.

Geological Map of the Ōshima Group.

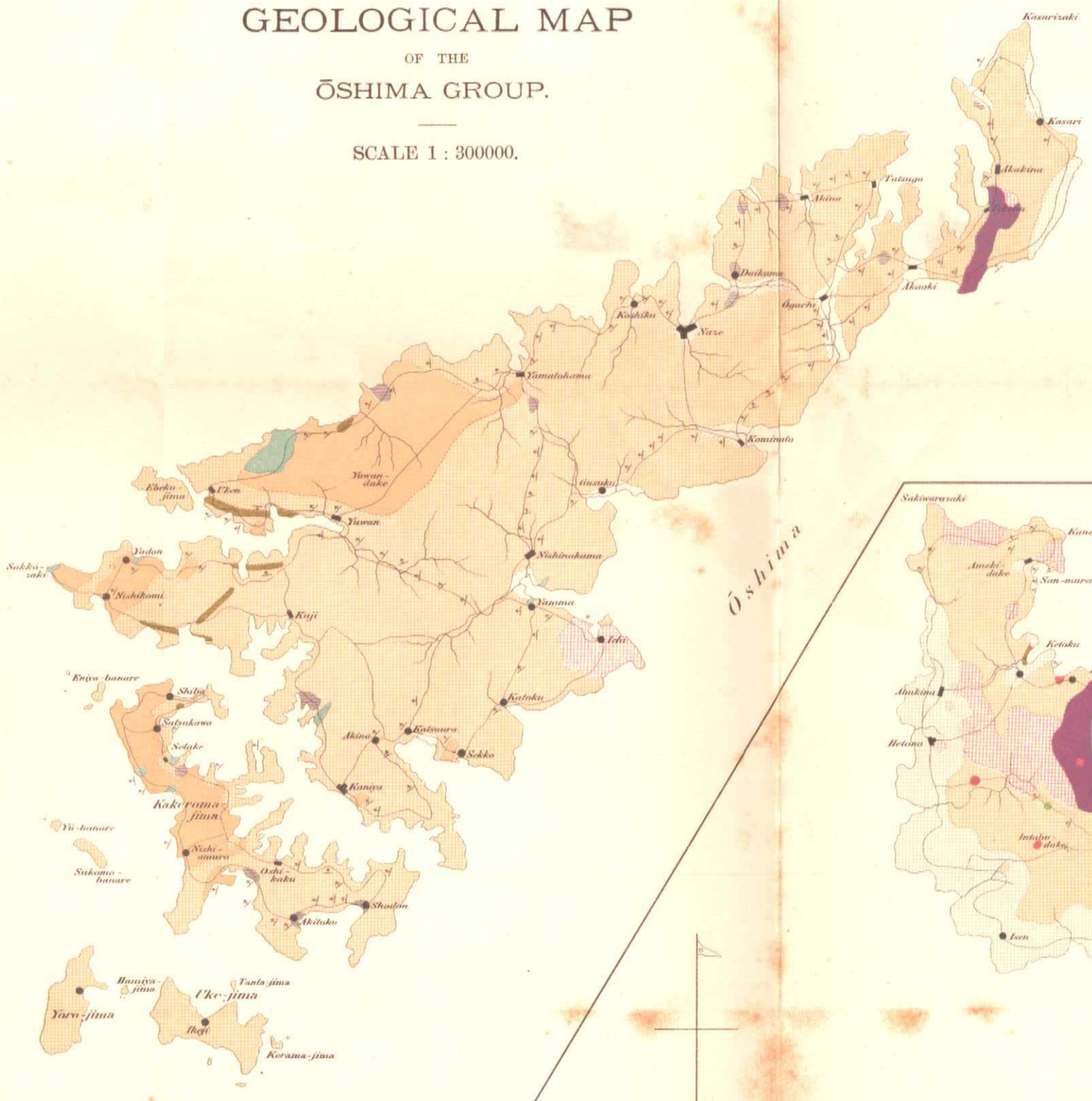
Scale 1 : 300.000.

GEOLOGICAL MAP

OF THE

ŌSHIMA GROUP.

SCALE 1 : 300000.



LEGEND.

- Palaeozoic clayslate, sandstone, and pyroxenite or amphibolite.
- Palaeozoic compact quartzite.
- Palaeozoic schalstein.
- Palaeozoic limestone.
- Tertiary deposits.
- Raised coral reef.
- Alluvial deposits.
- Granite.
- Diorite.
- Porphyrite.
- Quartz-porphyry.
- Serpentine.

Yoshiwara, Geologic Structure of the Riukiu Curve.

PLATE II.

Plate II.

Map of the Riukiu Curve.

Scale 1 : 3.000.000.

Geological Map of the Okinawa Group (excluding the Kerama and Iheya Subgroups, Kume-jima, Tonaki-jima, Aguni-jima, and Tori-shima.)

Scale 1 : 200.000.

LEGEND.

- Alternation of Palaeozoic clayslate, sandstone, and pyroxenite or amphibolite.
- Palaeozoic clayslate.
- Palaeozoic pyroxenite or amphibolite.
- Palaeozoic sandstone.
- Palaeozoic compact quartzite.
- Palaeozoic schalstein.
- Palaeozoic limestone.
- Tertiary deposits.
- Raised coral reef.
- Alluvial deposits.
- Diabase.
- Porphyrite.

GEOLOGICAL MAP

OF THE

OKINAWA GROUP.

SCALE 1 : 200000.

MAP

OF THE

RIUKIU CURVE

SCALE 1 : 3000000.

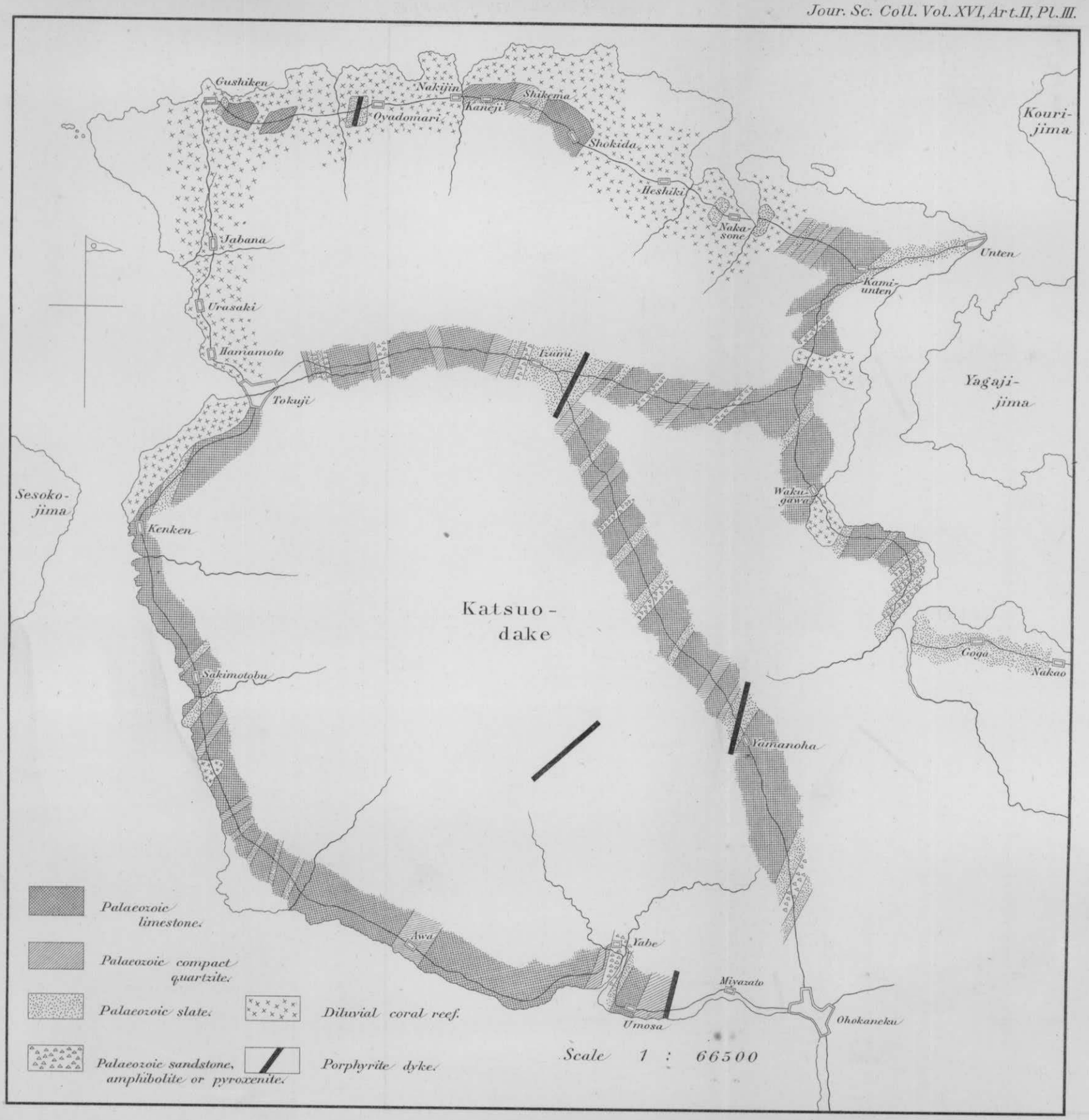
Yoshiwara, Geologic Structure of the Riukiu Curve.

PLATE III.

Plate III.

Geological Map of the Yaeyama Subgroup (excluding Yonaguni-jima.)

Scale 1 : 200.000.



Yoshiwara, Geologic Structure of the Riukiu Curve.

PLATE IV.

Plate IV.

Geological Exposures observed in the Motobu Region, Okinawa-jima.

GEOLOGICAL MAP

OF THE

Yaeyama Subgroup

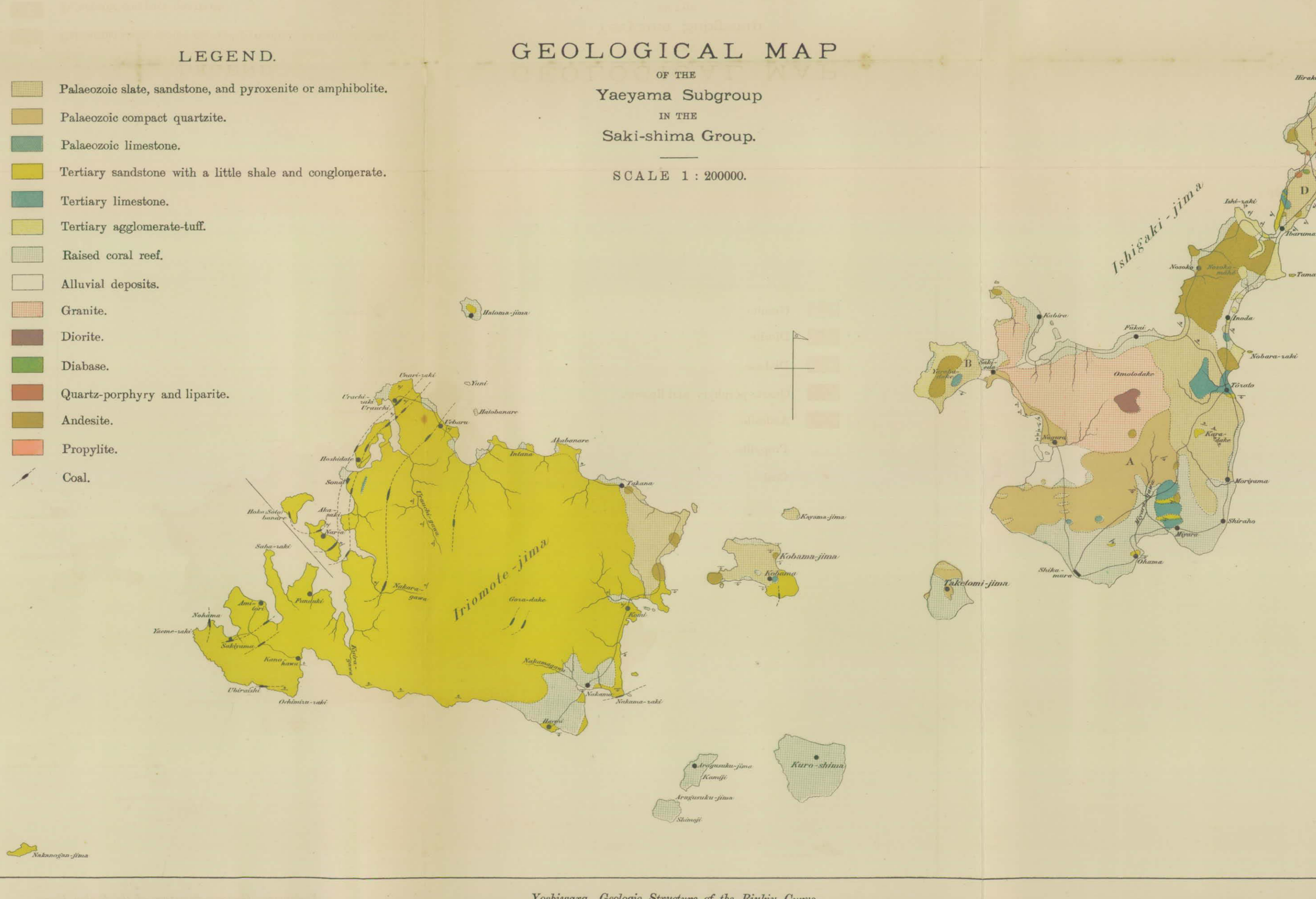
IN THE

Saki-shima Group.

SCALE 1 : 200000.

LEGEND.

- Palaeozoic slate, sandstone, and pyroxenite or amphibolite.
- Palaeozoic compact quartzite.
- Palaeozoic limestone.
- Tertiary sandstone with a little shale and conglomerate.
- Tertiary limestone.
- Tertiary agglomerate-tuff.
- Raised coral reef.
- Alluvial deposits.
- Granite.
- Diorite.
- Diabase.
- Quartz-porphyry and liparite.
- Andesite.
- Propylite.
- Coal.



Yoshiwara, Geologic Structure of the Riukiu Curve.

PLATE V.

Plate V.

Fig. 1.—View of Ishigaki-jima, seen from Taketomi-jima.

Yarabu peninsula (andesite, agglomerate-tuff, and Palæozoic slate, sandstone &c.)

Omotodake (granite).

Bannā-and Maise-dake (Palæozoic compact quartzite &c.).

Region near Kwannon (Palæozoic compact quartzite).

Region near Shikamura (raised coral reefs).

Fig. 2.—View of the Northern Side of Yonaguni-jima.

Raised coral reefs.

Tertiary sandstone.

Fig. 1.

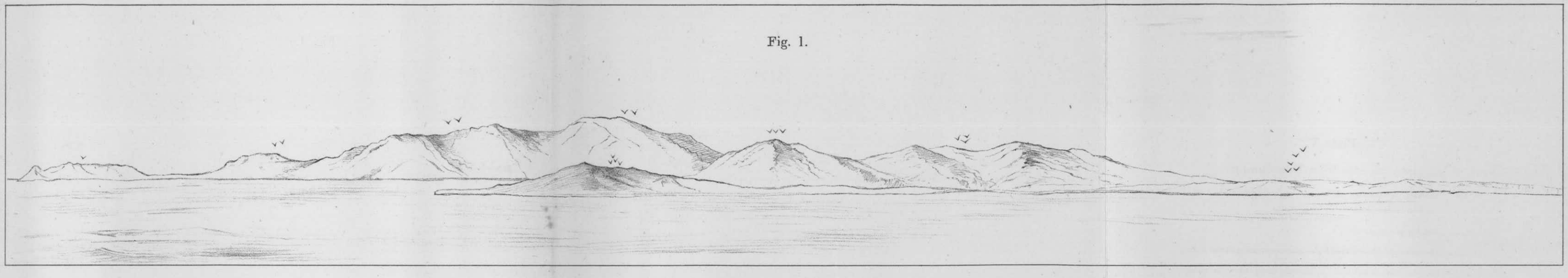
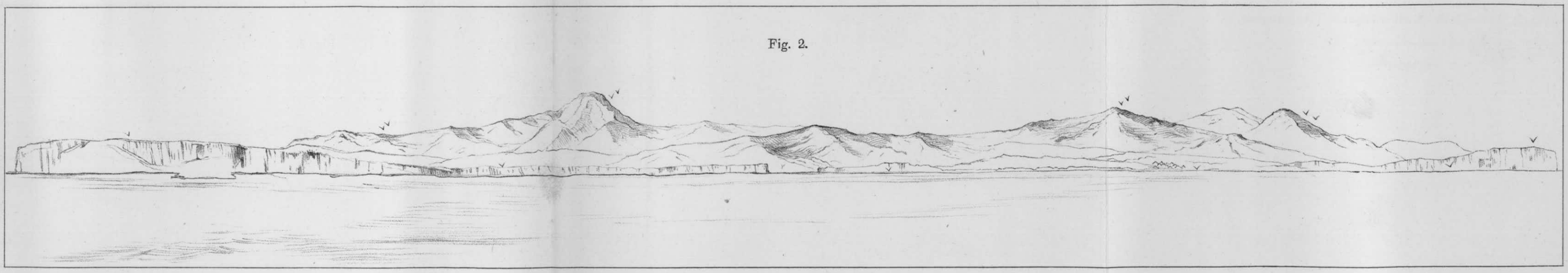


Fig. 2.



Yoshiwara, Geologic Structure of the Riukiu Curve.