THE GEOLOGY AND MINERAL RESOURCES

OF THE

JAPANESE EMPIRE

IMPERIAL GEOLOGICAL SURVEY OF JAPAN

TOKYO, 1926

PREFACE

Since the "Geological Map of the Japanese Empire" on the scale of 1 : 1,000,000, and the "Outlines of the Geology of Japan" which accompanied it, were published in 1902, twenty-four years have elapsed. Even the publication of the "Geological Map of the Japanese Empire" on the scale of 1 : 2,000,000, took place fifteen years ago. In the mean time, our knowledge of the geology of the country had advanced so far that we needed a new map and a text brought up to date. While this was under consideration, we were informed last year that the International Geological Congress would be held in Madrid in May, and that the Pan-Pacific Science Congress would meet in Tokyo in October and November, both in this year. Accordingly, in order to avail of this opportunity, we determined to publish a revised edition of the geological map on the scale of 1 : 2,000,000, and also a text dealing with the geology and mineral resources of the Japanese Empire in general. In this attempt the members of the Survey have been engaged in co-operation with the Geological Survey of Korea, and have been so fortunate as to succeed in bringing their work to its final completion. Chapters of the text, except the one on Korea, were assigned to the several geologists of the Survey, and were afterwards edited by myself.

Sincere thanks are due to various authors, whose valuable publications we have consulted freely and to whom, accordingly, we are under great obligations.

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PART I
GEOLOGY AND MINERAL RESOURCES OF JAPAN

GENERAL REMARKS

The Empire of Japan, off the eastern coast of the Asiatic continent, stretches from 119° 20′ to 156° 32′ E. Long. and 21° 45′ to 50° 56′ N. Lat. Its long chain of islands extends over 4,700 Km. in graceful curves forming three arcs, viz.: Ryūkyū, Japan Proper, and Chishima. The three arcs, in combination with the peninsulas of Korea and Kamtchatka, and the Island of Saghalien, enclose successively the Eastern China Sea, the Sea of Japan and the Okhotsk Sea.

From a geological point of view, the islands of the Japanese Empire are nothing but the summits of a great mountain system that flanks the Pacific side of the Asiatic continent, from which they were detached by the depression of the intervening seas. Consequently the country is devoid of extensive plains and in most parts its features are mountainous.

Along the whole length of the chain from Hokkaidō to Taiwan (Formosa), the geological structure of the islands reveals the existence of two parallel zones curving towards the northwest. Of these, the one that lies on the convex (Pacific) side is usually called the "Outer Zone," and that on the concave side, the "Inner Zone." In the former, the geological formations, ranging from the Pre-Carboniferous to the Cainozoic, are better developed and more regularly arranged; while in the latter there prevails much complicated structure and various eruptive rocks make their appearance.

Apart from these two zones, Honshū or the Main Island is divided into two parts, "North Japan" and "South Japan," by the "Fuji Volcanic Zone" which traverses the middle of the island from the Pacific Ocean to the Sea of Japan. This volcanic zone represents a great ruptured tract of the land, and where the famous volcano Fuji, and the magnificent cones of Hakoné, Yatsugataké, Myōkō and others were built up. The volcanic chain is traceable further south to Izu Shichitō (Seven Islands), Ogasawarajima (Bonin Islands) and Iwōjima (Sulphur Islands) and even to the Mariana and Caroline Islands.

Thus the islands of Japan may be subdivided into four zones; namely, the "North Inner" "North Outer" "South Inner" and "South Outer." They are not only different from one another geologically and topographically, but also their climates and civilizations are special to themselves.

The lowest or oldest stratified rocks composing the Japanese Islands are the schists system of the Pre-Carboniferous age, which consists of various kinds of crystalline phyllitic rocks. In former times, the gneissose granite which is shown on the geological map as "Schistose granite" and the phyllitic schists mentioned above were respectively regarded as the Archaean gneiss and crystalline schists. Subsequent researches, however, led to the conclusion that the greater part of the gneissose granite is younger than the phyllitic schists as well as the Carboniferous rocks, and is indeed Post-Carboniferous granite which became schistose, through dynamometamorphism, although some part of it may represent the Archaean gneiss.

The age of the phyllitic schists is still uncertain, but as they are usually conformable with the overlying Carboniferous strata, it is quite probable that they are not so old as the Archaean. Accordingly, for the sake of convenience, they will be described as Pre-Carboniferous under the Palaeozoic, until the determination of their ages be established.

The Carboniferous and Permian formations are made up of a group of slate, sandstone, quartzite, schalstein and limestone with certain fossils. Granite, diorite, gabbro and diabase are eruptive rocks intruding these formations.

In the Mesozoic formation, the Triassic and Jurassic sediments are limited in extent. The Cretaceous, however, is tolerably well-developed in many places from Saghalien to Kyūshū, and consists chiefly of alternations of sandstone and slate, occasionally intercalating schalstein layers. The eruptive rocks in this formation are granite, porphyrite, gabbro and serpentine.

During the Cainozoic Era, especially in the Tertiary Period, volcanic activity was intense throughout the country. Liparite, andesite and basalt were erupted in several places, and their various tuffs are widely distributed in North Japan. That the volcanic activity continued into the Quaternary Period is evident from the volcanic sediments in the Pleistocene strata, and from numerous volcanic cones, many of which have displayed fearful activity within historical times. Some of these volcanoes still remain more or less active.

The sedimentary formations and contemporaneous igneous rocks occurring in Japan may be tabulated in chronological order as in Table I.

Table I.

Sedimentary Formations			Igneous Rocks
Cainozoic	Quaternary	Recent Pleistocene { Loam / Terrace Deposits	Liparite, Andesite, Basalt.
	Tertiary	Pliocene; Musashino Formation, Tertiary of Tanabe, Kakegawa, etc. Plant fossil Bed of Mogi, Upper Tertiary of Hokkaidō. Miocene; Plant fossil Bed of Itsukaichi, *Orbitoides*-Limestone of Nakaozaka, Shiramizu (coal-bearing) Series of the Jōban District, Middle Tertiary of Hokkaidō. Oligocene and Eocene; Lower Tertiary (Coal-bearing Series) of Hokkaidō, Coal-bearing Series of Northern Kyūshū, *Nummulites*-Beds of Ogasawara and Ryūkyū.	Liparite, Andesite, Basalt.
Mesozoic	Cretaceous	Senonian-Gault; Futaba Series, Izumi Sandstone, *Trigonia*-Sandstone and *Ammonites* Beds of Hokkaidō. Neocomian; Lower Bed of Miyako Series, Ryōseki Series and Torinosu Limestone.	Granite, Quartz-porphyry, Diorite, Diabase, Porphyrite, Peridotite, Gabbro.
	Jurassic	Malm; Upper Shizukawa Series, Tetori Series, Dogger; Middle Shizukawa Series, Liasssic; Lower Shizukawa Series.	Porphyrite.
	Triassic	Rhaetic; Plant Bed of Yamanoi. Noric; *Pseudomonotis*-Beds. Ladinic; *Daonella*-Beds of Rikuzen and Tosa, Anisic-Skytic; *Ceratites*-Beds.	Porphyrite.
Palaeozoic	Permian and Carboniferous	Upper and Middle divisions of the Chichibu System.	Granite, Diorite, Diabase, Gabbro, etc.
	Pre-Carboniferous	Mikabu Series (Lower division of the Chichibu System), Sambagawan Series.	Granite, Amphibolite, Serpentine.

The areas covered respectively by the sedimentary groups and the igneous rocks are roughly estimated as follows:—

	Sq. km.	Of all Japan
Palaeozoic	75,426	16.39 %
Mesozoic	46,498	10.11 "
Tertiary	93,276	20.27 "
Quaternary	90,101	19.59 "
Older Igneous Rocks	73,673	16.02 "
Younger Igneous Rocks	81,048	17.62 "
	460,022	100.00

It is clear from the above figures that the area covered by the Cainozoic Group and younger igneous rocks occupies nearly two-thirds of the total area of Japan.

As for important mineral deposits, the metalliferous veins or masses of gold and copper ores, coal and petroleum are found almost exclusively in the Tertiary rocks. The chief exception is cupriferous pyrite in bedded form, which is characteristic of the Palaeozoic phyllitic schists or clayslates.

CHAPTER I

SEDIMENTARY FORMATIONS

Japan seems to lack the Archaean Group. The oldest sedimentary formation found is the Palaeozoic, and thereon the Mesozoic, Tertiary and Quaternary occur in successive order.

PALAEOZOIC GROUP

The Palaeozoic Group may be divided into

I Pre-Carboniferous
II Carboniferous
III Permian
IV Ryōkê metamorphics.

The Pre-Carboniferous is a series of crystalline schists and is covered conformably by the Carboniferous strata. The rocks in the upper part of the schist series are chiefly pyroxenite and phyllites, and they pass gradually into the Carboniferous rocks. The boundary between the Carboniferous and the Permian is also obscure ; in most cases, they seem to form a continuous Permo-Carboniferous Series. Biotite-gneiss and biotite-schist, found in contact with schistose granite, are mainly metamorphosed products derived from Palaeozoic rocks, and are specially classified as Ryōkê Metamorphics.

I. PRE-CARBONIFEROUS SYSTEM

BY K. ISHII

As stated above, the rocks of this system consist of crystalline schists of various kinds in the lower horizon ; while in the upper they are pyroxenite or amphibolites with phyllites, intercalating limestone and quartzite layers. According to Dr. B. Kotō, the system is divided into the two series :

(A) Sambagawan Series (crystalline schists)
(B) Mikabu Series (pyroxenite and phyllites)

(A) SAMBAGAWAN SERIES

Dr. Edmund Naumann first applied the name, The Crystalline Schists System, to the group of the metamorphic schists, as petrographically and stratigraphically distinct from the gneissic schists, that is the Ryōké Metamorphics.

The Sambagawan Series comprises various schists of a phyllitic or highly schistose aspect with the characteristic components such as sericite, chlorite, epidote, glaucophane, piedmontite, etc., but almost free from biotite. They are accompanied by basic eruptives such as serpentine, gabbro and garnet-amphibolite, but not by granite. Although the rocks of the Sambagawan are clearly distinguishable from those of the Ryōké Metamorphics (with the exception of amphibole-schist in the chlorite-schist series, a rock allied to that which occurs in the Ryōké Metamorphics), the distinction between the Sambagawan and the Mikabu which consists of pyroxenite and phyllites, is not always clearly marked.

The rocks belonging to this Series are distributed over the islands of Honshū, Shikoku, Kyūshū, Taiwan, Ryūkyū and Saghalien, traces of them also being reported from Hokkaidō.

(1) KARAFUTO (JAPANESE SAGHALIEN): In Karafuto the Sambagawan occurs along the east side of the median depression, occupying a certain area in the north-western part of the Suzuya Mountains. It trends N-S and is made up essentially of sericite-schist, graphite-schist and chlorite-schist, accompanied by gabbro. These closely resemble the Mikabu; and it is most noticeable that there is no sharp boundary between the Series and the Palaeozoic complex.

(2) HOKKAIDŌ: The Sambagawan is not indicated on the geological map of Hokkaidō. But according to K. Jimbō, such rocks as glaucophane-sericite-schist, garnet-amphibolite, graphite-schist, chlorite-schist, etc. occur sporadically, in scanty exposures and as river pebbles, in a few localities on the eastern flank of the Yezo Mountains.

(3) ABUKUMA MOUNTAIN: A good exposure of a thick series of dark green schistose rocks; designated as the Gozaisho Series by Kotō, may be seen in the valley of the Same-gawa in the central part of the mountains. The rocks closely resemble the amphibolites in the Mikabu. Near Kamimisaka occurs chlorite-schist with piedmontite, which may belong to the Sambagawan.

(4) KWANTŌ MOUNTAIN: The Sambagawan comprises the oldest rocks in these mountains. The rocks are exposed in a thin zone on the north-eastern flank of the mountains with a strike approximately NW-SE. Kotō opened the way for the study of the crystalline schists by a detailed investigation of the rocks in the Chichibu district, which are classified by him as follows:—

Upper Sambagawan:—Epidote-sericite-gneiss

Middle Sambagawan:—Spotted graphite-schist and spotted chlorite-schist

Lower Sambagawan:—Normal sericite-schist intercalating graphite-schist and piedmontite-schist.

Subsequently, Prof. H. Yabé established the successive order of them as follows:—

Upper:— Spotted graphite-schist

Middle:—Sericite-schist and piedmontite-schist intercalating spotted graphite-sericite-schist and occasionally spotted chlorite-amphibole-schist

Lower:— Thick platy graphite-sericite-schist and coarse grained graphite-sericite-schist, rarely intercalating chlorite-amphibole-schist.

Alternations of spotted chlorite-schist and graphite-schist constituting the middle Sambagawan attain a considerable thickness, forming the main bulk of the Sambagawan not only in the Kwantō Mountains, but in other regions as well.

Yabé observed that biotite-schist interbedded in such alternation was a rare exception.

(5) TENRYŪGAWA REGION: A narrow belt of the Sambagawan is exposed in the valleys of the Mibu-gawa and Misakubo-gawa, tributaries of the Tenryū, and on the lower course of the Tenryū between the Akaishi fissure and the Toyokawa fault. In the vicinity of the Misakubo, there is an outcrop showing alternations of spotted chlorite-schist and spotted graphite-schist with piedmontite-schist in the lower horizon. They are overlaid by graphite-phyllite. Near Nishido, on the lower course of the Tenryū, a wide exposure of graphite-phyllite is seen. All the different members of the Sambagawan on the lower course of the Tenryū were studied by S. Nōtomi in 1920–1921. According to him, the whole series is divided into seven zones, viz. (in descending order)

1. Sericite-graphite-schist
2. Epidote-amphibole-schist intercalating thin beds of graphite-schist

3. Graphite-schist intercalating thin beds of chlorite-schist
4. Epidote-chlorite-schist, graphite-chlorite-schist and graphite-schist
5. Epidote-amphibole-schist intercalating thin beds of graphite-schist and graphite-chlorite-schist
6. Graphite-schist intercalating thin beds of epidote-chlorite-schist and chlorite-schist
7. Graphite-schist and graphite-chlorite-schist intercalating thin beds of quartz-schist, limestone, epidote-chlorite-schist and spotted chlorite-schist.

The general strike is NE with the dip NW 40°–60°. A thick bedded mass of pyritic copper ore occurs in this series in the Kuné district.

(6) **KII PENINSULA:** The Sambagawan exposed on the south of the Kino-kawa consists of glaucophane-schist, normal sericite-schist, quartz-schist and piedmontite-schist in the lower portion, and spotted chlorite-schist and spotted graphite-schist in the upper. They are overlaid by graphite-phyllite and pyroxenite of the Mikabu.

(7) **SHIKOKU:** The Sambagawan attains a full development in this island forming the protaxis of the Shikoku Mountain Range. Here the rocks are more varied than those of the Kwantō Mountains, and the stratigraphical successions differ not only from those in the latter, but somewhat also from those in other localities in the island itself.

The Sambagawan is mainly made up of graphite-schist, chlorite-schist, sericite-schist and graphite-sericite-schist, with thin layers of glaucophane-schist, piedmontite-schist and amphibole-schist. Besides them, crystalline limestone, ferruginous quartzite, sericite-gneiss known by the name of the Ōboké-gneiss, and garnet-amphibolite are also observed in the island. The glaucophane-schist and the Ōboké-gneiss are characteristic rocks not found in the Kwantō and Tenryū regions.

Among the schists mentioned above, the first four predominate and their alternations form thick strata throughout the island. In the eastern part of the island, the graphite-sericite-schist prevails instead of the graphite-schist which is common in the western part; while in the middle part the sericite-schist is more common than in the others.

The glaucophane-schist, the piedmontite-schist and the spotted schists serve as a good mark in the stratigraphy of the schist complex.

In the vicinity of Tokushima, in the eastern part of the island, the following grouping was established by Mr. T. Suzuki:

Upper:— Epidote-gneiss, graphite-gneiss, sericite-gneiss

Middle:—Spotted chlorite-amphibolite, spotted graphite-schist
Lower:— Sericite-schist, piedmontite-schist, glaucophane-schist.

In the middle of the island, the following divisions were made by Prof. T. Ogawa: (in descending order)

Besshi Beds

Upper
1. Graphite-schist and chlorite schist
2. Chlorite-schist, graphite-schist and piedmontite-schist

Lower
3. Calc-amphibole-schist, amphibole-schist, garnet-sericite-schist, garnet-amphibolite, chlorite-schist, graphite-schist, glaucophane-schist and piedmontite-schist
4. Sericite-schist.

Ōboké Beds.
1. Chlorite-phyllite and graphite-phyllite
2. Ōboké-gneiss and schist.

In the western part of the island, S. Noda and S. Kōzu determined the stratigraphical succession of the schists as follows:—

Upper
(Chihara Beds)
1. Graphite-schist and chlorite-schist
2. Spotted chlorite-schist
3. Piedmontite-schist, sericite-quartz-schist and chlorite-amphibole-schist
4. Chlorite-schist and graphite-schist.

Middle
(Izushi Beds)
5. Graphite-schist and chlorite-schist
6. Ferruginous quartzite
7. Chlorite-amphibole-schist
8. Chlorite-schist and graphite-schist with zones of sericite-gneiss and piedmontite-calc-mica-schist
9. Piedmontite-schist
10. Chlorite-schist and graphite-schist with intercalations of glaucophane-chlorite-schist.

Lower
(Hizuchi Beds)
11. Graphite-phyllite and chlorite-phyllite
12. Graphite-phyllite with intercalations of sericite-gneiss and limestone
13. Graphite-phyllite intercalating chlorite-amphibolite.

According to the classifications given above, the phyllite group occupies the lowest horizon except in the east. Although it has not yet been determined whether the beds of Hizuchi and Ōbokė are identical or not, it is noteworthy that they closely resemble the Mikabu Series in the Kwantō mountains and occupy the lowest horizon of all the schist series.

The strike of the Sambagawan in Shikoku is E-W in general, but locally it varies between NE-SW and NW-SE.

(8) **KYŪSHŪ:** The Sambagawan reappears on the other side of Bungo Strait in the neighbourhood of Saganoseki, where it consists mainly of graphite-schist with subordinate chlorite-schist and rarely thin limestone. The small outcrop of the schists near *Takahama*, in the western part of the Amakusa Islands, consists of sericite-schist with overlying spotted graphite-schist and spotted chlorite-schist. The strike is N 40°W and the dip is about NE 30°. In *Sonogi Peninsula*, Hizen, the rocks consist predominantly of graphite-schist and subordinately of chlorite-schist and glaucophane-schist.

(9) **RYŪKYŪ:** Our knowledge of the crystalline schists of the Ryūkyū Islands is meagre. The exposures in the Okinawa Islands and in Ishigaki-jima seem to be mainly those of graphite-schist and chlorite-schist.

(10) **TAIWAN:** A long belt of crystalline schists, exposed along the eastern side of the axial range, on the west of the longitudinal valley of Taito, consists of graphite-schist, chlorite-schist and sericite-schist. In general, the strike is in harmony with the trend of the Taiwan Mountain Range, but it changes to E-W in the extreme north with a northward dip, and turns nearly N-S in the south, with a westward dip. A thick crystalline limestone forms the intermediate zone between the Sambagawan and the Mikabu.

(B) THE MIKABU SERIES

Heretofore this Series has been known as the lower division of the so-called Chichibu system, which comprises also the Carboniferous and Permian strata as its upper and middle divisions. It seems more reasonable to separate it from the complex of Carboniferous and Permian, and bring it under the same group as the crystalline schists, if its petrographical character as well as its lack of organic remains is considered. It is chiefly found to occur in the Chichibu district, Shikoku, Chūgoku and western Kyūshū.

The rocks consist essentially of pyroxenite or amphibolite with phyllites, often accompanying limestone and quartzite. The pyroxenite is a compact, fine-grained, gray or dark green rock, more or less fissile, consisting essentially of pyroxene. In an agglomeratic variety of pyroxenite, fragments of rocks of various sizes are contained in a grayish green groundmass. The included rock-pieces are macroscopically dark gray and compact; under the microscope they show a hyalopilitic structure and contain pseudomorphs of tremolite, chlorite, etc. after feldspar, pyroxene and olivine, as in the pyroxenites of Isé, western Kii and Tosa. The pyroxenite, of which Kasayama in the eastern part of the Kwantō Mountains principally consists, contains a glassy substance in thin lenticular form, which shows clearly a fluidal structure. Pyroxenite of this kind may have been derived from volcanic tuffs by metamorphism.

Phyllites are classified into chlorite-, graphite- and quartz-phyllite according to the predominant component minerals, it being often difficult to distinguish them from the Sambagawan schists.

Amphibolite is a fine crystalline, black or dark green rock with a silky lustre and, in the planes of schistosity, has several zones of amygdaloidal vesicules filled with quartz.

(1) **HOKKAIDŌ:** Pyroxenite with crystalline limestone is reported to occur at Kamuikotan in Ishikari, and also blocks of pyroxenite are found in the valleys of the Teshio-gawa and Mitsuishi-gawa.

(2) **ABUKUMA MOUNTAINS:** The chief rocks are amphibolites which correspond to the pyroxenite in other regions. The amphibolites become more crystalline as they approach the schistose granite in the west. In the southern part, a fine white crystalline limestone is interstratified. The strike in the central part is NW, the dip being steeply toward E.

Amphibolite has been found in Taga, and allied rocks near Numata, both in small areas.

(3) **KII AND SHIKOKU:** Pyroxenite and graphite-phyllite are exposed only in the northern part of the peninsula, traversing it from east to west, and extending to Shikoku, keeping the same direction and stratigraphical order.

(4) **CHŪGOKU:** In the environs of Tokuyama and Yamaguchi, phyllitic rocks occur with northward dip.

(5) **KYŪSHŪ:** In the Tsukushi Range of the northern part of Kyūshū, amphibolite with subordinate layers of limestone and mica-schist are found; they often closely resemble the amphibole-schist of the Sambagawan.

II. CARBONIFEROUS AND PERMIAN SYSTEMS

BY T. OGURA

These, taken together, correspond to the Upper and Middle divisions of the so-called Chichibu system and, forming a continuous series, lie directly and conformably upon the Pre-Carboniferous. T. Harada and others recognized the Chichibu system in the Kwantō Mountains, and in it they established three divisions-Upper, Middle and Lower. Such rocks especially those belonging to the Upper and Middle divisions are widely distributed throughout the Japanese Islands and form a series of strata of enormous thickness. The stratigraphical succession of the formation varies in different parts of the country. But the easily recognizable and almost never absent rocks, such as crumpled quartzite and hornstone of various colours, adinole slate, schalstein, radiolarian slate and Fusulina and Crinoidal limestones are marks of correlation.

Fossiliferous limestones with clayslates occurring in the formation are the most important of all the Palaeozic rocks, as they are the only widely spread representatives of the Carboniferous and Permian systems found in Japan. The formation in several districts may sometimes represent the Carboniferous or the Permian only, but in most cases it seems to be recognizable as Permo-Carboniferous. As already mentioned, the Lower division of the Chichibu System is classified as the Mikabu series of the Pre-Carboniferous with the so-called Crystalline Schists.

In the Outer Zone of the Japan arc, the formation is regularly arranged, parallel with and on the outer side of, the older Pre-Carboniferous, while in the Inner Zone it is divided into several blocks distributed in an irregular manner.

Brief local descriptions may be given as follows:

(1) KARAFUTO (JAPANESE SAGHALIEN): The formation here seems to consist of clayslate, quartzite, sandstone, conglomerate, limestone, etc., the strata generally running N–S and dipping 50°–60° W. The stratigraphical and palaeontological studies have not yet been completed.

(2) HOKKAIDŌ: The formation is found on the western flank of the Yezo Mountains along the granite zone of the Hidaka Range, and also in Oshima and Shiribeshi, generally running NE. By far the greater part of the Palaeozoic rocks of the central mountains are of this formation, consisting of sandstone and clayslate with subordinate layers of limestone, schalstein, quartzite, hornstone and adinole slate, with the strike generally

NNW. Along the peripheries of the granite masses of the central mountains, the Palaeozoic rocks are changed into mica-schist and hornblende-schist by contact metamorphism.

(3) **AOMORI DISTRICT:** The Palaeozoic crops out in patches near Kominato in the Shimokita peninsula and near Kotomari in the Tsugaru peninsula. The rocks consist chiefly of quartzite and hornstone with limestone. The strike is ENE.

(4) **KITAKAMI MOUNTAINS:** According to R. Yendo, the formation consists of

Middle Permian	(1)	Clayslate and sandstone
	(2)	*Fusulina* limestone
Perm-Carboniferous	(3)	Clayslate and sandstone
	(4)	*Crinoid* limestone
Upper Carboniferous	(5)	Clayslate and sandstone with non-fossiliferous limestone
Lower Carboniferous	(6)	*Coral* zone
	(7)	Coarse sandstone

Fossils present are: in (2) *Fusulina* limestone *F. amedaei* Deprat, *Maeandrostia* sp., *Mizzia* cf. *velevitina* Schubert; in (3) Clayslate and sandstone, *Lyttonia richthofeni* Kayser em. *H.*, *Richthofenia*, *Productus* sp. *Spiriferina cristata* King; in (6) *Coral* zone, *Lithostrotion pseudomartinis* Y. et H., *Diphyphyllum flexuosum* Y. et H., *Diphyphyllum* sp., *Syringopora geniculata* Phillips, *Lonsdaleia japonica* Y. et H., *Chaetetes* sp.; in (7) Coarse sandstone, *Cyathopyllum*, *Serpula*, *Fenestella*, *Spirifer*, *Euomphalus*, *Conularia*, pygidia of *Phillipsia*-like *Trilobites*, etc. were found in certain localities in this district.

(5) **NIIGATA DISTRICT:** Here the Palaeozoic is separated into many small areas by the granite and other eruptives or by the covering of younger strata. The rocks are mainly sandstone and clayslate, limestone being of rare occurrence. The strata are much disturbed, but NE and NW strikes are prevalent.

(6) **TAGA RANGE:** The rocks are clayslate, limestone and siliceous slate. The strike is NNW, the dip being steeply toward E or W.

(7) **TSUKUBA-YAMIZO RANGE:** The rocks are clayslate and sandstone. The strike is NW in the northern part and NE on the south of Torinokoyama. In the southern part, the rocks are much metamorphosed by the eruptives of Tsukuba.

(8) **ASHIO DISTRICT:** Sandstone, clayslate, quartzits, schalstein and limestone constitute the formation. A specimen of *Helicoprion* has been found in the *Crinoidal* limestone at a quarry south of the Ashio copper mine in Kozuké. It closely resembles *H. Bessonowi* Karpinsky, found in the Permo-Carboniferous Artinsk formation of Russia.

(9) **CHŌSHI PENINSULA:** The Palaeozoic found in patches in the environs of Chōshi consists of sandstone and an alternation of hornstone, clayslate and sandstone intercalated with thin limestone. The hornstone usually contains imperfect remains of *Radiolaria,* and the limestone is characterized by *Neofusulinella Giraudi* Deprat, which is closely allied to the species from the Permian limestone of Indo-China. The sandstone in the south strikes N 50°–75° W or E–W, dipping 25°–60° SSW or S, and the alternations of hornstone, clayslate and sandstone in the north are folded into two anticlines and three synclines, with the strike generally N 50° E.

(10) **CHICHIBU MOUNTAINS:** The Palaeozoic of the Chichibu Mountains appears south of the Pre-Carboniferous zone. The so-called Chichibu System was first recognized here, and was classified as follows:

Upper	1.	Hornstone, clayslate, sandstone
	2.	*Fusulina* limestone
	3.	Upper adinole slate, hornstone (radiolarian slate), schalstein
Middle	4.	Adinole slate, hornstone (radiolarian slate)
	5.	Graywacke sandstone, clayslate
	6.	Lower schalstein, quartzite, adinole slate, limestone with *crinoids* and *corals*
	7.	Adinole slate, radiolarian slate
	8.	Red and green quartzite
Lower	9.	Pyroxenite, amphibolite, serpentine and gabbro

Of these, the Upper and Middle divisions represent the Carboniferous and Permian, while the lower corresponds to the Mikabu Series. The strata are folded into many synclines and anticlines with the strike generally NW.

(11) **AKAISHI RANGE:** The greater part of the range is composed of rocks of this formation, while the hilly tract on the southwest of the range consists of the pyroxenite complex. A large anticline passes through the northeast of Akaishi-yama, the direction being NNE. West of the anticline, a long persistent syncline runs parallel to it.

(12) **KII PENINSULA:** The formation occupies a wide zonal area across the peninsula with the strike generally ENE. *Fusulina* limestone is found at Itokawa in the Arita-gawa district. No sharp line of distinction between the Palaeozoic and the Mesozoic on the south has yet been observed.

(13) **SHIKOKU:** The formation here consists of rocks nearly identical with those of the Kii Peninsula and the Chichibu Mountains. The boundary between the Palaeozoic and the Mesozoic on the south is alse not clearly defined.

(14) **ŌMI DISTRICT NEAR TOYAMA:** The rocks consist of clayslate, sandstone, schalstein, quartzite, adinole slate and *Fusulina* limestone. The limestone is about two kilometers thick and is renowned for its richness in Carboniferous and Permian fossils. According to Prof. I. Hayasaka, they are:

in the lower horizon; *Lonsdaleia floriformis crassiconus* (McCoy) Smith, *Pugnax acuminatus* Mart., *Spiri er humerosus* Phillips, *Syringothyris cuspidata* Mart., etc.

in the middle horizon; *Productus giganteus* Sow. *edelburgensis* Phillips, and *P. semireticulatus* Mart., etc.

in the upper horizon; *Fusulina brevicula* Schwager, *F.* cf. *japonica* Gümb., *Schwagerina* (*Verbeekina*) *deprati*, *Y.*, *Doliolina lepida* Schwager, and *Neoschwagerina craticulifera* Schwager, etc.

(15) **HIDA PLATEAU:** In the Kiso district in the centre of the plateau, the strata consist of

1. Clayslate, sandstone, hornstone
2. Clayslate, hornstone, limestone
3. Clayslate, sandstone, hornstone
4. Clayslate, sandstone with hornstone and limestone
5. Schalstein

Crinoidal and *Fusulina* limestones are found. The strike is WNW in the north but gradually changes to N-S in the south.

According to Dr. B. Kotō, the *Fusulina* limestone of Akasaka near Gifu is divisible into several beds which are as follows:

1. Brecciated limestone, composed of fragments of the limestones below it;
2. Black marble, containing *Bellerophon*, *Murchisonia*;
3. Black earthy limestone, containing *Schwagerina* and *corals*; the former are distributed throughout the rock, while the latter occur in only a part of it,

4. Black limestone, traversed by small veins of calcite and poor in fossils, only rarely containing *Crinoids*, *Fusulina* and *Schwagerina* in certain parts;
5. *Kasumi-ishi*, a white limestone rich in fossils, including large *Fusulina*, *Pleurotomaria*, *Corals*, 2 *Crinoids* and small *Bellerophon*;
6. Dark gray limestone, hard and compact, with a few large specimens of *Fusulina*;
7. *Samé-ishi*, a hard compact gray limestone rich in fossils: abundant *Fusulina japonica* and bivalves;
8. White crystalline limestone, fossilless.

The fossils found here are *Fusulina japonica* Gümb., *F. exilis* Schwager, *Schwagerina verbeeki* Geinitz, *S. craticulifera* Schwager, *Fusulinella* sp., *Lingulina* sp., *Tetrataxis conica* Ehrenb., *Endothyra* cf. *crassa* Brady, *Chimacammina protenta* Schwager, *C. cribrigera* Schwager, besides *Archaeocidaris*, *Poteriocrinus*, *Pentacrinus*, *Trochammina*, *Textularia*, *Favosites*, *Pleurotomaria*, *Bellerophon* aff. *hiulcus* Sow., *Lyttonia richthofeni* Kayser, *Scacchinella*, *Reticularia lineata* Mart., *R. Waageni* Loczy em. Frech., *R.* cf. *inequilateralis*, Gemmellaro.

(16) **TAMBA PLATEAU:** The rocks are similar to those of the Hida plateau. The strike is ENE in the north, NE in the east and NW in the west. *Fusulina* limestone occurs in thick beds.

(17) **CHŪGOKU:** The rocks of the Okayama district are clayslate, sandstone and schalstein, which form thick beds with a general trend ENE to E-W, dipping northward. In the Taishaku district, NE of Hiroshima, the strike of the alternating strata of sandstone and hornstone is ENE, forming anticlines and synclines. *Fusulina* limestone occurs in large areas near Taishaku and Takahashi. Near Iwakuni, the Palaeozoic consisting of clayslate, sandstone and hornstone runs generally E-W with a dip of 30°–60° toward N. The rocks of the formation are altered to mica-schist by contact with granite. In Akiyoshi, NW of Yamaguchi, *Fusulina* limestone forms the most prominent limestone plateau in Japan, showing a karst topography.

According to Y. Ozawa, the following fossils, mostly new species determined by him, occur in the Akiyoshi limestone: *Nagatophyllum satoana*, *Lonsdaleia irregularis*, *Polycoelia japonica*, *Fistulipora nagatoana*, *F. columnaris*, *Dibunophyllum sugosum* var. *smithi*, *Fusulinella biconica*, *Fusulina stoffi*, *Doliolina verbeeki* var. *sphaerica*, *Yabeina mimina*, *Spirillina grandis*; also *Lonsdaleia floriformis crassiconus* (McCoy) Smith, *Fusulinella* *bocki* Möller, *Fusulina muongthensis* Deprat, *Doliolina clanclive* Deprat, *D. lepida* Schwager, *Fenestella perelegans* Meek, *Mizzia velevitana* Schubert, *Sumatrina annae* Volz, etc.

Calamites (*Arthropitys*) sp. was found in the limestone near the Sasagatani mine in Izumo, and is the only plant fossil in the palaeozoic formation of Japan, although a doubtful *Sigillarian* stem of the *Favularia* type from Ichinosẹ near Shizuoka has been recorded.

(18) **KYŪSHŪ MOUNTAIN RANGE** (Central part of Kyūshū): The Palaeozoic traverses the Island of Kyūshū from east to west as a continuation of Shikoku. It is stratified as shown below:

In the eastern part;

1. *Crinoid* limestone, hornstone, conglomerate
2. Schalstein
3. *Fusulina* limestone, hornstone
4. Graywacke sandstone, clayslate, hornstone
5. *Crinoid* limestone
6. Graywacke sandstone, clayslate
7. Schalstein
8. Phyllitic slate, graywacke sandstone
9. Schalstein
10. Graywacke sandstone, clayslate
11. Schalstein
12. Graywacke sandstone, clayslate

In the western part;

1. Black siliceous slate, radiolarian slate, green and brown schalstein, *Fusulina* limestone
2. Graywacke sandstone, clayslate, hornstone
3. Schalstein, green slate
4. White, red and green slaty quartzite

(19) **RYŪKYŪ ISLANDS:** The Palaeozoic in the islands of Ōshima, Naha and Ishigaki consists of sandstone, clayslate, quartzite, limestone and schalstein.

The general strike is parallel to the main axis of each island and is NE-SW.

(20) **TAIWAN (Formosa):** The central mountain range stretching longitudinally from north to south of the island consists of a thick formation composed chiefly of clayslate which is considered to be of the Palaeozoic. A gradual transition to the crystalline schists on the east and

to the Tertiary beds on the west is observed. The rocks in the lower part of the formation are phyllite, quartzite, metamorphosed sandstone and crystalline limestone which may represent the Mikabu Series, while the upper part intercalating thin layers of sandstone may belong to the Mesozoic. The strike coincides in general with the direction of the mountain range. On the east, the strata dip steeply towards the east; while on the west, they form an anticline and a syncline in the neighbourhood of the water-shed, making a rather gentle slope near the boundary of the Tertiary.

III. RYŌKÉ METAMORPHICS

BY K. ISHII

Ryōké Metamorphics comprise chiefly biotite-gneiss and mica-schists frequently intercalated with quartz-schist and crystalline limestone, and rarely accompanied by amphibole-schists. They are usually injected by schistose granites, the so-called Gneiss, and cut again by the younger granites.

Such metamorphics are best developed in the Ryōké district in the Tenryū-gawa region, and the late Dr. Harada first gave to them the name of the " Ryōké Gneiss and Schist " which has since been applied by many geologists to allied rocks found in several other localities. The same rocks in the Abukuma plateau form the " Takanuki Series " of Dr. Kotō.

By far the greater number of such metamorphic rocks seem to have been derived from the rocks of the Carboniferous and Permian, mainly by the contact action of the schistose granites and also partly by dynamometamorphism, and good examples showing the gradual transition between the two are observable in the Tenryū-gawa region, the Kasagi district and the shores of the Inland Sea.

The distribution of the Ryōké Metamorphics is nearly confined to the main arc of Honshū island; in the Inner Zone of South Japan, namely, in the Tenryū-gawa region, Hida plateau, Kii peninsula, Shores of the Inland Sea and sporadically in Oki, Noto and Southern Kyūshū; and in the Outer Zone of North Japan, namely, in the Abukuma plateau and its environs.

Biotite gneiss: This rock consists mainly of quartz, feldspar, and biotite frequently with hornblende, having sillimanite, garnet, muscovite and magnetite as well as graphite as accessories. It is highly schistose and shows a wavy structure under the microscope; still some parts retain the appearance of graywacke sandstone, due to their low crystallinity. Generally the texture of the gneiss is somewhat coarser than that of the mica-schists.

Mica-schists : Essential components are quartz and biotite, not rarely with feldspar and muscovite; while sillimanite, garnet, tourmaline, andalusite, magnetite and graphitic substances occur as accessories. Sometimes the content of sillimanite, garnet, and andalusite attains an amount so considerable as to justify the distinction of the rock by the name of sillimanite-biotite-schist, garnet-biotite-schist, etc.

Quartz-schist : This rarely contains biotite, feldspar or garnet as accessories. In some parts, it has the appearance of hornstone or quartzose sandstone, with intercalations of thin black bands of biotite.

Crystalline limestone : Several contact minerals such as augite, hornblende, garnet and wollastonite are found to occur in this rock.

(1) **TENRYŪ-GAWA REGION :** Ryōké Metamorphics found on the upper course of the Tenryū comprise biotite-gneiss and biotite-schist intercalating several layers of crystalline limestone. Those which lie between the large injected masses of the schistose granites sometimes show clear schistosity; while some found near the eastern foot of Komagatake, where the injection masses are very few, preserve the appearance of the original rocks, and gradually pass into the rocks of the Carboniferous and Permian.

Ryōké Metamorphics as seen in Mikawa between the Yahagi-gawa and the lower course of the Tenryū consist of predominating mica-schists and quartz-schist with poor crystalline limestone, and are cut by the two-mica-granite in forms of dykes and sheets. This complex passes also into spotted biotite-slate and meta-sandstone, probably belonging to the Carboniferous.

Among the mica-schists, the biotite-schist predominates with some modifications as sillimanite-biotite-schist and andalusite-biotite-schist. The sillimanite occurs as usual in the pheripheral zone of the complex which was subjected to the highest metamorphism, while the andalusite is rather more frequent in the spotted biotite-slate. This is the most striking fact in the occurrence of the minerals.

The Ryōké Metamorphics maintain a general strike of nearly N-S on the upper Tenryū, and NE-SW in Mikawa.

(2) **HIDA PLATEAU :** In the Hida plateau occur the so-called orthogneiss, metagneiss and paragneiss.

The orthogneiss is nothing but the schistose granite of other regions; the metagneiss and the paragneiss, including hornblende-gneiss, biotite-gneiss, graphite-gneiss, mica-schists and crystalline limestone, correspond to the Ryōké metamorphics.

In Hida and the northern part of Etchū, the Ryōké Metamorphics have a NNE strike which changes to nearly ENE in the southern portion of the plateau.

(3) **KII PENINSULA:** In the Kii peninsula Ryōké Metamorphics, mainly biotite-schist with intercalations of quartz-schist and crystalline limestone, are found near Kasagi, Toba, etc. They occur sporadically in narrow areas between the injected masses of the schistose granites. Some of them, as exposed near Kasagi, have the appearance of sedimentaries and gradually pass into the normal Palaeozoic rocks. The complex has a general NE strike in the north-eastern part of the district, but it changes to E-W in the western part.

(4) **SHORES OF THE INLAND SEA:** Ryōké Metamorphics are found on the northern and southern shores of the Inland Sea, and also sporadically in several islands. The rocks are mica-schists and biotite-gneiss, frequently with crystalline limestone and quartz-schist which sometimes attains a considerable thickness. Amphibole-schist is occasionally interbedded in the mica-schists and gradually passes into the latter.

On the northern shore biotite gneiss occurs in the peripheral portion of the complex, where contact metamorphism was most active. The mica-schists which include several varieties such as biotite-schist proper, sillimanite-biotite-schist, garnet-biotite-schist and andalusite-biotite-schist, come next to the biotite-gneiss, and on the other side pass into spotted biotite-slate or spotted clayslate, as may be seen in several other localities.

Amphibole-schist resembles massive hornstone, and consists mainly of quartz and hornblende, accompanied by a few feldspars and biotites. It sometimes passes into biotite-schist, with the gradual increase of biotite in place of hornblende. The general strike of the Ryōké Metamorphics in this district is approximately E-W.

(5) **OKI ISLANDS:** In the Oki Islands the two-mica-schist of the Ryōké metamorphics, together with schistose granites, constitutes the foundation of the islands. The strike is N-S and the dip W.

(6) **KYŪSHŪ:** A petty outcrop of Ryōké Metamorphics, amid volcanics in Bungo, consists of biotite-gneiss and biotite-schist with the strike NNE.

MESOZOIC GROUP

BY Y. CHITANI

The Mesozoic Group of Japan comprises three great divisions, each characterized by typical fossils. Compared with the Palaeozoic formation, the extent of the Mesozoic is limited, as building of the ground-structure of the Japanese Islands had been already completed when the deposition of the Mesozoic took place.

I TRIASSIC SYSTEM

The Triassic of Japan consists of marine and estuary deposits distributed in small areas in Rikuzen, Awa, Tosa and Higo in the Outer Zone, and in Mino, Bitchū and Nagato in the Inner Zone. The correlation of the Japanese Triassic is shown in Table II.

Table II.

<table>
<tr><th></th><th>Stages</th><th>Japanese Triassic</th></tr>
<tr><td rowspan="3">Upper Trias</td><td>Rhaetic</td><td>Plant bed of Yamanoi</td></tr>
<tr><td>Noric</td><td>Pseudomonotis bed of Rikuzen, Bitchū, Nagato, Awa, Tosa, Higo and Mino
Plant bed of Bitchū</td></tr>
<tr><td>Carnic</td><td></td></tr>
<tr><td rowspan="2">Middle Trias</td><td>Ladinic</td><td>Daonella bed of Tosa and Rikuzen</td></tr>
<tr><td>Anisic</td><td rowspan="2">Inai Series { Ceratite bed of Rikuzen
(Fossilless part)</td></tr>
<tr><td>Lower Trias</td><td>Scytic</td></tr>
</table>

(1) **INAI SERIES OF RIKUZEN**:—The Series consists of non-fossiliferous sandy clayslate, associated with conglomerate in the lower, and *Ceratites* bed in the upper. The upper bed consists of shale with sandstone. The fossils from the bed are as follows:

Ceratites (*Hollandites*) *japonicus* v. Mojs.
C. *nodai* Diener.
C. *haradai* v. Mojs.
Japonites planiplicatus v. Mojs.
Danubites naumanni v. Mojs.

Anolcites (?) *gottschei* v. Mojs.
A. (?) *kitakamiensis* Diener.
Gymnites watanabei v. Mojs.
G. sp. (aff. *kirata* Diener).
Sturia japonica Diener.
Ptychites inaicus Diener.
P. sp.
Monophyllites (*Ussurites*) *yabei* Diener.

(2) **DAONELLA BED**:—This bed consists of clayslate, and is found at Rifu near the city of Sendai and in the Zōhōin valley of the Sakawa in Tosa. Fossils from Rifu are *Monophyllites*, *Arpadites* (?), *Ceratites* and *Ptychites* (?), and those from Sakawa are *Daonella Sakawana* v. Mojs. *Daonella kotoi* v. Mojs. and *Arpadites sakawanus* v. Mojs.

(3) **PLANT FOSSIL BED OF NARIWA IN BITCHU**:—This bed consists mainly of alternations of sandstone and shale intercalated with conglomerate often containing anthracite. From it the following fossil are recorded:

Neocalamites sp.
Podozamites distans Presl.
Cladophlebis haiburnensis L. et H.
C. *denticulata* Brongn.
Ctenis sp.
Dictyophyllum cf. *remauryi* Zeiller.
Nilssonia sp.

The bed was formerly distinguished as the Rhaetic Stage, but lately T. Akagi reported that the bed is lower than the Pseudomonotis bed.

(4) **PSEUDOMONOTIS BED**:—This bed occurring in the southern part of the Kitakami Mountains consists of sandstone and clayslate in which *Pseudomonotis ochotica* (kayserl) Teller was found.

This fossil was also lately reported from a black clayslate in Kasuga-mura in Mino and Kamikito-mura in Awa (Shikoku). The *Pseudomonotis* bed in the Sakawa Basin which lies 40 km. west of the city of Kōchi, contains the following fossils:

Pseudomonotis ochotica Teller,
Ceratites sakawanus v. Mojs. etc.

The bed at Kuriki in Higo consists of alternations of fine-grained, dark gray sandstone and shale including *P. ochotica* Teller.

At Nariwa in Bitchū, the bed consists of shale interstratifying with sandstone. On the northeast of Tsuyama in Mimasaka, *P. ochotica* var. *eurhachis* was also discovered.

(5) **PLANT BED OF YAMANOI IN NAGATO**:—This bed corresponding to the Rhaetic consists of shale and sandstone, often intercalating conglomerate and bituminous coal. The sandstone in the upper horizon of the coal-bearing series here contains the following fossils: *Cladophlebis nebbensis* Brgnt., *C. Yamanoiensis* Yok., *Dictyophyllum nathorsti* Zell., *D. japanicum* Yok., *D. kochibei* Yok., *Podozamites lanceolatus* Lindl. et Hutt., *Nilssonia inouyei* Yok., *Baiera paucipartita* Nath.

II JURASSIC SYSTEM

The Jurassic System of Japan consists of marine deposits as in Nagato and Tango in the Inner Zone, in Iwaki and Rikuzen in the Outer Zone, and of brackish-water deposits, as in Echizen, Kaga, Etchū, Echigo and the boundary region of Mino and Hida in the Inner Zone. The Jurassic deposits of Japan are correlated as follows:—

Table III.

Stage	Jurassic of Japan		
Malm	Shizukawa Series	Upper	Tetori Series
Dogger		Middle	
Lias		Lower	Ink-stone Series

(1) **INK-STONE SERIES**:—In Nagato, the Series is classified into two parts. The upper part consists of shale, sandstone, and conglomerate, which are tufaceous, besides schalstein and breccia, often bearing limestone. There are two varieties of schalstein, violet and green, of which the violet variety furnishes the best Japanese ink-stones (ink-basins). The lower part consists of shale, sandstone and conglomerate, not tufaceous. Anthracite is intercalated in both upper and lower beds. These beds are referable to the Upper Lias. At Nakayama and Ishi-machi in the same province, *Hildoceras chrysanthemum* Yok., *H. densicostatum* Yok., *H. inouyei* Yok., *Grammoceras* (?) *okadai* Yok., *Harpoceras* sp., *Coeloceras subfibulatum*

Yok., *Dactylioceras helianthoides* Yok., *Trigonia inouyei* Yehara, and *Cyclolites* sp. were found.

(2) **SHIZUKAWA SERIES**:–The Jurassic on Shizukawa-Bay in the Kitagami Mountain-land rests directly upon the synclinal fold of the Trias. It is represented by marine deposits which are divisible into the Upper, Middle and Lower beds. The lower beds consist of shale and sandstone with conglomerate in the lower part. Ammonites imbedded in the shale that forms the upper half of the bed are *Harpoceras ikianum* Yok., *Schlotheimia jimboi* Yok., *Lytoceras* cf. *lineatum* Schl., and *Grammoceras chibai* Yok.

The middle beds of the Series consist of sandstone and sandy shale with conglomerate in the base which rest unconformably upon the lower beds. The fossils from the middle beds are *Trigonia V-costata* Lycett (*Undulatae*), *Belemnites*, etc.

The upper beds consist of black shale intercalated with sandstone. Fossils found in the upper part of the bed are *Cyrena lunulata* Yok. *C. elliptica* Yok. *Perna rikuzenica* Yok. *Gervillia trigona* Yok. *Trigonia hosouraensis* Yok.

(3) **TETORI SERIES**:–The rocks belonging to this series are exposed in detached areas over Echizen, Etchū, Echigo, Kaga, Mino, Hida and Shinano in the Inner Zone.

The series in Echizen is divided into three parts, the lower (*Ammonites*-bed), the middle (Plant bed) and the upper (*Cyrena*-bed). The lower bed consists of conglomerate intercalated with sandstone and shale in the lower part, and alternate layers of sandstone and shale with conglomerate in the upper part. Various forms of *Ammonites* have been collected from the upper part in the villages of Kaizara, Nagano and Shinoyama. The chief locality for them is Horadani in the village of Kaizara. Fossils found are *Perisphinctes* (*Ataxioceras*) sp., *P.* (*Biplices*) *kaizaranus* Yok., *P.* (*Grossouria*) *hikii* Yok., and *Oppelia echizenica* Yok.

In the villages of Nagano and Shimoyama, *Perisphinctes* (*Procerites*) *matsushimai* Yok. and *P.* (*Biplices ?*) *kochibei* Yok. are found.

The middle bed consists chiefly of sandstone and shale. Table IV. shows the fossils which were discovered in the shale and were described by M. Yokoyama together with their localities.

The upper bed consists of sandstone with shale. At Izuki, the bed contains fossils of *Cyrena*, *Dosinia* and *Turritella*.

(4) **THE JURASSIC OF ŌSHIMA IN RIKUZEN**:—This contains plant fossils and is referable to the Tetori Series. The fossils are *Cladophlebis denticulata* Brongn., *Coniopteris hymenophylloides* Brongn., *Podozamites lanceolatus* Lind., *Williamsonia* sp.

(5) **THE JURASSIC OF KAGAHARA IN KOZUKE**:—This consists of sandstone in the lower part and brownish black shale in the upper, and occurs in a small narrow area along the margin of the so-called Sanchū-graben. Fossils from the sandstone are *Cyrena* sp. *Ostrea* (*alectryonia*) sp., *Myacites* sp., *Melania* sp., *Pleurotoma* sp., *Monotis* sp., etc. Fossils from the shale are *Thyrsopteris* cf. *maakiana* Hr. *T.* aff. *elongata* Geyler, *Nilssonia comtula* Hr., *Dicksonia* sp. (?), *Podozamites lanceolatus* L. et H. (?) *P. reinii* Geyler, *Cyprassidium* sp., *Brachyphyllum* sp.

(6) **PLANT FOSSIL BED AT KITAOTARI IN SHINANO**:—This consists of sandstone intercalated with shale and gives the following fossils: *Equisetites* sp., *Cladophlebis denticulata* (Brgn.) Font., *Clathropteris* sp., *Podozamites lanceolatus* L. et H., *Ginkgo* sp., *Phoenicopsis angustifolia* Heer, *Czekanowskia* sp.

(7) **THE JURASSIC IN TANGO**:—This consists of shale and sandstone often containing *Trigonia costatae* and fragments of *Ammonites*.

(8) **THE PLANT FOSSIL BED OF OGUSHI IN NAGATO**:—This consists of clayslate containing *Onychiopsis elongata* (*Goniopteris* sp. ?).

III CRETACEOUS SYSTEM

The Cretaceous System is widely distributed in the Outer Zone of Japan. The correlation of several beds belonging to this system is shown in Table V.

In the Cretaceous terrain there occur several zones or patches of the Jurassic and Triassic strata. However, these areas are either limited in extent or hardly discriminable from that of the Cretaceous.

(1) **TORINOSU LIMESTONE**:—A dark bituminous, sometimes oolitic, limestone occurs in the series of sandstone and shale, developed in the provinces of Tosa, Satsuma, Kii, Musashi (Itsukaichi) and Iwaki (Sōma). The limestone is rich in characteristic fossils, and as they were first collected at Torinosu near Sakawa in Tosa, the name, Torinosu Limestone, is used to designate that particular bed. The fossils include foraminifera, corals, bryozoa, echinoids, bivalves and gastropods.

Table V.

	Stages	Substages	Hokkaidō	Honshū	Shikoku	Kyūshū
Upper Cretaceous	Senonian		Hakobuchi Sandstone Upper *Ammonites* Beds { *Pachydiscus* bed, *Scaphites* bed	Futaba Series Toyajō Series { Toyajō bed	Izumi-Sandstone	*Ammonites* bed of Amakusa
	Turonian		Upper *Acanthoceras* Zone (or *Mammites* bed)	Suhara bed		
	Cenomanian		*Trigonia* Sandstone { *Pectunclas* Zone, *Thetis* Zone, Lower *Acanthoceras* Zone	*Trigonia* Sandstone (Kii)	(Awa, Tosa)	(Amakusa)
Lower Cretaceous	Gault					
	Neocomian	Upper: Apatian, Barremian	Lower *Ammonites* Beds { Upper, Lower	Miyako Series, Cretaceous of Chōshi, Kagahara and Oshima		
		Middle: Hauterivian				
		Lower: Valanginian		Ryōseki Series Torinosu Limestone		

Sakawa :—M. Neumayr, M. Yokoyama, H. Yabé and I. Hayasaka have recognized the following species:—

Cyclammina litus Yok.
Textularia cf. *cordiformis* Schw.
Pulvinuliva (?) sp.
Chaetetopsis crinita Neum.
Convexastraea orientalis Neum.
Metasolenopora rothpletzi Yabé.
Stromatopora japonica Yabé.
Circoporella semiclathrata Hayasaka.
Myriopora pyriformis Y. et H.
Cidaris cf. *glandifera cordiformis* Schw.
Hemicidaris cf. *crenularis* Ag.
Terebratula bisuffarcinata Zut.
Rhynchonella haradai Neum.
Harpoceras japonicum Neum.
Nerinea cf. *viturgis* Römer.

E. Sagawa found a limestone full of shells closely resembling *Alectryonia amor* d'Orb. at Ogawa, west of Sakawa, and also found *Thamnastrea, Isastraea, Calamophyllia, Montlivaultia* (?), *Chaetetopsis crinita* Neum., *Cidaris* cf. *grandifera* Goldf., *Nerinea* cf. *dilatata* d'Orb. in the limestone of the Shiraishi-gawa, 40 Km. west of Sakawa, where the layers of the limestone interstratify with plant beds of the Ryōseki Series.

Prof. T. Iki found in the Monobe-gawa valley on the east of the city of Kōchi *Chaetetopsis crinita, Thamnastrea, Latimeandra, Nodosaria, Belemnites, Nerinea* and *Chemnitzia.*

Musashi and Iwaki:—*Cidaris* cf. *glandifera* and *Chaetetopsis crinita* are very common at Itsukaichi in Musashi. The Cretaceous in the district of Sōma in Iwaki consists of sandstone and shale, with two layers of fossiliferous oolitic limestone which contains *Chaetetopsis crinita.* The formation is overlaid conformably by a plant bed of the Ryōseki Series.

(2) **RYŌSEKI SERIES**:—The Series has a wide distribution over the provinces of Tosa, Awa, Kii, Kōzuké, Iwaki, Rikuchū and Rikuzen. As the Series occurs at Ryōseki near Sakawa in Tosa, the name, Ryōseki Series, is used to denote this plant-fossil bearing series. The rocks consist of conglomerate, sandstone and shale, interstratifying plant-fossil beds. A *Cyrena* bed occurs in the lower horizon of the series. The plant fossils from the Series are shown in the accompanying table VI. The Series is rather widely distributed in the islands of Honshū and Shikoku.

(3) **OMOTO SERIES**:—This occupies a small area near Omoto in Rikuchū and consists of a sandy shale with intercalated porphyrites. The fossils from the shale described by Yabé are *Onychiopsis elongata* Geyler, *Cladophlebis browniana* Dkr., *Cladophlebis* sp., *Coniopteris* sp., *Nilssonia schaumburgensis* (Dyr.) var. *parvula* Yabé, and *Zamiophyllum buchianum* (Ett.)?

The Series may be correlated with either the Ryōseki Series or the Tetori Series.

(4) **THE CRETACEOUS OF ŌSHIMA IN RIKUZEN**:—The bed consists of a tufaceous sandstone overlying a tuff, black shale with oolitic limestone and several layers of quartzose rock alternating with sandstone. Fossils from the bed are *Crioceras* (*duvali* group), *Trigonia hokkaidoana, Gervillia haradai.*

(5) **THE CRETACEOUS OF KAGAHARA IN KŌZUKÉ**:—The fossiliferous sandstone in the Sanshū-Graben lies on the Ryōseki Series with no noticeable unconformability, and is intercalated with shale and conglomerate. The fossils are *Crioceras* (*duvali* group), *Desmoceras* (s.s.), *Toxoceras* (?), *Lytoceras, Trigonia hokkaidoana, T. pocilliformis, Gervillia forbesiana* d'Orb., and *G. haradai* Yok.

(6) **THE CRETACEOUS OF CHŌSHI IN SHIMŌSA**:—This consists of conglomerate, sandstone and shale. The fossils from the bed are *Trigonia*

pocilli'ormis, Acanthoceras sp., *Helicoceras* sp., *Desmoceras sugata* Forbes, *Cinuria* sp., *Pinna* sp., *Anotina* sp., and *Plicatula* sp.

(7) MIYAKO SERIES:—A sandstone occurs near Miyako in Rikuchū in seven patches, and contains *Trigonia hokkaidoana* Yehara and *Orbitolina.* The greater part of the sandstone belongs to the same horizon as the Lower *Ammonites* bed of Hokkaidō. The uppermost part of this series is referable to the Upper Neocomian.

(8) THE IZUMI SANDSTONE OF AWAJI:—The Izumi sandstone developed in the Outer Zone of Japan consists of alternate layers of sandstone and shale with conglomerate.

In Awaji, there are six fossil zones:

Zone I occurs in the shale in the lowest horizon of the Izumi sandstone near Minato and Anaka. The fossils from this zone are *Pravitoceras sigmoidale* Yabé, *Turrilites oshimai* Yabé var., *Turrilites otsukai* Yabé, *Nucula* sp., and *Cucullaea* cf. *striatella* Mich. *Turrilites oshimai* and *T. otsukai* occur in the *Pachydiscus* and *Scaphites* beds of the Upper *Ammonites* bed of Hokkaidō.

Zone II occurs also in the shale at Katada and Iiyamadera. The fossils are *Cucullaea* cf. *striatella* Mich., *Inoceramus* cf. *regularis* d'Orb., *Turrilites oshimai* Yabé, *Pachydiscus* cf. and *subtililobatus* Jimbō.

Zone III occurs in the sandstone and sandy shale at Chikusamura and Sumotomachi, containing *Pecten* sp., *Natica* sp., *Ostrea* sp., *Exogyra* sp.

Zone IV occurs in the shale at Uchida, Takehara, Onohanadani and Kashiwabarayama, with *Pravitoceras sigmoidale* Yabé, *Inoceramus* cf. *regularis* d'Orb., *Anisoceras awajiense* Yabé, *Hamites* sp., *Ostrea* sp., and *Deltocyathus* sp.

Zone V occurs in the conglomerate near Kogabi in the town of Yura. containing *Inoceramus* cf. *regularis* d'Orb.

Zone VI occurs at Ama and contains *Cycadeoidea* cf. *ezoana* Krysht.

(9) IZUMI-SANDSTONE OF UWAJIMA, IYO:—According to S. Yehara, the Izumi-sandstone of Uwajima forms an inverted isoclinal fold. It consists of conglomerate, sandstone and shale; its stratigraphy in descending order is as follows:—

1) Furushiroyama-Shale
2) Eisugahama-Sandstone
3) Makinoyama-Conglomerate

In the Furushiroyama-Shale *Gaudryceras denseplicatum* var. *nonstriata* Yeh., *Inoceramus uwajimaensis* Yeh., *I. akamatsui* Yeh., *I.* cf. *regularis*

Table IV.

Jurassic Plants of Kaga, Hida and Echizen (Yokoyama).

No.	Names.	Kaga.			Echizen.		Hida.		Occurrence of Identical or Allied Species in other Countries.
		Shimamura.	Yanagidani.	Ozō.	Hakogase.	Tanimura.	Okamigō.	Ushimaru.	
	CLASS I. CRYPTOGAMAE.								
	ORDER 1. FILICACEAE.								
	Fam. 1. Polypodiaceae.								
1	*Thyrsopteris murrayana* Brgt. . .	—	—	—	—	—	+	—	Siberia, Yorkshire.
2	„ *prisca* Eichw. . . .	+	—	—	—	—	—	—	Siberia, Russia.
3	„ *kagensis* Yok. . . .	+	—	—	—	+	—	—	
4	*Dicksonia gracilis* Hr.	+	—	—	—	—	+	—	Siberia.
5	„ *acutiloba* Hr. var. . . .	+	—	—	—	—	—	—	Siberia.
6	„ cf. *glehniana* Hr. . . .	—	—	—	+	—	—	—	Siberia, Yorkshire.
7	„ *nephrocarpa* Bunb. . .	+	—	—	—	—	—	—	Siberia, Yorkshire.
8	*Onychiopsis elongata* Geyl. . . .	+	+	+	+	+	+	—	
9	*Adiantites heerianus* Yok.	+	—	—	—	—	—	—	
10	„ *kochibeanus* Yok.	+	—	—	—	—	—	—	
11	„ *lanceus* Yok.	—	—	—	+	—	—	—	
12	*Asplenium whitbiense* Brgt. . . .	+	—	+	—	—	—	—	Siberia, China, Mongolia, India, (Jabalpur and Kach), Yorkshire, Turkestan, Rajmahal.
13	„ *argutulum* Hr. . . .	+	—	+	+	—	+	—	Siberia, Mongolia, Russia, Yorkshire.
14	„ *distans* Hr.	+	—	+	+	—	—	+	Siberia, Yorkshire.
	Fam. 2. Sphenopterideae.								
15	*Sphenopteris* sp.	—	—	—	+	—	—	—	*Sphenopteris williamsonis* Brgt. of Oolite and *S. mantelli* Brgt. of Walden.
	Fam. 3. Pecopterideae.								
16	*Pecopteris exilis* Phill.	+	—	—	—	—	—	—	Spitzbergen, Yorkshire.
17	„ *saportana* Hr.	+	-	—	—	—	—	—	Spitzbergen.
	Fam. 4. Taeniopterideae.								
18	*Taeniopteris* (?)	—	—	+	—	—	—	—	
19	*Macrotaeniopteris* cf. *richthofeni* Schenk.	+	—	—	—	—	—	—	China.
	ORDER 2. RHIZOCARPEAE.								
	Fam. 1. Salviniaceae.								
20	*Sagenopteris* sp.	—	—	+	—	—	—	—	*Sagenopteris rhoifolia* Presl. of Liassic and Rhaetic of Europe.
	ORDER 3. CALAMARIEAE.								
	Fam. 1. Equisetaceae.								
21	*Equisetum ushimarense* Yok. . .	—	—	—	—	—	—	+	*Equisetum buchardti* Schimp. of Wealden.
22	„ sp.	—	—	—	—	—	+	—	
	CLASS 2. PHANEROGAMAE.								
	SUBCL. GYMNOSPERMAE.								
	ORDER 1. CYCADEACEAE.								
	Fam. 1. Zamieae.								
23	*Anomozamites* sp.	+	—	—	—	—	—	—	
24	*Nilssonia orientalis* Hr.	—	—	—	+	—	—	—	Siberia, Yorkshire.
25	„ *ozoana* Yok.	—	—	+	—	—	—	—	
26	„ *nipponensis* Yok. . . .	+	—	—	—	—	+	—	*Nilssonia acuminata* Göp. of Rhaetic.
27	„ (?)	—	—	+	—	—	—	—	
28	*Dioonites kotoei* Yok.	+	—	—	—	+	—	—	*Dioonites brongniarti* Schenk of Wealden.
29	*Zamites parvifolius* Geyl.	+	—	—	—	—	—	—	
30	*Podozamites lanceolatus* Lind. . .	+	—	—	+	+	+	+	Siberia, China, Spitzbergen, Yorkshire.
	var. b. *intermedia* Hr.	+	—	—	—	—	+	—	Siberia, China, Mongolia.
	var. c. *eichwaldi* Hr.	+	—	—	—	+	+	+	Siberia, China, Spitzbergen, Russia.
	var. d. *minor* Hr.	+	—	—	—	—	—	—	Siberia.
	var. e. *latifolia* Hr.	+	—	—	—	—	—	—	Siberia, China, Mongolia.
	var. f. *brevis* Schenk.	—	—	—	—	—	+	—	China.
	var. g.	+	—	—	—	—	—	—	
31	*Podozamites tenuistriatus* Geyl. .	+	—	—	—	—	+	—	
32	„ *reini* Geyl.	+	+	+	—	+	+	—	
33	„ sp.	—	—	—	—	—	+	—	
34	„ sp.	+	—	—	—	—	—	—	
35	*Dictyozamites indicus* Fstm. var. *distans*	—	—	+	—	—	—	+	*Dictyozamites indicus* Fstm. Rajmahal.
36	„ *grossinervis* Yok. . .	+	—	—	—	—	—	—	
	Fam. 2. Cycadeae.								
37	*Cycadeospermum japonicum* Geyl.	+	—	—	—	—	—	—	
	ORDER 2. CONIFERAE.								
	Fam. 1. Taxaceae.								
38	*Ginkgodium nathorsti* Yok. . . .	+	+	—	—	—	+	—	
39	*Ginkgo digitata* Brgt.	—	-	—	—	—	+	—	Siberia, Spitzbergen, Yorkshire.
40	„ cf. *lepida*	—	—	—	+	—	—	—	Siberia.
41	„ *sibirica* Hr.	+	—	—	—	—	—	—	Siberia.
42	*Czekanowskia rigida* Hr. (?) . .	—	—	+	—	—	+	—	Siberia, China, Russia, Yorkshire, Rhaetic of Sweden.
43	*Taxites* sp.	—	—	+	—	—	+	—	*Taxites brevifolius* Nath. of Yorkshire.
44	„ sp.	+	—	—	—	—	—	—	
	Fam. 2. Abietaceae.								
45	*Pinus* cf. *prodromus* Hr.	+	—	—	—	+	—	—	Siberia, Spitzbergen.
46	„ *nordenskiöldi* Hr.	+	—	—	—	—	—	—	Siberia, Spitzbergen, Russia, Andö ? Nancy ?
47	*Palissya* sp.	+	—	—	—	—	—	—	*Palissya jabalpurensis* Fstm. Jabalpur.
	INCERTAE SEDIS.								
48	*Vallisnerites jurassicus* Hr. (?) .	+	—	+	—	—	—	—	Siberia.
49	*Carpolithes ginkgoides* Yok. . . .	—	—	+	—	—	—	—	

d'Orb. and *Helicoceras* cf. *venustum* Yabé were obtained by him. In the Ebisugahara-Sandstone, *Inoceramus* and some other lamellibranchs were found at Narufuji, and from the Makinoyama-Conglomerate *Inoceramus* cf. *regularis* was obtained.

(10) **IZUMI-SANDSTONE IN THE ŌNO-GAWA BASIN, BUNGO:**— According to Yehara, the Izumi-Sandstone is divided into three beds as shown in descending order as follows :—

1) Inukai-Shale,
2) Katagasé-Sandstone,
3) Haji-Conglomerate.

From the Inukai-Shale *Inoceramus uwajimaensis*, *I. akamatsui* and *I.* cf. *regularis* were procured by Yehara. The Katagasé-Sandstone at Kofuji-mura yielded *Trigonia datemasamunei* var., *Callista* cf. *plana* Sow., *Pectunculus* sp., *Cucullaea* sp., *Pinna* sp., *Colisocolus* sp., *Fulguraria* sp., *Turritella* sp. No fossil has yet been found in the Haji-Conglomerate.

(11) **TOYAJŌ SERIES:**—The Cretaceous near Toyajō in Kii is correlated with the Senonian as the Toyajō Series. The Series is divided into two beds, the Suhara bed in the lower and the Toyajō bed in the upper.

The fossil from the Suhara bed is *Acanthoceras* sp. allied to *A.* (*Calycoceras*) *naviculare* Mantell.

Fossils from the Toyajō bed are *Gaudryceras denseplicatum* Jimbō, *Tetragonites* cf. *cala* Forbes, *Turrilites* (*Bostrychoceras*) *otsukai* Yabé, *T.* (B.) *japonicus* Yabé, *T.* (*Hyphantoceras*) *oshimai* Yabé var., *Pravitoceras sigmoidale* Yabé, *Baculites* sp., *Pachydiscus rotalinoides* Yabé, *Kossmaticeras* sp., *Inoceramus* cf. *regularis* d'Orb., *I. schmidti* Michael.

The Toyajō Series is considered to be older than *Zone I* of the Izumi-sandstone of Awaji, and to correspond to the Lower zone of the Upper *Ammonites* bed of Hokkaidō.

(12) **CRETACEOUS OF AMAKUSA:**—The rocks are sandstone, conglomerate, schalstein and shale. According to Yehara, the stratigraphical succession in ascending order is as follows :

1) *Trigonia* Sandstone bed
    i) *Trigonia longiloba* zone
    ii) *Pectunculus* zone
2) *Ammonites* bed
    i) *Peroniceras* zone
    ii) *Pachydiscus* zone
    iii) *Inoceramus* zone

(13) **FUTABA SERIES**:—Recently Tokunaga discovered various forms of *Ammonites*, *Trigonia* and teeth of Reptiles in the Futaba district in Iwaki. The Series consists of alternate layers of sandy shale and fine grained hard sandstone in the lower part, blue sandy shale in the middle, and hard coarse-grained sandstone in the upper. The lower bed gives *Puzosia* sp., *Baculites* sp., *Gaudryceras* sp., *Bostorychoceras otsukai* Yabé, *Hamites* sp., *Yabeiceras* sp., *Trigonia subovalis*, *Yezoites* sp., teeth of *Icthyosauria* and *Plesisaurus*.

(14) **MIKURA SERIES AND MINEOKA SERIES**:—The rock group on the southern part of the Akaishi Range in Suruga and Tōtōmi was named the Mikura Series by K. Nakashima. The Series consists of sandstone and shale with intercalating siliceous limestone and hornstone. Siliceous limestone is exposed in three zones and contains *Globigerina*, *Nodosaria*, *Discorbina* (?), *Dactylopora* (?). Dr. B. Kotō discovered *Lithothamnium* in it.

The Mineoka Series in the Bōsō Peninsula, which is composed of cherty shale, sandstone and marly shale, probably corresponds to the Mikura Series. The age of these two series is still uncertain, but here it is assumed to be the Cretaceous.

(15) **THE CRETACEOUS OF HOKKAIDŌ**:—The Cretaceous of Hokkaidō occupies a comparatively extensive area along the western flank of the Yezo Mountains and appears in small patches in Kushiro, Nemuro and Shikotan Islands. According to Yabé the stratigraphical succession is as follows :—

(a) Lower *Ammonites* bed
(b) *Trigonia* Sandstone
(c) Upper *Ammonites* bed
(d) Hakobuchi Sandstone

(a) Lower *Ammonites* bed :—This bed is divided stratigraphically into two parts, upper and lower. The Lower consists of gray to black shale interbedded with reef-making limestone, containing *Orbitolina* cf. *concava* and *Inflaticeras imaii* Yabé et Shimizu. The Upper consists of gray shale intercalated with sandstones containing *Lytoceras yezoense* Yabé.

(b) *Trigonia* Sandstone :—This sandstone is intercalated with shale and conglomerate. Three fossil horizons have been established ;

(i) Lower *Acanthoceras* zone
(ii) *Thetis* zone
(iii) *Pectunculus* zone.

(i) Lower *Acanthoceras* zone consists of sandstone containing *Acanthoceras rhotomagense* var. *asiatica*, *Turrilites komotai*, *Trigonia subovalis*, *T. hokkaidoana*, *T. brevicula*, and *Nucula milnei*.

(ii) The *Thetis* zone consists of green sandstone containing *Thetis* aff. *affinis*, and *Desmoceras dawsoni* var. *japonica*.

(iii) The *Pectunculus* zone consists of hard gray sandstone containing many specimens of *Pectunculus*.

(c) Upper *Ammonites* bed :—This bed consists of shale rarely intercalating sandstone. Marly nodules in the bed contain abundant fossils. Three subdivisions have been recognized :

(i) Upper *Acanthoceras* zone
(ii) *Scaphites* bed
(iii) *Pachydiscus* bed.

(i) The Upper *Acanthoceras* zone consists mainly of shale containing *Mammites* sp. and *Acanthoceras* sp.

(ii) The *Scaphites* bed contains many fossils which are as follows :

1. *Gaudryceras limatum* Yabé
2. *Tetragonites popetensis* Yabé
3. *Nipponites mirabilis* Yabé
4. *Prionotropis* cf. *serratocarinatus*
5. *Scaphites puerculus* Jimbō
6. *S. yokoyamai* Jimbō
7. *S. planus* Yabé
8. *S. yonekurai* Yabé
9. *S. stephanoceroides* Yabé
10. *Puzosia planulatiforme* Jimbō
11. *P. yubarense* Jimbō ;

besides.

12. *Gaudryceras tenuiliratum* Yabé
13. *Desmoceras damesi* Jimbō
14. *Phylloceras yezoense* Yokoyama
15. *P.* cf. *ramosum* Meek.
16. *Tetragonites sphaeronalus* Jimbō
17. *T. glabrum* Jimbō
18. *Turrilites venustus* Yabé
19. *T. otsukai* Yabé

The last eight fossils are also imbedded in the following *Pachydiscus* bed.

(iii) The *Pachydiscus* bed also contains many fossils as shown below :

1. *Phylloceras surya* Forbes
2. *Gaudryceras denseplicatum* Jimbō
3. *G. striatum* Jimbō
4. *G. yokoyamai* Yabé
5. *Tetragonites* cf. *epigonus* Kossmat
6. *Turrilites orientale* Yabé
7. *Baculites teres* Forbes.
8. *Hamites pseudogaultinus* Yokoyama.
9. *H.* cf. *vancouverensis* Whiteaves.
10. *H. indicus* Forbes.
11. *H. largesulcatus* Forbes.
12. *H. quadrinodosus* Jimbō
13. *H. haradanus* Yokoyama

14. *H. sanushibensis* Yabé
15. *Placenticeras subtilistriatum* Jimbō
16. *Acanthoceras pseudodeverianum* Jimbō
17. *Holcodiscus kotoi* Jimbō
18. *H. jimboi* Yabé
19. *H. japonicus* Yabé
20. *Pachydiscus teshionensis* Jimbō
21. *P. koluturensis* Stoliczka
22. *P. ariyalurensis* Stoliczka
23. *P. rotalinoides* Yabé
24. *P. sutneri* Yokoyama
25. *P. sphaericus* Yabé
26. *P. kossmati* Yobé
27. *P. haradai* Jimbō
28. *P. naumanni* Yokoyama
29. *P. teshioensis* Jimbō
30. *P. subtililobatus* Jimbō
31. *P. yezoensis* Yabé
32. *Desmoceras laeve* Yabé
33. *D. semicostatum* Yabé
34. *Puzosia indopacifica* Kossmat.
35. *P. yezoense* Yabé
36. *Hauericeras gardeni* Baily
37. *H. angustum* Yabé
38. *Ganthiericeras* sp.
39. *Barroisiceras* sp.
40. *Inoceramus* cf. *regularis* d'Orbigny
41. *I. schmidti* Michaelis
42. *I. naumanni* Yokoyama
etc.

(d) Hakobuchi sandstone :—The Hakobuchi sandstone was named by H. Imai after the local name of the gorge of the middle Yubari-gawa, about 1 km. east of the Mitsubishi Ōyūbari colliery. The sandstone series consists of the upper sandstone, conglomerate, the middle sandstone, the *Nilssonia*-bed and the lower sandstone. The *Nilssonia*-bed is not older than the Senonian and contains many plant fossils as follows :

Filicales :

Pteris frigida Heer
Asplenium dicksoniamum Heer (?)
Pecopteris torellii Heer (?)

Cycadales :

Glossozamites (?) imaii Endō
Phyllites sp. (cf. *Sphenozamites rogersianus* Fontaine)
Cycadeoidea nipponica Endō
Nilssonia cf. *orientalis* Heer
,, cf. *johnstruppi* Heer
,, cf. *serotina* Heer
,, sp.

Coniferales :

Libocedrus sabiniana Heer
Sequoia heterophylla Velenovsky

Dicotyledones:

Populus denticulata Heer
„ *arctica* Heer (?)
Rhamnites apiculatus Lesquereux
Protophyllum obovatum Newberry

(16) THE CRETACEOUS OF KARAFUTO (JAPANESE SAGHALIEN):— This consists of shale, sandstone and conglomerate, containing *Ammonites, Helcion, Inoceramus,* etc. It seems to be in the same horizon as the Cretaceous of North Saghalien, which is compared by A. Kryshtofovich with that of Hokkaidō as shown in Table VII.

Table VII.

Hokkaidō		North Saghalien	
Senonian	*Pachydiscus* Upper *Pachydiscus* Lower	Orokkian	Plant-beds Inoceramus beds Plant-beds
Turonian	*Scaphites*	Gyliakian	*Pteris* *Nilssonia* *Aralia polevoii*
	Mammites		
Cenomanian	*Pectunculus*		
	Thetis		
	Trigonia		
	Lithoceras		
Lower Cretaceous		Ainuan	*Gleichenia*, etc.

IV MESOZOIC FORMATIONS OF UNKNOWN AGE

The Mesozoic in the southwestern part of Shikoku and the southern part of Kyūshū seems to belong to the Upper Cretaceous, from the similarity of its rocks, though no fossil has yet been found.

In Taiwan the formation, consisting mainly of clayslate with thin layers of sandstone in its upper part, stretches along the western and eastern flanks of the axial mountain range. Apparently it forms the transition member between the Palaeozoic on the one hand and the Tertiary on the other, and is assumed to represent the Mesozoic, mostly Cretaceous.

CAINOZOIC GROUP

The two great divisions of the Cainozoic group, the Tertiary and the Quaternary, are both represented in Japan.

TERTIARY SYSTEM

BY K. WATANABE

The Tertiary System constitutes a large and important portion of the geology of Japan. The rocks are sands, gravels, clays, sandstones, shales, conglomerates and tuffs with intervening layers of limestone, dolomite, marl, chert, diatom-earth, coal and lignite. The tuffs are widely spread, and often attain enormous thickness; while the sandstones and shales frequently assume a tufaceous character.

(A) PALAEOGENE

An Eocene Nummulitic bed was first discovered in 1902, in Ogasawara-jima (Bonin Islands). A. G. Nathorst had pointed out that the plant fossils from Takashima in Kyūshū appeared to be of an age older than his "Pre-Pliocene Flora" from localities in Honshū; but it was not until 1911 that the Eocene evidence of the coal-bearing series of Miike and Amakusa in Kyūshū was proved by Yokoyama. Since that time the Tertiary Coal-bearing Series of Northern Kyūshū has been refered to the Palaeogene. Recently the Sasebo coal-bearing strata, which overlie the Eocene Coal-bearing Series of the Karatsu coal-field, have been assigned by Tokunaga to the Oligocene. The Coal-bearing Series of Hokkaidō and Karafuto which contains the so-called "Arctic Miocene Flora" has been compared with the Kenai Series of Alaska by Yabé and others, and it is generally believed that the Series is of the Palaeogene age.

(i) **NUMMULITIC TUFF OF OGASAWARA-JIMA (BONIN ISLANDS):**—The Nummulitic tuff of Haha-jima (Hillsborough) is full of *Nummulites* which Tokunaga identified as *N. javanus* Verbeek and *N. baguelensis* Verbeek. Yabé has also detected microscopic forms resembling *Nummulites vredenburgi* and *N. laevigatus*, and believes that the tuff represents the Upper Lutetian. The other fossils found in association with the Foraminifera are *Sagenina regularis* (Douvillé), *S. expansa* Yabé, *Placopsilina cenomana* d'Orb., *Lituotuba? eocenica* Yabé, *Orthophragmina colcanapi* Douvillé? *Alveolina* cf. *javana* Verb. *Uhligina boninensis* Yabé et Hanzawa, *Schizaster nummuliticum* Tok., *Nerita* cf. *schmedeliana* chemn., *Lithothamnium* sp.

Table VIII.

	Amakusa Coal-field		Miike Coal-field		Takashima Coal-field		Sasebo & Karatsu Coal-field		Chikuhō Coal-field	
Lower Oligocene							Sasebo Coal Measures *Brachyodus japonicus*			
Eocene	Sakasegawa Group	Sakasegawa Shale Itchōda Sandstone (5–15) *Manda fauna*	Manda Group	Yotsuyama Sandstone Kattachi Sandstone *Manda fauna*	Ashiya Group	Iōjima Bed Okinoshima Bed	Ashiya Group	Hatatsu { Shale, Sandstone (180) Yukiaino Sandstone *Manda fauna* (280) Sari Sandstone	Ashiya Group	Wakita Bed (150) Sakamizu Shale (200) Yamaga Bed *Manda fauna* (250–300)
Eocene	Hondo Group	Toishi Sandstone *coal* Kyōragi Shale and Sandstone *coal*	Ōmuta Group	Nanaura Sandstone *Upper Orthaulax Zone* *coal* Tauka Sandstone *coal*	Takashima Group	*Nelumbium* *Upper Orthaulax Zone* Main Coal Measures of Hashima	Auchi Group	Ōtōgé Sandstone (60) Iwaya Sandstone *Nelumbium* (180) Kishiyama Bed (50)	Otsuji Group	Onga Group *coal* (330–450)
Eocene	Miroku & Fukami Group	Shiratakė Sandstone *Nummulites* (6–130) *Lower Orthaulax Zone*	Ōmuta Group	Komenoyama Bed *Nummulites* *Lower Orthaulax Zone*	Takashima Group	Futagojima Group Coaly shale and Marine Beds	Kiuragi	Kiuragi Bed (230) *coal* *Marine shells*	Otsuji Group	Ideyama Group *coal* (600)
Eocene	Miroku & Fukami Group	Akasaki Bed Variegated shale with sandstone & conglomerate (18–45)		Akasaki Bed		Akasaki Bed		Takuharu Bed	Nōkata Group	Uwaishi Bed (270) variegated shale, *shells* Takeya Bed (100–130) Honsō Bed, varigated shale, *shells* Ōyaké Bed variegated shale

(Figures in the table show the thickness of the beds in meters.)

At Okimura and also on Ishikado-yama in Haha-jima, an earthy tufaceous limestone is seen lying almost horizontally upon the Nummulitic tuff and overlain by a hard and compact to porous limestone. According to Yabé, it contains *Pellastispira madraszi* Hantken, *P. madraszi* Hantken var. *douvillei* Boussac, *P. orbitoidens* Provale ?, *Orthophragmina* cf. *fritschi* Douvillé, *Heterostegina* sp., *Orthophragmina* sp., *Amphistegina lessoni* d'Orb., *Carpentaria* sp., *Carcarina* sp. and *Nummulites* sp.

The presence of *Pellastispira* and *Orthophragmina* shows that the tuff is of the Upper Eocene.

(ii) NUMMULITES BED OF RYŪKYŪ:—In Ishigaki-jima, a limestone lying between sandstone and agglomeratic tuff yields *Pellastispira madraszi* Hantken and *P. madraszi* var. *douvillei* Boussac, which are of the Upper Eocene.

(iii) NUMMULITES BED OF TAIWAN:—In the Clayslate Formation (Cretaceous to Tertiary) of Kukunosha in Akō-chō, Mr. Deguchi found an impure limestone containing numerous species of *Orthophragmina* and a small Nummulites belonging to the group of Radiatae.

(iv) COAL-BEARING SERIES OF NORTHERN KYŪSHŪ:—The Coal-bearing Series of Northern Kyūshū is an important representive of the Japanese Palaeogene and consititutes the coal-fields of Chikuhō, Miiké, Karatsu, Sasebo, Takashima and Amakusa. The strata of these coal-fields are compared in Table VIII.

Eocene Section :—The lower and middle parts of the Eocene Series are, in greater part, deposits of fresh water or of continental origin, intercalating many important coal seams. Two marine fossil zones have been recognized in it by Mr. T. Nagao; namely, the lower and the upper Orthaulax zones. In the Amakusa Islands the lower Orthaulax zone is found intercalated in the Shiratakė sandstone and its contemporaneous beds. The most important fossil is *Nummulites amakusensis subamakusensis* Yabé et Hanzawa, closely allied to the European species *N. planulatus-elegans*. There are also *Orthophragmina* sp., *Orthaulax japonicus* Nagao and *Venericardia nipponica* Yok. The upper Orthaulax zone is contained in the Nanaura sandstone of the Miiké coal-field and also in the upper part of the Main Coal Measures of the Takashima coal-field. The *Nummulites* of the lower Orthaulax zone are believed by Yabé to be those of the Londinian (Ypresian to Lower Lutetian Stage). The Fukami Group of Amakusa are marine representatives corresponding to the Miroku group (including the Akasaki shale and the Shiratakė sandstone).

The Main Coal Measures of Takashima have yielded *Sabal nipponica* Krysht., *Osmunda lignitum* Giebel, *Lastraea japonica* Krysht., *Acrostichum* *hesperium* Newberry, *Salvinia formosana* Heer and *Nelumbium* sp. Mr. A. Kryshtofovich compared the plant bed of Takashima with the Green River Group of Wyoming of North America.

The Sakasegawa and the Ashiya Group are essentially of marine deposits containing invertebrate fossils besides a few plants. These are known as the Manda Fauna and were obtained from the base of the Ashiya Group, having been described by Yokoyama. They are *Pentacrinus ariakensis* Yok., *Terebratula miikensis* Yok., *Perna nishiyamai* Yok., *Pholadomya margaritacea* (Sow.), *Crassatella usca* Yok., *Venericardia nipponica* Yok., *Cardita mandaica* Yok., *Venus mitsuiana* Yok., *Parrisolax blackei* Gabb., *Aturia zigzag* (Sow.), *Homolopsis japonicus* Yok., *Xanthilites pentagonalis* Yok., *Lamna* cf. *cuspidata* Ag.

Aturia zigzag (Sow.) is reported to occur also at Takashima. *Aturia* from the Ashiya Group of Meinohama, Chikuzen, is of two types closely allied to *A. rovasendiana* Paroma and *A. charlesworthi* Foord. *Pholadomya margaritacea* (Sow.) from Kyūshū is said to be a form equivalent to *P. nasuta* Gabb. from the lower Eocene Martinez of California.

Oligocene Section: A series of coal-bearing and marine strata chiefly consisting of sandstone with subordinate layers of shale rests upon the Ashiya Group of the Karatsu coal-field and extends over the whole area of the Sasebo and Imari coal-fields. The strata attain a total thickness of 1,000 meters. Three coal-bearing zones are contained in the series and in the lowest zone, there has recently been discovered an Anthracotherid tooth, *Brachyodus japonicus* Mats. comparable with the European *Brachyodus porcinus* Grew. and Egyptian *B. rugulosus* Schmidt of the Lower Oligocene (Sannoisian).

(v) **ISHIKARI SERIES OF HOKKAIDO**:—The Ishikari Series or the so-called Lower Tertiary Coal-bearing Series, extends in one or several zones along the western flank or foot hills of the central meridional range, running north-south and unconformably overlying the Cretaceous rocks. In the eastern part of Hokkaidō it is known to occur in Tokachi, Kushiro and Nemuro. It consists of continental and coastal plain deposits with some shallow water marine ones between, characterized by the Arctic Miocene Flora and molluscan shells of fresh or brackish water. The rocks are shale, sandstone and conglomerate with intercalations of marl, tuff and coal. It is generally accepted that the age of the Ishikari Series is probably Upper Eocene or Oligocene. Kryshtofovich compared the Series with the Green River Group of Wyoming on the basis of its plant fossils.

The Ishikari Series of Ishikari is strongly folded, often overturned or even overthrust. The embedded coal seams are extensively worked at present. Plant fossils from Sorachi, collected by M. Lyman, were studied long ago by Lesquereux with the following results:

Equisetum sp., *Sequoia langsdorfii* Brongn. (abundant) *Populus arctica* Hr., *Populus* sp., *Juglans acuminata* var. *latifolia* Hr.(?), *Fagus* sp. (fragment), *Acer* sp., *Quercus platania* Hr. (?) (fragment), *Carpinus grandis* Ung., *Platanus guillelmae* Göppert (?) (fragment). K. Jimbō enumerated from Sorachi coal-field, *Sequoia* cf. *disticha* Hr. and *Taxodium distichum miocenum* Hr.

The stratigraphy of the Ishikari coal-fields has already been studied in some detail. According to Mr. H. Imai, the ascending succession is as follows:

	Rock Zones	Fossils
1.	Noborikawa coal-bearing Group	*Knightiophyllum* etc.
2.	Horokabetsu Shale	Some plants & shells.
3.	Yūbari coal-bearing Group	*Osmunda heeri*, *Pteris grönlandica*, etc.
4.	Wakkanappe Shale	*Venericardia* & *Mya*.
5.	Wakkanappe Sandstone or Shell Bed	*Crassatella* cf. *fusca*.
6.	Bibai coal-bearing Group	*Sabal nipponica* Krysht.
7.	Lower *Corbicula* Bed	*Corbicula*, *Modiola*.
8.	*Woodwardia* Zone.	*Woodwardia* cf. *maxonia* etc.
9.	Ikushumbetsu coal-bearing Group.	do. *Corbicula*, *Ostrea*.
10.	Upper *Corbicula* Bed	*Liquidambar formosana*.
11.	Ashibetsu coal-bearing Group.	*Nelumbium*.

In the Uryū-Rumoi coal-field, the Lower Tertiary contains coal-seams in its lower portion, while the upper portion is associated with petroliferous marine deposits, coal being rare.

From the coal-bearing bed of the Shitakara coal-field in Kushiro, Jimbō obtained *Cephalotaxus* sp., *Cercidiphyllum* sp., *Vitis* sp., *Fagus* sp., *Alnus* aff. *incana* Wild., *A.* aff. *viridis* D. C., *A.* aff. *maritima* Nath. Of plants collected by Jimbō, Kryshtofovich determined the following: (from Shitakara) *Sequoia Langsdorfii* Brong., *Alnus kefersteinii* Göpp., *Ficus* cf. *alaskana*; (from Charagawa) *Zelkova ungeri* Kovats., *Ficus grönlandica*, *Vitis* cf. *brunneri*, *Platanus guillelmae* Göpp.

(vi) **COAL-BEARING SERIES OF THE LOWER TERTIARY IN KARAFUTO:** —Closely associated with, but probably resting unconformably upon, the Cretaceous Formation, there is found a coal-bearing series in the lowest portion of the Tertiary on both sides of the western range. It is called the Naibuchi Coal-bearing Series. It consists of shales, sandstones and conglomerates with subordinate tuffs and embeds many workable coal-seams. It also contains numerous fossil plants, the so-called "Arctic Miocene Flora". The Series seems to be referable to the Ishikari Series of Hokkaidō and the Due Coal-bearing of Russian Saghalien.

In the Naibuchi Coal-bearing Series, Y. Ōtsuki, H. Tanakadaté and K. Nishiwada found the following plant fossils:

Taxodium distichum miocenum Heer.	*Corylus* sp.
Carpinus cf. *grandis* Ung.	*Platanus aceroides* Göpp.
Ficus alaskana Newb. ?	*Acer otopterix* Göpp.
Castanea sp.	*Populus arctica* Heer.
Populus cuneata Newb.	*Magnolia nordenskiöldi* Heer.
Alnus kefersteinii Göpp.	*Juglans acuminata* Al. Brown.
Chamaerops sp.	*Paliurus* sp.

(vii) **MISAKA SERIES:**—This is a Tertiary formation, probably of the Palaeogene age. What was called the Misaka Series by Mr. Suzuki is a thick accumulation of normal clastic and pyroclastic rocks exposed in the environs of the Volcano Fuji and the eastern flank of the Akaiishi Range. Similar rocks are found in several detached areas in the provinces of Shinano, Echigo, Kōzuké and Iwashiro. As the Series consists of rocks of older aspects than the prevalent Tertiary types and in some cases even shows unconformability with the overlying Tertiary beds, it has long been thought to be Mesozoic.

The Misaka Series in general consists of shales, sandstones, conglomerates and tuffs with intrusive of diabases, porphyrites and andesites. H. Yabé, H. Murakami and Tetsunosuké Katō studied the Misaka Series in the Ashigara and Dōshi districts, and recognized the following successions of rocks:

	Ashigara District in Sagami (After T. Katō and H. Yabé)		Dōshi District in Kai (After H. Murakami)	
Oligocene (?)	Nakagawa Zone. Amphibolite		—	
	Kurokura Zone	Schistose Diabase Massive Diabase	Lower Group	Diabase Diabase-tuff
Miocene	Kaminawa Zone	Lower Breccia (coarse breccia & tuff)	Middle Group	Devil's Breccia Variegated Tuff Andesite
		Calcareous Breccia with tuff. Upper Breccia (breccia and marly tuff.)	Upper Group	Calcareous Breccia Earthy Breccia Platy Tuff Hyalo-dacite Breccia

The amphibolite of the Nakagawa Zone has an appearance like that of the Mikabu Series. In the calcareous breccia of the Kaminawa Zone are intercalated small lenticular masses of limestone which have yielded higher organized foraminifera showing Burdigalian affinities, such as *Lepidocyclina verbeeki* Newton & Holland, *Amphistegina lessoni* d'Orb., *Gypsina inhoerens* Schulze, *Rotalia schroeteriana* Parker et Jones, *Cycloclypeus* sp., *Operculina complanata* Defr., *Miogypsima* sp., *Lithothamnium ramosissimum* Reuss, etc.

These fossils show that at least the uppermost part of the Misaka Series evidently belongs to the Miocene.

(B) NEOGENE

The transgression of the Neogene Sea was probably the most extensive that had occurred in the land of Japan, since the time of the Palaeozoic. The greater part of the Neogene Series consists of shallow sea deposits mixed with some fresh-water ones. The marine Neogene is most widely spread especially in Northern Japan and contains " *Thyasira-Phacoides* Fauna " of Yabé.

The Older Neogene is characterized by the presence of the plants of the " Pre-Pliocene Flora " of Nathorst, although sometimes also by the occurrence of *Miogypsina* and *Nephrolepidina* limestones. The rocks are sandstones, shales, cherts, and conglomerates with a considerable amount of pyroclastics ; and the strata are strongly tilted and folded. They have a wider distribution than the younger Neogene Series and constitute high hills and mountainous regions.

The Younger Neogene abounds in molluscan fossils, the greater part of which belong to the species now living in the neighbouring seas, described by Reeve, Adams, Sowerby, Gould, Lischke, Dunker, Schrenck, et al. The rocks are unconsolidated sands and gravels, soft shales or mudstones, clays and soft tuffs. The strata are in most cases only slightly disturbed. The Series shows in many cases a distinct clino-unconformity with the underlying Older Neogene. In some cases, however, especially in the oil-fields of Northern Japan, the boundary between these two formations is not quite clear, being usually regarded as conformable.

The uppermost part of the Neogene Series, so far as it was not taken away by later denudation, locally indicates shallow water or fresh-water facies, usually consisting of coarse materials, such as loose sand and gravel with some clay layers and occasional tuffs. It forms either low terraces or flanks of hills frequently covered by the Pleistocene gravel beds. This series is very often unconformably underlain by another Tertiary formation and is known as the "Uppermost Tertiary" or "Diluvio-Tertiary".

(1) **NEOGENE OF THE KWANTŌ DISTRICT**:—The Older Neogene rocks are found in the mountain lands bordering the Kwantō Plain, usually associated with those of the Younger Neogene; but with a few exceptions they have not yet been stratigraphically classified. The Musashino Formation of Yokoyama is an important representative of the Younger Neogene in the Kwantō district. Its base is clearly seen at Zushi where it shows an unmistakable clino-unconformity against the Hayama Series which belongs to the Older Neogene. The Musashino Formation is divided by Yokoyama into two parts, the Lower and the Upper. The Lower Musashino extends from Zushi and Yokosuka northwards to the vicinity of Yokohama. The Upper Musashino is not only exposed at the base of bluffs and cuttings of low plateaus near Tōkyō, but also widely in the Kwantō Plain, covered by gravel, sand and clay, of aqueous origin, as well as by aeolian loam beds of the Pleistocene age. The Older and the Younger Neogene formations in the Kwantō district are compared in Table IX.

Table IX.

		Tōkyō, Yokohama and Immediate South	Miura Peninsula	Bōsō Peninsula	Chōshi	Ashigara District	Kwantō Mountains	North of the Kwantō Plain
Younger Neogene	Upper Musashino (in part)	Miyata Bed, Tōkyō Bed, Naganuma Bed,		Sanuki Bed	Uppermost Pliocene (Sand and Clay)	Yamakita Gravel Bed		Plant Bed of Shiobara
	Lower Musashino or Miura Series	Kuragi Shale, Kanazawa Sandstone, Ōfuna Shale, Kamakura Sandstone, Zushi Shale		Miura Series: Nokogiri Beds, Nabuto Shale	Pliocene (Lower Musashino) Sandy Tuff, Tufaceous Shale & Sand	Ashigara Tertiary	Tertiary of Usui-gawa, Shimonita, Chichibu and Ichinokaya	Liparitic Tuff with Shell Zones of Shiobara.
						Thrust Fault		
Older Neogene			Hayama Series	Sakuma Series	Miocene ? Tuff	Lepidocyclina Bed of Dōshi, and Kaminawa Zone of Misaka Series	*Orbitoides* Limestone of Naka-Ozaka Plant Fossil Bed of Itsukaichi	Plant Fossil Bed of Kamikanazawa

(a) OLDER NEOGENE:

(i) **HAYAMA AND SAKUMA SERIES**:—The Hayama Series of the Miura Peninsula consists of folded strata of tuffs, sandstones and shales of harder character in comparison with those of the Musashino Formation. Fossils are rare, only some foraminifera such as *Amphistegina*, having been detected in the limestone interbedded in it in the neighbourhood of Uraga.

In the Bōsō Peninsula, the Older Neogene is known as the Sakuma Series resting unconformably upon the Mineoka Series which probably corresponds to the Mikura Series. The Sakuma Series is composed of conglomerate and alternating beds of sandstone and shale.

(ii) **LEPIDOCYCLINA BED OF DŌSHI IN KAI AND THE KAMINAWA ZONE OF THE MISAKA SERIES OF ASHIGARA** :—The Older Neogene exposed on the north and west of the Ashigara Range in Kai, forming a narrow belt and representing the upper part of the Misaka Series, consists mainly of hard green tuff with andesite sheets. Near Yoshida on the north of Mt. Fuji, bones and teeth of *Physterinae*, teeth of *Miliobates cornuata* Gthr., *Astriclypeus integer* Yosh. and shark's teeth, together with fossil shells have been found in the green tuff. The limestones at Mizuhomura, Ōtsuki, Kaisawa, etc. yields *Orbitoides* and *Lithothamnium*, which are specifically identical with those of the upper part of the Misaka Series already mentioned.

(iii) **ORBITOIDES LIMESTONES OF NAKA-OZAKA IN KOZUKÉ** :—At the northeastern border of the Kwantō Mountains there are Older as well as Younger Neogene. The Older is represented by the alternations of sandstones and shales of Naka-Ozaka with layers of *Orbitoides* limestone and the Younger by tufaceous clastics with Pliocene shells. According to Yabé, the *Orbitoides* limestone contains *Lepidocyclina japonica* Yabé, *L. douvillei* Y. et H., *L. glabra* Rutten, *Miogypsina* sp., *Amphistegina lessoni* d'Orb.

(iv) **PLANT FOSSIL BED OF ITSUKAICHI** :—The Older Neogene found in the small besin of Itsukaichi, west of Tōkyō, contains lithographic marl, and yields Miocene plants besides some crabs; the Miocene plants are *Castanea kubinyi* Kovats., *C. ungeri* Hr., *Fagus* sp., *Juglans acuminata* Al. Br., *Planera ungeri* Ett., *Comptoniphyllum japonicum* Nath., and *Sapindiphyllum dubium* Nath.

(v) **PLANT FOSSIL BED OF KAMIKANAZAWA IN HITACHI** :—On the southwest of the Abukuma Plateau, the Neogene strata which occupy the intermontane valleys of the Yamizo Range are composed of conglomerate, sandstone, shale and thick tuff, and contain thin coal seams and plant remains. Nathorst described, from his "Pre-Pliocene Flora" of Kamikanazawa in Kuji-gori, Northern Hitachi, the following plants: *Sequoia* sp., *S. disticha* Heer ?, *Cyperites* sp., *Salix lavateri* Heer, *Comptoniphyllum japonicum* Nath., *Zizyphus tiliaefolius* Ung., *Juglandiphyllum* sp.

(b) YOUNGER NEOGENE:

(i) **LOWER MUSASHINO (MIURA SERIES) IN SAGAMI** :—The lowest part of the Series consists of a tufaceous shale (Zushi Shale), parted by thin sandstone layers, with a sandstone bed at the base. The shale is followed above by thick beds of sandy pumiceous tuff and tufaceous sandstone (Kamakura sandstone). Upon this is a massive tufaceous shale (Ōfuna shale) with sandstone beds (Kanazawa sandstone) in its upper part. The uppermost portion of the Series is made up of sandy to tufaceous clayey shale (Kuragi shale) exposed in the Kuragi district south of Yokohama. It attains a total thickness of probably several hundred meters.

The Series is rich in organic remains, which are mostly mollusca, but sometimes plants, worms, echinoids, foraminifera, etc.

From the shell bed of Naganuma in Sagami, Yokoyama described 86 species of mollusca, of which 53 are living and 33 not yet known to live in the neighbouring seas.

The shell beds of Koshiba, Ōfuna, Kanazawa, Nojima, Kamakura and Zushi are all evidently to be included in the Lower Musashino or Miura Series. Yokoyama determined 235 species of mollusca, some of which, however, seem to belong to the deposits decidedly younger than the Lower Musashino. Nevertheless, the percentage of the extinct forms exceeds 37%, the number amounting to 88 or at least 82. The common and abundant forms number 28, and those not living in the adjacent seas, 34. The common forms are;

1. *Pleurotoma cosibensis* Yok.
2. *Voluta megaspira* Sow.
3. *Mitra pacifera* Yok.
4. *Chrysodomus phoeniceus* Dall.
5. *Chrysodomus pericochlion* var. *schrencki* Yok.
6. *Trophon inermis* Sow.
7. *Trophon nipponicus* Yok.
8. *Priene oregonensis* Redf.
9. *Turritella nipponica* Yok.
10. *Natica janthostoma* Desh.
11. *Bembix crumpii* Pils.
12. *Dentalium complexum* Dall.
13. *Dentalium weinkauffi* Dkr.
14. *Corbula venusta* Gld.
15. *Cardium modestum* Ad. et Rve
16. *Venericardia ferruginea* Ad.
17. *Crassatella oblongata* Yok.
18. *Pecten irregularis* Sow.
19. *Pecten vesiculosus* Dkr.
20. *Ostrea musashiana* Yok.
21. *Pectunculus nipponicus* Yok.
22. *Parallelodon obliquatus* Yok.
23. *Limopsis tokaiensis* Yok.
24. *Limopsis crenata* Ad.
25. *Leda ramsayi* Smith.
26. *Terebratulina crossi* David.
27. *Terebratulina quantoensis* Yok.

As pointed out by Yokoyama, it is a notable fact that there are many northern or boreal forms in the Koshiba fauna. These forms are Nos. 4, 8, 14, 16, in the above list and *Admete viridula* (Fabr.), *Pollinices pallidus* Brod. et Sow., *Leptothyra amusitata* Gld., *Margarita umbilicalis* Brod. et Sow., *Astarte hakodatensis* Yok., *Pecten swiftii* Bern., *Nucula insignis* Adams and *Trophon subclavatus* Yok., besides two deep-sea forms, *Lima goliath* Smith and *Leda ramsayi* Smith.

(ii) **MIURA SERIES OF BŌSŌ**:—On both wings of the axial mountains of the Bōsō Peninsula there is found the Lower Musashino or the Miura Series which rests unconformably on the Sakuma Series and forms low plateaus. It has at its base the massive Nabuto shale containing *Thyasira bisecta* Conrad.

(iii) **ASHIGARA TERTIARY**:—In the Ashigara district, north of Hakoné, there is a series of conglomerate and sandy shale, which is referable to the Lower Musashino. *Limopsis azumana* Yok. which occurs in the Lower Musashino of Koshiba is common at Ninomiya, Sagami. Similar fossils are also found at Hamagurizawa (Yotsukurazawa) and Oyama.

(iv) **TERTIARY OF THE CHICHIBU BASIN**:—The ascending order of superposition of the rocks is (1) conglomerate, (2) sandstone, (3) sandstone and shale (4) shale. From it Brauns described 20 species of shells, having much in common with those in the Tōkyō Bed. *Thyasira bisecta* Conrad which is not found in the latter is found here. Yokoyama described 45 species of mollusca, collected by Tokunaga, and assumed that the Tertiary in the basin is of the Lower Pliocene. The most common species, both extinct and living are

1. *Terebra emicula* Yok.
2. *Voluta megaspisa*, Sowerby var. *striata* Yok.
3. *Turritella nipponica* Yok.
4. *Turbo* (*Batillus*) *cornutus* Gm.
5. *Dentalium weinkauffi* Dkr.
6. *Tellina optiva* Yok.
7. *Clementia speciosa* Yok.
8. *Cardium pauperculum* Yok.
9. *Lucina borealis* L.
10. *Diplodonta tokunagai* Yok.
11. *Crassatella pauxilla* Yok.
12. *Lima goliath* (Sow)
13. *Arca amicula* Yok.
14. *Yoldia gratiosa* Yok.
15. *Terebratulina japonica* (Smith.)

(v) **TERTIARY OF THE USUIGAWA AND SHIMONITA**:—The group of tufaceous clastics exposed along the Usui-gawa is a formation corresponding to the Taga Formation (Pliocene) of Northern Hitachi.

Closely related to the above are formations consisting of conglomerate and sandstone with lignite in the lower part, seen in the vicinity of Shimonita and also at Ichinokaya on the upper course of the Saimoku-gawa in Kōzuké. The stratigraphical relation of these Formations to the *Orbitoides* limestone of Naka-Ozaka is at present unknown.

(vi) **LIPARITIC TUFF OF SHIOBARA**:—In the vicinity of the Shiobara hot spring the prevailing rock is a thick liparitic tuff with sandstone. Fossil shells contained in them according to Yokoyama are *Priene oregonensis* Redf., *Polinices ampla* Phil., *Panope generosa* Gld., *Tellina* *dissimilis* Mart., *Macoma praetexta* Mart., *Lucina borealis* L., *Pecten Swiftii* Bern., *Nucula mirabilis* Ad. et Rve., *Spisula grayana* Schr., *Mitylus giganteus* Holm., besides *Mitra pristina, Dosinia kaneharai, Cardium shiobarense, Pecten kaneharai, Sigaretus festivus,* etc. specified by Yokoyama. Of 25 shells determined by him, 8 are extinct and 4 are new forms. The fauna is considered to be probably not younger than the Middle Pliocene.

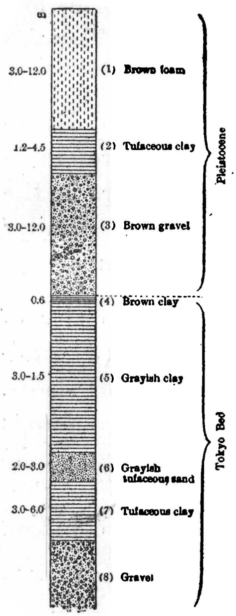

Fig 1. Section of the Pleistocene and the Tōkyō Bed in Tōkyō

(c) UPPERMOST SERIES:

(i) **UPPER MUSASHINO AND TŌKYŌ BED**:—

In Tōkyō, the exposures of the Upper Musashino, locally known as the Tōkyō Bed, have been examined at Ōji, Tabata, Surugadai, Shinagawa, etc. Throughout these places the stratigraphical succession is nearly the same, as shown in Fig. 1. A geological section obtained at Ōji is given in Fig. 2. At Ōji and Tabata, the clay containing impressions of leaves is separated from the uppermost loam by clay and gravel without unconformability ; a little lower lies a sandy layer with abundant shells. At Tabata, teeth of *Elephas namadicus* Falc. et Caut. var. *naumanni* (Mak.) and bones of mammals have been found in a sandy layer between the plant and shell beds.

According to Tokunaga, the Tōkyō fauna indicates a colder climate than now, and of the numerous shells he recognized as surely extinct are *Cardium braunsi, Tellina serricostata, Pecten tokyoensis, Pleurotoma ojiensis, Trochus angulatus, Turbonilla paucicostata,* and *Odostomia takinokawensis* Yok.

Yabé supports Tokunaga's view that the shell bed of Tōkyō belongs to the Pleistocene. He and S. Hanzawa have also described 38 species of foraminifera found in the shell bed of Shinagawa. Yokoyama described about 100 species of molluscs from Ōji, 30 species from Tabata, and 62 species from Shinagawa. All these fossils are those included in the Manzakian Fauna which are found

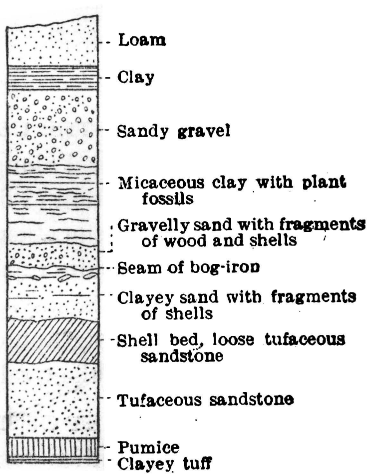

Fig. 2.—Section at Ōji mill, 1/500.
(After Suzuki)

in the Narita Bed. Of these fossils, about 20 species are not known to live in the Japanese waters.

(ii) **UPPER MUSASHINO OF KAZUSA**:—For the Upper Musashino Formation in the environs of Minatomachi in Kazusa, the local name of the Sanuki Bed is used by Yabé and others, who regard it as an equivalent of the Naganuma Bed of Sagami. Prof. H. Matsumoto described *Euelephas protomammonteus* Mats., *Cervus* sp., *Giraffa microdon*, *Stegodon orientalis* found in this bed at Minato, and concluded that the fauna is of the Upper Pliocene (Calabrian).

(iii) **PLANT FOSSIL BED OF SHIOBARA**:—Unconformably overlying the Pliocene marine tuff beds previously mentioned, is a tufaceous shale of lacustrine origin, yielding excellent specimens of the "Post-Miocene Plants" cited by Nathorst as follows:—

Thuites sp., *Betula alba* L. *fossilis* Nath., *B. sublenta* Nath., *Carpinus subjaponica* Nath., *Quercus crispula* Bl. *fossilis* Nath., *Q.* sp., *Fagus sylvatica* L. *fossillis* Nath., *Fagus japonica* Max. *fossilis* Nath., *Cercidiphyllum japonicum* S. et. Z. *fossilis* Nath., *Actinidiophyllum* sp., *Tilia* sp. (cf. *cordata* Mill.) *Acer* cf. *nordenskiöldi* Nath., *Acer* sp. and *Myriophyllum* sp.

Nathorst considered these fossils to be a little younger than the Mogi Flora in Kyūshū.

(2) JOBAN DISTRICT:

In a narrow strip of land lying on the Pacific side of the Abukuma Plateau, the Neogene forms the hills skirting the plateau. The Neogene of Jōban is divisible into three formations, each separated by distinct erosional unconformities; namely, the lower,—the Shiramizu Series; the middle,—the Yunagaya Series; and the upper,—the Shirado Series.

(a) OLDER NEOGENE:

(i) **SHIRAMIZU SERIES (MIOCENE)**:—The Shiramizu Series, or the Jōban coal-bearing Series, extends from south of Takahagi northwards to the vicinity of Tomioka. The lowest portion of the Series is composed of fresh-water deposits containing coal seams which are extensively worked. The upper portion abounds in molluscan remains. The ascending succession of strata given by Prof. Nakamura is as follows:

1) Basal conglomerate and sandstone; 10 to 45 meters thick.
2) Coal-bearing beds; 70 meters thick.
   a) Lower coal-bearing bed; 15 meters thick.

b) Shiramizu sandstone; fine sandstone, locally conglomeratic.
c) Upper coal-bearing bed; 3 to 20 meters thick, averaging 10 meters.

3. Iwaki sandstone; green sandstone 90 to 290 meters thick, with conglomerate and coarse grained quartz sandstone.

a) The first sandstone
b) Nametsu conglomerate
c) The second sandstone
d) Tochikubo conglomerate
e) The third sandstone
f) Takakura sandstone
g) The fourth sandstone

4) Asagai sandstone (*Cardium* Bed); fine grained green sandstone, richly fossiliferous, 30 to 120 meters thick.

5) Shirasaka Shale; gray to black fissile shale, non-fossiliferous, 115 to 180 meters thick.

From the Coal-bearing Beds of Kōya and Azuhata, the following plant fossils were described by Nathorst; *Sequoia disticha* Heer, or *S. langsdorfii Brong.*, *Acer arcticum* Heer, *Juglans acuminata* Al. Br., *Juglans nigella* Heer, *Carpinus* sp. Besides these, Nakamura found in the Coal-bearing beds, *Glyptostrobus ungeri* Heer, *G. europeus* Brong., *Populus zaddachi* Heer, *Salix lavateri* Heer, and *Betula prisca* Ett.

In the Iwaki sandstone, he also found *Sequoia disticha* Heer and *Zelkova ungeri* Heer. The plant fossils belong to the so-called Arctic Miocene Flora; but some are of opinion that the Coal-bearing beds beneath the Iwaki sandstone may possibly be the Palaeogene.

The Asagai sandstone in the upper part of the Series is richly fossiliferous, and is characterized by *Turritella tokunagai* Yok., *Tellina besshoensis* Yok., *Thyasira bisecta* Conrad, *Cardium tristiculum* Yok., *Mya crassa* Grew., *Papyridea nipponica* Yok., *Venericardia tokunagai* Yok., *V. pacifera* Yok., *Nucula insignis* A. Ad., etc. which are mostly extinct forms. Tokunaga made a large collection of the Iwaki and Asagai fossils which have been lately studied by Yokoyama who referred their geological age to the Miocene. The Asagai sandstone is considered by some as almost contemporaneous with the Poronai Series of Hokkaidō.

(ii) **YUNAGAYA SERIES (MIOCENE)**:—The Series, which is considered to be the Upper Miocene is sometimes called the Kamenoo Group. The ascending succession of rocks as determined by Nakamura is given below, slightly modified;

1) Goyasu sandstone ;

a) Basal conglomerate ;

b) Goyasu sandstone ; with thin lignite seams.

c) Yotsunami sandy shale ; with *Thyasira bisecta* Conrad, etc.

2) Mizunoya shale and sandstone ; with *Yoldia sagittaria* Yok., etc.

3) Kamenoo shale (*Leda* Bed); highly fossiliferous, characterized by *Venericardia orbica* Yok., *Pecten tairanus* Yok., *Leda pennula* Yok., *L. inermis* Yok., *Yoldia tokunagai* Yok., and *Nucula eximia* Yok.

4) Yasaka Shale.

(b) YOUNGER NEOGENE:

SHIRADO SERIES (PLIOCENE):—This, also known as the Taga Series, or sometimes as the Tokiwa Series, is extensively developed along the Jōban coast, and may be traced from the northeastern part of the Kwantō Plain to the environs of Sendai in Rikuzen. In the Iwaki district, this formation consists of the following beds from the base upwards:

1) Misawa Sandstone and Ishimori Agglomerate: The sandstone often contains marine fossils such as *Thyasira bisecta* Conrad, *Cultellus izumoensis* Yok., *Lucina borealis* L., and *Solemya tokunagai* Yok. Near Nakoso, *Cerithium baculum* Yok. has been found. It occurs also in the Pliocene of eastern Mino and of Tanabé in Kii.

2) Nakayama Tuffite and Shale: The tuffite has a fossil zone yielding *Mactra spectabilis* Lke., *Spisula grayana* Schr., *Panope generosa* Gld., etc. The shale sporadically contains *Lucina borealis* L., *Pecten Kimurai* Yok., etc.

3) Kobana Sandstone:

4) Ona Sandy Shale: with *Venericardia ferruginea* Ad., *Turritella nipponica* Yok., etc.

5) Usuiso Sandstone and Izumida Shale: The Izumida shale contains *Yoldia tokunagai*, etc. The Usuiso sandstone is interbedded in the lower part of the shale.

Of about 110 fossil shells of the Shirado Series, described by Yokoyama, 22 are extinct, 70 are common with those of the Musashino and other Pliocene formations and 15 go up to the Miocene. Shark-teeth are not uncommon. *Carcharodon megalodon* (Charlesworth), *Isurus hastalis* (Ag.), *Carcharodon carcharias* Ag. and *Carcharinus commersoni* Blainville are known to occur in Taga-gōri. *Linthia nipponica*, a sea urchin, is characteristic. At Hanareyama in Hitachi, in the uppermost portion of this series have been found teeth of *Mastodon* (*Tetraphodon*) cf. *latidens* Clift.

(3) ENVIRONS OF SENDAI:

In the environs of Sendai, the Neogene has been studied by Hayasaka, Shimidzu and others who recognized the following succession of rocks:

Miocene	Baba Group: Sandstone and shale with plant fossils. Nagabukuro Group: Green tuff, sandstone and conglomerate. Takadaté Group: Andesite agglomerate and tuff.
Miocene or Pliocene	Moniwa Group: Tuff and conglomerate with shells. Akihoishi Group: Liparitic tuff-breccia and some shale, with *Taxodium distichum miocenum* Heer, *Betula brongniarti* Ett., *B. macrophylla* (Göpp.), and *Alnus nostratum* Heer.
Pliocene	Sawoyama Group: Sandstone and a small amount of shale and sandy shale with fossil shells. Mitaki Group: Sandstone and shale with tuff, tuff-breccia and agglomerate, 20–25 m. thick, with plant fossils. Lower Umoregi Group: Tuff and sandstone, 15 m., with *Fagus sy'vatica* L. var. *sieboldi* Max. *Sasa* cf. *borealis*. Tatsunokuchi Group: Tufaceous sandy shale, 30 m. thick, with *Mactra sachalinensis* Schrenck, *Mya arenaria* L., *Panope generosa* Gld., etc.
Uppermost Pliocene	Middle Umoregi Group: Shale with tuff and sandstone; conglomerate at the base; 18–20 m. thick. Upper Umoregi Group: Shale with sandstone and pumice. Dainenji Group: Loose sandstone with shale 10–15 m. thick.

Groups Baba to Takadaté may belong to the Older Neogene. The formation from the Moniwa up to the Tatsunokuchi inclusive can be traced farther to the south and is known to be an equivalent of the Tokiwa or Shirado Series of Iwaki and Hitachi. The Mitaki Group of Shiogama contains *Sabal* sp., *Juglans nigella* Heer ?, *Fagus* sp., *Castanea kubinyi* Kovat., *Ficus* sp. and *Liquidamber formosana* Hance *fossilis* Nath., *Vitiphyllum* sp. A. Kryshtofovich believes that these plants are somewhat older than the Mogi Flora, while the Akihoishi Flora (his Sendai Flora) is of the Miocene.

(4) FUKUOKA DISTRICT IN MUTSU:

At Hiranuka in Ichinohe-gōri, the following plant fossils were found by Nakamura in a tufaceous sandstone forming the lower part of the Series:

1. *Taxodium distichum miocenum* Heer ?
2. *Sequoia disticha* Heer.
3. *Sequoia Langsdorfii* Brong.
4. *Betula priosca* Ett.
5. *Betula sachalinensis* Heer.
6. *Alnus Kefersteinii* Ung.?
7. *Carpinus* sp.
8. *Fagus antipofi* Heer.
9. *Fagus* sp.
10. *Quercus* cf. *stuxbergi* Nath.
11. *Quercus* sp.
12. *Juglans acuminata* Al. Br.
13. *Populus latior* Al. Br. ?
14. *Juglans nigella* Heer.
15. *Salix lavateri* Al. Braun
16. *Salix raeana* Hr.?
17. *Ulnus* cf. *elegantior* Nath.
18. *Planera ungeri* Ett.
19. *Zelkava keaki* Sieb. *fossilis* Nath.
20. *Ficus* sp.
21. *Polygonum* sp.

In a shale lying much higher than the plant bed, *Vicarya* cf. *callosa Jenkins* and *Desmostylus nipponicus* Yosh. et Iw. were found. From the sandstone upon the shale, *Isurus* (*Oxyrhina*) *hastalis* Ag., *Carcharodon megalondon* (Charlesworth) and *Carcharinus commersoni* Bl. were obtained. The upper part of the Series is probably contemporaneous with the Tokiwa (Shirado) Series of Iwaki.

(5) WESTERN PART OF NORTHERN HONSHŪ (MUTSU, UGO, UZEN AND ECHIGO):

In the western part of Northern Honshū the Neogene extends from Shinano and Echigo on the south-west, through Uzen and Ugo, to the northern end of Mutsu. Table X shows a summary of stratigraphical relations of the various oil-fields hitherto surveyed. Unconformity has never been observed except at the base of the so-called " Uppermost Series."

The Older Neogene of this region consists of thick white liparitic tuffs, green andesitic or basaltic tuffs, shales, cherts, sandstones and some conglomerates of a rather hard character, with many interstratified flows or sheets of liparite, andesite, basalt and their agglomerates.

The lower part contains the Pre-Pliocene Flora and in a few cases coal-seams are interbedded. The upper part of this Series consists mainly of marine deposits and is presumably petroliferous. This Older Neogene and the younger volcanic effusives, are the main constituents of the Ōü Range and other mountainous regions.

The Younger Neogene on the other hand generally forms lowlands and low hills on both sides of the Ōü Range. It occurs widely in the coastal lowlands, the strata being gently folded and constituting the greater part of the oil-lands. The rocks are chiefly shales, sandy shales, sandstones, unconsolidated sands, clays and conglomerates with andesitic tuffs. The fossil contents and the topographical features of the Younger Neogene resemble those of the Musashino Formation in the environs of Tōkyō.

Table X.

		Daishaka Oil-field in Mutsu	Akita Oilfields in Ugo. Summerized Section	Akita Oilfields in Ugo. Oga Peninsula	Oilfields of Mogami Distr. in Uzen	Southern part of Uzen & northern part of Echigo	Echigo Oil-fields	Chikuma Range in Shinano & Western part of Echigo
Younger Neogene	Upper most Series	Volcanic tuff and Sand	Uppermost Series Sand, Clay and Gravel 50–100		Upper Lignitic, Loose Sand, Lower Lignitic	Sand and Gravel	Uppermost Series Clay, sand and gravel	
Younger Neogene	Sawane Tertiary in Sado.	Sandstone	Sandstone 200–250	Shibikawa Sand 250	Sandstone and Alternation of Sandstone and Shale 200		Tsukayama Sand-stone Wanazu Sandstone	Lignite Bed with plants
Younger Neogene	Sawane Tertiary in Sado.	Shaly Sandstone Sandy Shale	Sandy Shale 450 (200–100)	Wakimoto Sandy Shale	Shaly Sand-stone and Sandy Shale 400	Sandy Shale Bed	Shiraiwa Sandy Shale (Turritella Zone)	Sandstone Series with Sakae fauna ?
Younger Neogene	Sawane Tertiary in Sado.	Massive black Shale	Alternation of Sandstone and Shale and Gray Shale 500 (100–1000)	Kitaura Alter-nation, Nomura Gray shale	Gray Shale Bed 450	Gray Shale Bed	Nishiyama Gray Shale (Pectun-culus Zone) Shiiya Alternation	Sandstone, Shale Conglomerate of Gōzu
Older Neogene	Aikawa Tertiary in Sado	Platy Black Shale	Upper Tuff 100–400 Black Shale 400	Funakawa Black Shale	Black Shale } 900	Numazawa Black Shale with Sand-stone	Kubiki & Nana-tani Black Shale	Susobana Tuff Kubiki Black Shale
Older Neogene	Aikawa Tertiary in Sado	Siliceous Shale and Green Tuff	Lower Tuff 50–100 Siliceous Shale 200–300	Daijima and Nishikurosawa Beds 480	Siliceous Shale and Green Tuff } 900	Myōzawa Green Tuff with Sandstone & Shale	Thick Tuff with Sandstone and Shale	Alternation of Sandstone and Shale with Shells at Semmi
Older Neogene	Aikawa Tertiary in Sado		Green Tuff 500	Sugoroku pyroclastics		Tabanematsu Basal Conglom-erate	Basal Conglome-rate with plants at Kwannonzawa	Basal Conglom-erate with plants at Nambayama

(Figures in the table show the thickness of the beds in meters.)

(a) OLDER NEOGENE:

(i) **WESTERN PART OF MUTSU AND UGO:** The Green Tuff Bed. The tuff is intercalated with tufaceous shale, sandstone, chert and conglomerate. In a limestone interbedded in this Green Tuff at Tanosawa in Mutsu, *Operculina complanata* Defr. (var. *granulosa* Leymerie) has been found.

Siliceous Shale Bed. The occurrence of cherts or siliceous shales seems to be a characteristic feature of the petroliferous strata in the western coastal region of northern Honshū. They contain sponge-spicules (Monactionellids) and some diatom remains, as in the Monterey Shale of California. A calcareous sandstone at Nishikurosawa in Ugo yielded *Operculina complanata* and *Miogypsina* sp.

Black Shale Bed. This shale is often noduliferous and frequently contains diatoms (*Conscinodiocus* and others).

(ii) **UZEN AND NORTHERN ECHIGO:** Three beds, namely, Green Tuff, Siliceous Shale and Black Shale are recognized in the Mogami district as in the case of Ugo. At Aoisawa on the Mogami-gawa, *Thyasira bisecta* Conrad, *Cardium, Mya truncata* L., *Natica, Trophon,* etc. have been found in the Black Shale. On the south of Sakata, theOlder Neogene has a conglomerate overlain by Green Tuff, with tufaceous shale containing plant fossils, and upon it Siliceous Shale and Black Shale in succession. Coal seams are embedded in the Siliceous Shale bed. Plant fossils from Aburado are *Sequoia* sp., *Fagus antipofi* Heer, *Alnus Kefersteinii* Unger. var., *Aesculiphyllum minus* Nath., *Abies* sp., *Tilia* sp., *Comptoniphyllum japonicum* Nath. Plant fossils at Yamakumada in Echigo are *Querciphyllum* cf. *lonchites* Ung. and *Sequoia langsdorffi* Brong.

(iii) **ECHIGO:** The three beds of the Older Neogene mentioned above are also found in the Kambara district of Echigo and the Aizu district of Iwashiro. The Black Shale Bed of the Echigo Oil-fields (corresponding to the Numazawa Shale of Uzen and the Funakawa Shale of Oga in Ugo) has been named the Kubiki Series by T. Iki. It is also known as the Nanatani Shale in the Niitsu Oil-field.

Plant fossils occurring in the tuff-beds of Kwannonsawa, Higashi-Kambara-gori, Echigo as cited by Al. Kryshtofovich are:

Pteris cf. *oeningenensis,* Al. Br.
Tauxus cf. *baccata* L.
Libocedrus sp. or *Thuya* sp.
Pinus sp. (leaves and seeds)
Quercus Nathorsti Krysht.
Quercus pregilva Krysht.
Quercus kazanskyi Krysht.
Quercus sp.

Castanea ungeri Hr.
Comptonia japonica Nath.
Comptonia naumanni Nath.
Carpinus sp.
Liquidambar formasana Hance.
Trapa yokoyamai Nath.

(b) YOUNGER NEOGENE:

(i) **THE NOMURA GRAY SHALE, THE KITAURA BED OF UGO, THE SHIIYA SERIES AND THE NISHIYAMA GRAY SHALE**:—The lowest division of the Younger Neogene is usually represented by an alternation of Gray Shale or Black Shale and sandstone, or often by a single bed of Gray Shale. In the Echigo Oil-fields, the former is known as the Shiiya Series and the latter as the Nishiyama Gray Shale. The corresponding beds in the Oga Peninsula in Ugo, are the Kitaura Bed and the Nomura Gray Shale. The alternating bed of shale and sandstone in southern Ugo is locally called the Katsurané Series.

The Gray Shale is transitional to the Black Shale and is usually massive and frequently noduliferous. In the Gray Shale, diatom casts, *Coscinodiscus robustus* Grev., *C. oculis-iridis* Ehrenberg, *Synedra*, etc. and spicules of Monactinellid sponges have been found. Common molluscan fossils in this shale are *Thyasira bisecta* Conrad, *Turritella saishuensis* Yok. and T. *nipponica* Yok. In the Shinjō-Mogami Oil-fields in Uzen, the Gray Shale Bed is characterised by the frequency of *Thyasira bisecta* Conrad.

(ii) **THE SHIRAIWA AND WAKIMOTO SANDY SHALE**:—This Sandy Shale is richly fossiliferous and frequently contains abundant diatoms. From the fossil beds, in the Wakimoto Sandy Shale in Ugo, corresponding to the *Turritella* Zone of Echigo, the following shells have been obtained :

Pectunculus yessoensis Jay.
P. albo-lineatus L.
Astarte borealis (Chem.)
Diplodonta usta Gld.
Venericardia borealis Conrad.
Cardium muticum Rve.
Macoma dissimilis Martens
Tellina venulosa Schrenck
Saxidomus purpuratus Sow. ?
Teresus nuttali Conrad
Polinices ampla Phil.
P. cf. *pallidus* Brod. et Sow.
Natica janthostoma Desh.
Trophon cf. *geversianus* Pallas.

From the Oga Peninsula, *Yoldia* cf. *lischkei* Smith, *Nucula mirabilis* Ad. et Rve., *Pseudamusium* cf. *randolfi* Dall., *Trophon muricatus* Mont. and 8 species of foraminifera have been recorded.

In the Mogami Oil-fields of Uzen, the Sandy Shale Bed is characterized by the occurrence of *Linthia nipponica* Yosh. besides *Thyasira bisecta* Conrad. In the Nishiyama and the Niitsu Oil-fields thick limestone, locally called "Natsukawaishi," contains fossil beds in which are found numerous remains of foraminifera, bryozoa, echinoidea, ostracoda, and minute mollusca. A calcareous algae, *Lithothamnium ramoisissimum* Reuss, has also been discovered. Yabé has described 9 species of foraminifera from the Natsukawa bed of Hotoke-tōgé in the Niitsu Oil-fieid. Yabé and Hanzawa described 65 species of foraminifera from the Natsukawa Limestone of Kutta in Echigo.

From the Shiraiwa Sandy Shale at Shiraiwa and Myōken, in Koshigōri, *Linthia nipponica* Yosh. has been recorded. Hayasaka described *Hemithyris psittacea* Gmelin var. *woodwardi* Ad. from the Natsukawa Limestone Bed of Ogi in Santō-gōri, Echigo.

(iii) **THE WANAZU, TSUKAYAMA AND SHIBIKAWA SANDSTONE:** The Shiraiwa or Wakimoto Sandy Shale passes above into a fine sandstone bed which is known as the Wanazu and Tsukayama, or Shibikawa Sandstones, respectively in the Echigo and Akita Oil-fields.

The Wanazu and the Shibikawa Sandstone are highly fossiliferous. From the corresponding bed in the Daishaka Oil-fields in Mutsu, *Pecten swiftii* Bern., *P. yessoensis* Jay, *P. cosibensis* Yok., *Venericardia ferruginea* Ad., and *Mitra ebenus* Lam. have been obtained. T. Iki obtained from the Shibikawa Sandstone, *Thyasira bisecta* Conrad, *Cardium muticum* Rve, *Pecten yessoensis* Jay, *Lucina borealis* L., *Nucula mirabilis* Ad. et Rve. and other shells.

(c) UPPERMOST SERIES:

This overlies unconformably the Younger Neogene and consists of unconsolidated sands, clays and gravels, sometimes with lignite beds. In places, these rocks are tufaceous and mixed with blocks of andesite. The strata have usually a gentle inclination or are nearly horizontal, in rare cases being highly disturbed.

In the Daishaka Oil-field in Mutsu, the Series is conformable to the Wakimoto Sandstone and abounds in fossils of marine shells and foraminifera. In Uzen, the Series occupies the Shinjō Basin, where it contains lignite seams in two horizons. The lignite seams are taken as corresponding to the Middle and Upper Umoregi group of Sendai. In Echigo, the Series occurs in the Nishiyama, Higashiyama, Uwonuma and Murakami Oil-fields.

(6) SADO ISLANDS:

In Sado, the Older Neogene received the name of "Aikawa Tertiary" and consists of tuffs, tuff-breccia, conglomerates, sandstones, cherts and interbedded liparitic and andestic sheets, cut by many auriferous veins.

The Younger Neogene is known as the "Sawané Tertiary." In the western part of the island, the Aikawa Tuffs are overlain unconformably by the Sawané Tertiary, consisting of basal conglomerate, sandstone, dolomitic cherty shale, etc. In the basal conglomerate were found the teeth of *Desmostylus*; and in the sandstone, *Operculina* and *Miogypsina*. Near Sawané, more than 100 species of molluscan fossils were collected, including *Thyasira bisecta*, *Pecten yessoensis*, *P. Swiftii* and *Lucina borealis* L.

(7) WESTERN ECHIGO AND NORTHERN SHINANO:

(a) OLDER NEOGENE: In the Chikuma range, this is divisible into three beds; viz, the Lower, the basal conglomerate; the Middle, an alternation of sandstone and shale; the Upper, black shale. From the Upper and Middle beds at Nambayama and Tsuchiro in the Kubiki district the following fossils have been collected; *Fagus* cf. *antipofi* Hr., *Juglans* cf. *acuminata* Al. Br., and *Salix* cf. *lavateri* Hr. Yokoyama described *Thyasira bisecta*, *Mactra seminiana* and *Arca amicula* from the Middle bed (?) of Semmi in Shinano.

(b) YOUNGER NEOGENE: In the Chikuma range, there is found a sandstone series resting unconformably upon the Kubiki Black Shale Series. The sandstone series is believed to be in the same stratigraphical position as the Shiraiwa Sandy Shale. Shell remains, 56 species, have been found at Sakae, Togakushi and Gōzu, of which 23 are of extinct forms. At Nakajō, in Sakae-mura, from the bed containing *Linthia japanica* Yosh. were obtained *Fagus japonica* Max. var. *fossilis* Nath., and *Zelkova keaki* Sieb. var. *fossilis* Nath., determined by A. Kryshtofovich.

(8) PLANT BEDS OF SHINANO:

The Tertiary in Shinano yielded plant fossils, most of which belong to the Pre-Pliocene plants of Nathorst, but seem to comprise floras of different stages. Plant fossils from Kita-aiki and Yosawa are of the Older Neogene, while some of the other localities are, according to A. Kryshtofovich, referable to his Sendai Flora, those from Sakaemura being evidently of the Pliocene age.

(9) ETCHŪ:

In Etchū, northwest of the Hida Mountains, the Neogene consists of volcanic tuffs and tuff-breccias with intervening agglomerates in the lowest part, overlaid by tufaceous sandstone and shale with thin coal seams and plant fossils. According to S. Ōtsuka, the beds are comparable with the Older Neogene of Echigo. On them there are beds of sandstone and tufaceous shale which probably belong to the Younger Neogene of Echigo.

(10) NOTO PENINSULA AND THE ADJACENT PART OF KAGA AND ETCHŪ:

The Tertiary in these regions appears to be partly the Older, partly the Younger Neogene. In marl nodules in the sandstone at Nadaura in Etchū occur *Thyasira bisecta* and other shells, at Soboura of Notojima *Periotic* and *Tympanic* of fossil whale and elephant teeth ; and at Shirogaminé in Etchū *Echinarachnius parma* Lam.

The sandstone of Hannoura and Nanao contains shark-teeth, molluscan shells, hexactinellid sponges, radiolaria and diatoms in fair abundance. Yabé determined 13 species of foraminifera in the sandstone of Izumodai in Hiuchidani in Kaga, and 6 species in the Nanao sandstone of Iwaya in Noto which abounds in *Terebratulina caputserpentis* L.

(11) KAGA AND ECHIZEN:

Here, the Neogene consists chiefly of volcanic clastics intercalating sandstone and marl layers as well as lava sheets. Nathorst described *Trapa yokoyamai* Nath. from a tufaceous shale of Ogoya in Kaga, and *Carpinus* cf. *grandis* Unger, and *Querciphyllum lonchites* U. from a tuff found at Ōtsuchi in Kaga. Probably in the horizons higher than the above, there are marine beds and a plant fossil bed. In a small outcrop at Ushigatani, near Katsuyama in Echizen were found Post-Miocene plants such as *Fagus japonica* Max. *fossilis* Nathorst, *Polygonum caspidatum* Sieb. *fossilis* Nath., and *Phyllites* sp. An elephant-tooth, *Elephas aurorae* Mats. was found at Tomuroyama, east of Kanazawa.

(12) TŌTŌMI AND SURUGA:

The Tertiary found in the west of Shizuoka is known as the " Ōi-gawa Tertiary." It is divisible into two major groups, the Lower and the Upper, which are not in conformity with each other.

(a) LOWER ŌI-GAWA TERTIARY:—This is supposed to be the Miocene and is composed of folded shales and sandstones with a subordinate amount of volcanic tuff and limestone. In the Sagara Oil-field, west of the Ōi-gawa, the bed is much folded with axes running NE-SW. T. Iki divided the upper part of it into (1) Megami shale with limestone, (2) Sugegaya Beds of shale and sandstone (3) Sagara shale, the last being the uppermost bed. A reef-like limestone in the Megami shale exposed at Ogami contains *Lithothamnium ramosissimum* Reuss, *Turbo mekamiensis* Nishiwada, *Stylophora*, *Milliopora*, *Pecten*, etc.

(b) UPPER ŌI-GAWA TERTIARY:—There are two distinct formations; the Kakegawa Series of the Lower Plioceneand the Ogasayama conglomerate of the Uppermost Pliocene, the latter being unconformable with the former.

M. Yokoyama described 42 mollusca from the Kakegawa Series of Dainichi, of which 38 are specifically determined. Of these 38, the following 15 are extinct :—

1. *Arca castellata* Yok.
2. *Drillia pseudo-principalis* Yok.
3. *D. quantoana* Yok.
4. *D. sobrina* Yok.
5. *D. dainichiensis* Yok.
6. *Olivella spretoides* Yok.
7. *Ancilla okawai* Yok.
8. *Mitra pristina* Yok.
9. *Eburna elata* Yok.
10. *Nassa demissa* Yok.
11. *Murex spinicosta* Braun.
12. *Galeodea (Sconsia) japonica* Yok.
13. *Turritella perterebra* Yok.
14. *Umbonium suchiense* Yok.
15. ,, *mysticum* Yok.

Murex spinicosta Braun is a Europian Miocene form, while *Galeodea japonica* occurs in the Pliocene of Izumo.

The Ogasayama conglomerate is composed of thick sand, gravel and some clay, lying upon the Kakegawa Series and covered by the Pleistocene terrace gravel.

(13) MIKAWA AND THE ADJACENT PART OF SHINANO:

In the Shidara basin of Mikawa, the Older Neogene consists of conglomerate, sandstone and shale with some volcanic tuffs. In the northwestern portion of the basin, scanty remains of Miocene (?) plants were found.

A small Tertiary area in the vicinity of Tomikusa in Shinano yields plant and shell fossils at Asano. Four fossiliferous beds were distinguished. The uppermost contains shell remains. The second is a tufaceous bed containing following plants: *Carpiniphyllum pyramidale* Göpp. sp. *japonicum* Nath., *Castanea kubinyi* Kovats, *Juglans* cf. *nigella* Hr., *Liquidamber formosana* Hance?, *Vitiphyllum labrusca fossilis?*

(14) MINO:

The Neogene, covering a wide area in the eastern part of Mino and adjacent districts, may be divided into the Older, the Younger and the Youngest.

The Older Neogene is exposed in Kani-gōri and is composed of massive tuff-breccia, with intercalations of sandstone, shale and volcanic tuff beds.

The Younger Neogene is the "Pliocene of Mino" and covers an extensive area, lying almost horizontal or gently folded. The rocks are tufaceous shale, tuff, sandstone and conglomerate. Lignite seams are contained in its lower part. Plant fossils collected by Rein at Tsukiyoshi and determined by Geyler are: *Castanea vulgaris* Lam. *fossilis*, *Ostrya virginica* Willd. *fossilis*, *Styrax obassia* S. et Z. *fossilis* and *Quercus stuxbergi* Nath. Nathorst takes these plants for younger than the Mogi Flora of Hizen. K. Ishii recently made a fair collection of fossils which were determined by Yokoyama. Of these, *Cerithium kobelti* Dkr., *Cerithium baculum* Yok., *Vicarya* sp. (formerly aff. *V. callosa* Jenkins), *Mactra semmiana* Yok., *Cultellus izumoensis* Yok., *Cardium shinjiense* Yok., *Tellina altenata chibana* Yok. and *Lucina borealis* Y. are the most common. A marine mammal *Desmostylus japonicus* Yosh. et Iw. resembling *D. hesperus* Marsh of California was discovered at Tsukiyoshi and Hiramaki. *Sciurid* sp., *Anchitherium hyphipopoides, Palaeotapirus yagii, Amphitragulus minoensis* and *Teleoceras pugnator*, all determined by Matsumoto, were also found in these strata. The widely spread strata in the east of the plain of Owari belong chiefly to the Youngest Series which may be taken as corresponding to the Ogasayama conglomerate of Tōtōmi. The pumice, porcelain-clay and lignites, the last locally called "Iwaki", are characteristic economic products. The strata are almost undisturbed and nearly horizontal.

(15) KINKI REGION:

Similar young formations occur in the western part of Owari, Isé and in the Kinki Region which comprises Ōmi, Iga, Settsu, Yamato and Izumi. Lignite beds are found here and there.

Gravelly deposits with sand and clay of fluviatile origin belonging to the Youngest Series are found in the Kinki Region, forming low flat-topped hills. These are poor in organic remains, but at Maiko near Kōbé, a bed of medium grained sand intercalated with clay layers contains marine and brackish molluscs. Of these J. Makiyama described 18 species, the greater part of which are those living in the adjacent sea. The extinct forms are *Pecten yagurai* Mak., and *Epitonium halimense* Mak. both being the most abundant individuals. *Pecten halimensis* Mak. and *Corbicula* cf. *nipponensis* Pils. are probably not living in Japanese waters. According to Makiyama the age of this fauna is not younger than that of the Upper Musashino.

(16) TERTIARY IN KII:

There are two different Tertiary formations in Kii. The Older is found on the southern and eastern coasts of the Kii Peninsula as well as along the Kumano-gawa. It consists of hard arcose sandstone, and platy shale, with layers of conglomerate and limestone, dipping steeply to the north. In some places coal-seams are interbedded. Fossils obtained from near the coal-seams are *Taxodium distichum miocenum* Hr., *Nerium*, *Pandanus* and *Cyperites*. In the limestone of Kishimoto and Hashigui were found *Pentacrinus, Dendrophyllia, Deltocyathus italicus* Et H., *Paracyathus, Corbula* and *Melanopsis*.

The Younger formation is of the Lower Pliocene found in the environs of Tanabé. The rocks are dominantly sandstones with some sandy clay and conglomerate. Marine fossils were found at Takinai, Niigishi, Ezurahama, etc. Of 26 molluscan species determined by Yokoyama, 16 are living and the remainder are not known as living.

(17) TANGO, TAJIMA AND HARIMA:

The Tertiary strata scattered in the provinces of Tango, Tajima, Harima, Inaba and Mimasaka may be divided into the Older and the Younger.

The Older formation, covering small areas, consists of hard shale with thin limestone, and yields at Kashiwaishi in Inaba a few Miocene plants, *Ficus* cf. *tiliaefolia* Br., *Pterocarpa* cf. *denticulata* Weber and *Taxodium disticum miocenum* Hr. The Younger formation which has a wider distribution consists mainly of loose layers of tuff and resembles the Younger Tertiary of the Kinki district.

(18) IZUMO AND IWAMI:

(a) SHINJI SERIES OF IZUMO:—For a Series composed of much indurated shale and sandstone with green tuff and tuff-breccia in the Shinji Range, north of Lake Shinji in Izumo, has been proposed the name of the Shinji Series which had once been considered as the Cretaceous. The Series yielded dicotyledonous leaves, such as *Fagus*, *Salix* and a shell of *Cyrena* at Kumotsu, *Sequoia* at Mihoseki, and is now taken for Miocene or perhaps still older.

(b) PLIOCENE OF IZUMO AND IWAMI:—On the coast of Izumo and Iwami, and on the south of Lake Shinji, there is a Younger series consisting of sandstone and shale with lignite in the lower part and tufaceous shale in the upper. The strata are mostly horizontal and form low ranges of hills. *Argonauta tokunagai* Yok. and *Nautilus izumoensis* Yok. were obtained at Ōba and Fujina, both in Iyu-gōri, Izumo. Yokoyama also described molluscs from Fujina and several other places west of there. Among 14 species, *Galeodea* (*Sconsia*) *japonica*, *Mactra fujinensis*, *Cultellus izumoensis*, *Tellina optiva*, *Cardium shinjiense*, *Pecten kagamianus* and *Yoldia gratiosa* are new forms, most of which also occur in the Pliocene of Hitachi and other places. By means of these fossils Yokoyama concluded that the Izumo Neogene is the Lower Pliocene.

(19) OKI ISLANDS:

On the Oki Islands the Tertiary strata, consisting of sandstone, shale, tuff and breccia, are found beneath volcanics and contain imperfect plant and shell remains at Kamiya, Dōgo. This island is the present south-western limit of all the known localities of *Thyasira bisecta* Conrad, found in the Neogene of Japan.

(20) SHŌBARA DISTRICT:

The Tertiary formation near Shōbara in Bingo yields *Vicarya* sp., which is closely allied to *V. callosa* Jenkins of the Miocene of Java. Also *Nodosaria raphanistrum* L. and *Operculina complanata* Defr. are reported to occur.

(21) NAGATO:

In Southern Nagato a Series, consisting of sandstone, shale and conglomerate, and containing coal, forms the Miocene (?) Coal-fields of Ubé. A fossil chelonia, *Trionyx ubensis* Chitani was found in the Series.

On the coast of the sea of Japan, in Ōtsugori in Nagato, the Neogene Tertiary consists of sandstone, shale and conglomerate, interstratified with limestone layers which contain abundant *Lithothamnium ramosissimum* Ruess.

(22) SHIKOKU:

(a) MIOCENE PLANT BED OF THE ISHIZUCHI MOUNTAINS:—The plants obtained from the sandstone associated with shale and tuff at Somano, Terayama and Myōgawa are *Araliphyllum naumanni* Nath. and *Textoria* cf. *japonica* Miq., etc.

(b) PLIOCENE DEPOSIT OF AKIGŌRI IN TOSA:—The loose sandstone, conglomerate, shale and some tuff forming low plateaus of limited and detached areas on the coast of Aki-gōri are but little tilted, and contain marine shells and foraminifera (*Operculina complanata* Defr., *Rotalia beccarii* L., etc.) at many places. This litteral deposit seems to be referable to the Pliocene of Tanabé in Kii and the Kakegawa Series of Tōtōmi.

(23) SOUTHERN PART OF HYŪGA:

(a) OLDER NEOGENE:—This forms a high mountain region south of the Ōyodo-gawa. At its base is an arcose sandstone, rarely containing foraminifera. Upon this occur thick beds of shale with thin layers of hard sandstone containing *Operculina complanata* Defr. Coal-seams are found in the lower part. In some places phosphatic nodules and lenses are found in the strata.

(b) YOUNGER NEOGENE:—This forms a broad elevated terrace covered by thick Pleistocene gravel on the north of the city of Miyazaki. It is mainly composed of unconsolidated sand and clayey shale, which lie almost undisturbed. The Series yields molluscan remains in the vicinity of Takanabé and other places.

(24) PLIOCENE PLANT BED OF MOGI:

In Hizen, the Younger Neogene formation, mainly consisting of white to gray tuff and shale, is found covering an andesite lava at Mogi near Nagasaki. The Mogi Bed abounds in plant fossils which were first noticed by Nordenskiöld and studied by A. G. Nathorst. According to Nathorst, the flora of Mogi indicates a cooler climate than that now prevailing in these regions. Of about 50 species of plants found there the majority are intimately related to those thriving in Japan. Among them, only *Fagus ferruginea* Ait. and *Taxodium distichum* Heer which are abundant as fossils, are extinct in Japan but living in America. *Rhus griffithsi* Hook., also not now found in Japan, is known to grow in the Himalayan forest. De Saporta noted the resemblance of the Mogi Flora to the mountain flora of the older Pliocene Cinerite of Cantal in France and assumed that the Mogi Flora also belongs to the same Pliocene Period.

(25) RYŪKYŪ:

(i) **ŌSHIMA AND OKINAWA GROUPS**:—The Tertiary rocks in Kikaiga-shima, Okinawa-jima and Miyagasaku-jima form elevated terraces covered by raised coral reefs. The rocks are shales and sandstones with layers of marl, limestone and rarely pumice. The foraminiferal fauna contained in the sandy mud of Okinaga near Itoman was examined by Messrs. Newton and Holland, who identified 38 species, now common in the surrounding sea. From the sandy muds of Haneji and Nakoshi, Yabé and Hanzawa described 65 species and varieties of foraminifera, the most abundant forms being *Operculina bartschi* Cushman, *O. bartschi* Cush. var. *punctata* Y. et H., and *O.* (*Opercullinella*) *vinosa* F. et M. all of which are now thriving in the Philippine Archipelago.

(ii) **MIYAKO AND YAEGAKI GROUPS**:—At Shimajiri on Miyako-jima, there is a small area with a bluish shale overlaid by a loose sandstone rich in fossils. *Pecten placunoides* Mart. and *Ranella elegans* Beck, contained in the sandstone, are known from the Miocene of Java, the former being also frequent in the Tertiary of Taiwan. *Xenophora* aff. *dunkeri*

Mart. and *Conus* aff. *jenkinsi* Mart. are also common. From the *lithothamnium* limestone of Sonai in Iriomote-jima, Newton and Holland described *Cellepora formosensis, Lepidocyclina angularis, L. sumatrensis, L. verbeeki, Lithothamnium ramosissimum* Reuss, etc. Yabé and Hanzawa found *Cyclypeus communis* Mart; Tokunaga collected *Echinodiscus formosus* Tok. and *Astryclypeus integer* Yosh. These fossils indicate the Burdigalian age of the Tertiary.

(26) **TAIWAN:**

(i) **WESTERN PART OF TAIWAN:**—In the Byōritsu oil-field which lies between the coal-field region on the north and the oil-field region on the south, the Neogene may be divided into three formations; viz., (1) basal conglomerate and sandstone, (2) coarse micaceous sandstone with shale which is petroliferous or coal-bearing, and (3) soft sandstone and sandy shale in alternation.

In the coal-field of the northern part of the island the petroliferous shale seems to diminish in thickness while the coal-bearing sandstone to attain a maximum development. Layers of arenaceous limestone are interbeded in the sandstone. S. Tokunaga found in this formation, *Pecten placunoides* Martin, *Astryclypeus integer* Yosh., and *Echinodiscus formosus* Yosh.

Newton and Holland detected in the limestone of Reisuikō, Taikoshō and Seikikō in Taihoku-chō, *Gypsina inhoerens* Schultze (?), *Cellepora formosensis* N. et H., *Lepidocyclina verbeeki* N. et H., *Lithothamnium ramosissimum* Reuss. In the oil-field of the south, the petroliferous shale has a considerable development, probably attaining a thickness of several thousand meters, and is followed above by a hard micaceous sandstone. Fossils in the shale are rare. Y. Deguchi collected *Lithothamnium* limestone at Takao in Tainan, which contains *Calcarina hispida, Cycloplypeus gümbelians* Brady (?), *Amphistegina lessoni* d'Orb (?), and *Gypsina vesicularis* Parker and Jones (?).

(ii) **KŌSHUN PENINSULA:**—The rocks in the Peninsula of Kōshun are conglomerate and sandstone in the upper, and shale in the lower horizons, lying unconformably on the Clayslate Formation. Hot springs gush out from the Tertiary, the most conspicuous being those of Shichōkei.

(iii) **TAITŌ COAST RANGE:**—Y. Deguchi collected an *Operculina* limestone at Pashi-pashi in Taitō containing *Amphistegina* sp. (*A. niasi* Verbeek ?), *Cycloclypeus communis* Mart., *Lepidocyclina* (*Nephrolepidina*), *Operculina complanata* Defr., *Carpentaria* sp., and *Gypsina inhoerens* Schultze. According to Yabé and Hanzawa this faunule indicates that the limestone is of the Aquitanian or Burdigalian age.

(27) WESTERN PART OF HOKKAIDŌ:

The Tertiary in the western part of Hokkaidō seems to be mostly the Neogene Tertiary, which has much similarity in lithological characters and stratigraphical succession to that of Northern Honshū.

Miocene plant fossils occur in the coal-field of Kayanuma and at Abura in Shiribeshi. Plant fossils from Abura are *Fagus* sp. and *Magnolia* sp. The diatomaceous earth of Setanai-gōri contains impressions of *Sequoia disticha* Hr., *Taxodium, Acer, Fagus* and *Quercus*. Dr. J. Pantocsek has already described 23 species of diatoms from Setanai.

In the Nigorikawa oil-field in Oshima, Mr. G. Kobayashi distinguished the following beds in descending order (1) Sandstone bed with *Pecten* (2) Gray Shale bed (3) Alternating beds of tuff, agglomerate and sandstone (4) Thick sandstone bed with thin shale. Beds (1) and (2) are probably referable to the Younger Neogene, and beds (3) and (4), or at least (4), to the Older Neogene of Northern Honshū.

(28) CENTRAL AND EASTERN PARTS OF HOKKAIDŌ:

(a) OLDER NEOGENE OR THE MIDDLE TERTIARY OF HOKKAIDO:

There are two important formations of the Older Neogene, the Poronai Series and the Kawabata Series. In Teshio, the latter is separated from the former by a distinct unconformity, while, in the Ishikari coal-field, there is a transitional bed called Momijiyama Series between them.

THE PORONAI SERIES:—This is composed of black shale about 1000 meters thick, intercalated with marl layers and nodules. Characteristic fossils are *Nucula poronaica* Yok., *Venericardia cipangoana* Yok., *Tapes ezoensis* Yok., *Turritella wadana* Yok. and *Thyasira bisecta* Conrad. This series occurs also in the Rumoi and Opiraushbets coalfields in Teshio.

THE MOMIJIYAMA SERIES:—According to Mr. S. Murata, this consists of four rock zones:

1. Green sandy shale at the base, 260 meters thick
2. Black shale, 150 meters thick
3. Green conglomerate, 6 meters thick
4. Black shale, more than 700 meters thick

THE KAWABATA SERIES:—This is an alternation of shale, sandstone and conglomerate. The Kotampets and Wempets Series of Teshio, the Mashiporo or Chiraipets Series of Kitami, and the Ompets Series of Kushiro are formations similar to the Kawabata Series. This Kawabata Series attains a thickness of some 4000 meters in Ishikari and Teshio. In the upper portion of these Series, many repeated beds of andesitic agglomerates and tuff-breccias are interbedded.

Of marine fossils found in this series, *Thyasira bisecta* Conrad is fairly common but few in individuals. *Pecten* sp. closely resembling *Pecten stanfordensis* Arnold of the Californian Miocene is found in the Ompets Series of Kushiro.

(b) YOUNGER NEOGENE OF THE UPPER TERTIARY OF HOKKAIDO:

The Upper Tertiary is generally composed of marine deposits and forms extensive hilly tracts or elevated tablelands. Lignite beds are found in the lowest portion in the Chikubets valley in Teshio, and the petroleum is known to occur in various horizons of the formation.

In the Sōya and Yufutts oil-fields the lower part of the Upper Tertiary consists mainly of "Hard shale"; the middle, of "Gray shale" and the upper, of "Fine grained sandstone." In the Ishikari oil-field a sandstone forms the lowest part, overlaid by alternating strata of the Hard shale and the Gray shale. The Wakkanai Shale (Hard Shale) is characterized by the occurrence of numerous *Thyasira bisecta* Conrad and it is thought that the shale may perhaps be contemporaneous with the Shiiya bed and the Nishiyama shale of Echigo. The Koituiyê Shale (Gray shale) is soft, containing abundant diatom casts and sponge spicules, sometimes passing into diatom-earth. Dr. J. Pantocsek described 26 species of diatoms from the lower course of the Wembets in Teshiro, and 3 species from Abashiri in Kitami. The Yūchi, or fine grained, sandstone is seen in the oil-field of Sōya in Kitami.

(c) THE UPPERMOST SARAPETS SERIES:—This is limited in its distribution, and forms low terraces bordering the plains of Teshio and of eastern Iburi, etc. It consists of sand, clay and gravel, resembling the Pleistocene terrace gravel in nature, but in a few cases dipping with rather steep angles up to 20 degrees.

Stratigraphical relations between the several Tertiary beds in the central and eastern parts of Hokkaidō are shown in Table XI.

Table XI.

				Ishikari Coalfields	Ishikari Oilfield	Teshio	Kitami	Kushiro
Uppermost	Neogene	Younger	Pliocene			Sarapets Series	Sarapets Series	Gravel, Sand & Clay Bed
Upper				Kamogawa Shale	Upper Sandstone Gray Shale Hard Shale Lower Sandstone	Yūchi Sandstone Gray Shale Hard Shale	Yūchi Sandstone Koituiyé Shale Wakkanai Shale	Koituiye Gray Shale Dark Gray Shale
Middle		Older	Miocene	Kawabata Series Momijiyama Series Poronai Series	Black Shale Bed	Kotampets & Wembets Series	Chiraipets & Mashporo Series	Ompets Series
						Poronai Series	Onishpets Shale?	Poronai Shale?
Lower	Palaeogene			Ishikari Series (Plant Bed) (Lower Tertiary coal-bearing)	absent	Okinai and Chikubets Series? Ishikari (Haporo) Series	Ishikari Series	Ishikari Series

(29) KARAFUTO (JAPANESE SAGHALIEN):

(a) OLDER NEOGENE:

(i) **YANGENAI SERIES**:—On the southern flank of the Northeastern Mountain Land, there is exposed a series consisting of andestic agglomerate, tuffs, sandstones and shales which bear the name of the Yangenai Series. It is separated from the Younger Neogene which is known as the Nokoro bed.

(ii) **KORSAKOFF SERIES**:—This is the Older Neogene which forms the eastern and western flanks of the Western Range as well as the Piedmont Plateau of the Suzuya Range. On the eastern flank, it is composed mostly of thick tuffs with some lignite beds. On the western flank, there is a thick bed of black shale resting on the Coal-bearing Series of the Lower Tertiary.

(iii) NAIBUCHI COAL-FIELD:—Covering the Naibuchi Coal-bearing Series, there is the Naibuchi Marine Series, which consists of shale and sandstone. An unconformity existing between these two series was described by Mr. T. Tokuda. A shell bed at the base of the Series contains *Thyasira bisecta* Conrad and others. The Series is believed to be referable to the Poronai Series of Hokkaidō.

The Tomarioro Bed in the Tomarioro valley and the Nakano Bed in Rutaka are considered as equivalents of the Kawabata Series of Hokkaidō.

(iv) NOTORO COAL-FIELD AND PONTO:—In the Notoro coal-field, the Older Neogene is represented by the so-called Lower Tertiary. In the neighbourhood of Notoro, the uppermost part of the Lower Tertiary is called the Upper Coal-bearing.

(b) YOUNGER NEOGENE:

This is known as the Nokoro bed or the *Mya crassa* Bed in the eastern part of Karafuto. The Bed appears to be almost contemporaneous with the Upper Tertiary of Hokkaidō.

Various Tertiary strata in Karafuto are correlated in Table XII.

Table XII.

		Northeastern Range	Susuya Mountains	Northern part of the Western Range	Southern part of the Western Range.		
					Naibuchi Coalfield	Notoro Coalfield	
Neogene	Younger	Nokoro	Nokoro	Nokoro or *Mya crassa* Bed		Upper Tertiary	Sand-stone Sandy Shale
Neogene	Older	Yangenai	Korsakoff	Korsakoff	Upper Coal-bearing	Upper Coal-bearing	
					Tomarioro or Nakano Beds	Lower Terti-ary	Shale, Sandstone & Conglo-merate
					Naibuchi Marine Series		Shale & Sandstone
Palaeo-gene		unknown	unknown	Coal-bearing Tertiary	Naibuchi Coal-bearing	Lower Tertiary Coal-bearing	

QUATERNARY SYSTEM

BY Y. IIZUKA

A. PLEISTOCENE

The Pleistocene deposits occupy an extensive area in central Saghalien, eastern Hokkaidō, northern and central Honshū, central and southern Kyūshū and western Taiwan.

The chief elements composing the deposits are sand, gravel, clay, pumice and loam, alternations of which form elevated plains and coastal and river terraces.

Saghalien :—In the environs of Toyohara, Sakai-hama and Shikka, the Pleistocene, consisting of sand and gravel, intercalated with peat and clay, forms broad river terraces. On the north of Maoka there develop magnificent coastal terraces in four steps.

Hokkaido :—The extensive flat land in Tokachi and Kushiro is covered with pumice and sand, rarely with intervening gravel beds. On the southern coast of the island typical coastal terraces, consisting of three or four platforms at different levels, are seen, their total height being more than one hundred meters.

Honshū :—In the vicinity of Hachinohé and Shichinohé in Mutsu, the Pleistocene forms an elevated plain and is composed of loam, pumice, clay, sand and gravel. The formation has a thickness of 10 to 20 meters, and at Horanai, south-east of Shichinohé, it is intercalated with a bed of diatom-earth, about 3 meters thick.

On the coast near Ajigasawa in Mutsu, and near Noshiro in Ugo, as well as on the island of Sado, the Pleistocene strata form splendid coastal terraces. The terraces near Ajigasawa consist of three steps, rising respectively, 50, 80 and 120 meters above the sea.

On the banks of the large rivers of northern Honshū, such as the Kitakami, Abukuma, Naka, etc., an alternation of loam, clay, sand and gravel forms the river terraces, which are from several to 30 meters in height. In the vicinity of Nagaoka, on the middle course of the Kitakami, peat beds, about one meter thick, are intercalated in the alternation, and this is the case also in the Iwaki plain.

Pleistocene deposits occupy the greater portion of the Kwanto Plain. They are nearly the same in their stratigraphy throughout the district and are invariably separated from the recent fluviatile deposits, above which they rise 20 to 40 meters in bold bluffs.

The elevated plain of Tōkyō and its vicinity is composed, in downward succession, of (1) brown loam, (2) yellowish brown clay, (3) brown sand and gravel, (4) brown clay, (5) bluish gray clay, (6) gray tufaceous sand, (7) tufaceous clay, (8) sand and gravel. The geology of the district has been investigated in detail, and the strata from (1) to (6) are regarded as Pleistocene by D. Brauns, while strata, (4) to (8), are assigned to the Pleistocene by S. Tokunaga. M. Yokoyama proposed the name of the Upper Musashino Formation for the whole series and the name of the Manzakian for stratum (8) which is especially fossiliferous. In this connection he remarked, "for Manzakian to be Pleistocene, there must be some unmistakable evidence, and until that evidence is found, I deem it most expedient to assign to the stratum a place in the Upper Pliocene." According to S. Shimizu stratum (3) is to be correlated with the Narita Bed, and the strata below it with the Tōkyō Bed of Yabé and Aoki, who consider these two series to belong to the Pleistocene and to coincide with the Upper Musashino Formation. T. Suzuki and K. Watanabé deem the strata from (1) to (3) to be of the Pleistocene, and the strata from (4) to (8) to be of the Tertiary.

The brown loam is a loose homogeneous mixture of clayey and sandy material with no sign of stratification, and is regarded as a subaerial deposit of volcanic ash. It has a tendency to split perpendicularly, as is so often seen on the face of bluffs. It intercalates, in its lower part, a thin bed of decomposed pumice, which is less than 0.5 meter in thickness in Tōkyō and its vicinity, and more than one meter in the western part of the Kwanto Plain.

The yellowish brown tufaceous clay, 1.2 to 4.5 meters in thickness, follows the brown loam.

The bed of sand and gravel is generally that of sand intermingled with gravel, occasionally with intervening clay beds of varying thickness, It has a thickness from 1.2 to 12 meters and often contains drift wood and clay-ironstone pseudomorphs after wood. Thin layers of bog-iron are found just beneath the clay bed, if at all.

The Pleistocene deposits in the neighbourhood of Narita in Shimōsa, are taken as a type of the same kind, and are called the Narita Bed. The Bed is a thick complex of marine sand with a slight intercalation of beds of clay and argillaceous sand. It is rich in shell remains, the most conspicuous species being *Mactra sulcataria*, *Tapes philippinarum*, *Telina venulosa*, *Solen krusenterni*, *Diplodonta pacifica*, *Pectunculus albolineatus*, and *Echinarachnius mirabilis*.

According to the results of the boring carried out by the Bureau of Reconstruction, the Pleistocene hidden under the recent fluviatile plain of Tōkyō is represented by a brown sand, 13 to 18 meters thick, which contains small pebbles and shell remains.

In the vicinity of Chōshi in Shimōsa, the Pleistocene strata form the upper half of the foundation of the elevated plain and consist of loam, (15–30 meters thick), an alternation of sand and sandy gravel (about 15 meters thick and fossiliferous) and sand with clay (about 3 meters thick) in descending order.

Near the town of Tateyama in Awa (in Honshu), there is the so-called Coral Bed of Numa. According to Yokoyama this coral bed is of the Youngest Pleistocene age, the fossils consisting of large masses of corals mixed with shell remains, including 124 species of which 23% are extinct.

In the Miura Peninsula and the neighbourhood of Yokohama, a loam bed overlies unconformably non-fossiliferous strata of sand and gravel, which Aoki has correlated with the Narita series, in the Miura Peninsula.

The Pleistocene terraces on the upper courses of the Shinano, Tenryū and Sagami Rivers consist mainly of thick gravel beds. In the gorges of Otagiri and Kotagiri on the Tenryū, high cliffs of the gravel bed reach a height of nearly 100 meters.

Pleistocene deposits forming the elevated plains in the neighbourhood of the cities of Okazaki and Toyohashi in Mikawa, are composed of loam and gravel intercalated with sand, and attain a thickness of about 20 meters.

Kyūshū :—Pleistocene sediments of volcanic ejectamenta, partly aqueous and partly subaerial, commonly with interstratified sheets of andesite, form wide tablelands in Kyūshū, as in the vicinities of Kurumé, Kumamoto and Ōita, and also in the undulatory tract extending over Satsuma, Ōsumi and Hyūga.

The Pleistocene on the north of Sadowara in Hyūga, is composed of beds of loam and an alternation of sand, clay and gravel, in the descending order, and forms a wide elevated plain along the coast.

Taiwan :—The elevated Pleistocene platform, about 90–300 meters high, forms a long intervening belt between the low Recent plain on the west and the Tertiary hill on the east. The uppermost stratum is laterite, attaining a thickness of 10 meters, the next is an alternation of gravel, sand and clay, of which the gravel stratum mainly developes at the platformof the town of Tōen, where it measures some two hundred meters in height and intombs remains of shell and coral.

Teeth and bones of fossil elephants, namely *Stegodon sinenesis* Owen, *Loxodonta namadicus* Falc. et Caut. and *Elephas indicus* L. have been found in the Pleistocene deposits in several localities.

B. RAISED CORAL REEFS

Raised Coral Reefs are found in the Ryūkyū Islands, Taiwan and the Bonin Islands.

In the Ryūkyū Islands, according to S. Tokunaga, the reefs, which project out from the islands and cover the eroded strata of older age, are mostly fringing reefs partly forming separate islands. They generally form terraces and table lands, the height varying from 3 to 268 meters.

The reefs are usually horizontal, resting on the uneven surface of either the inclined beds of the Tertiary or Palaeozoic formation, or upon igneous rocks.

The raised coral reefs are easily distinguishable from Recent reefs by the difference of height, by their indurated structure and by secondary colouration. They are often intercalated with loose brownish sand and rarely with a conglomerate and foraminiferous deposit which is about 3 meters thick at Tarama-jima.

In the Amami-Ōshima group, the reefs extend over the Palaeozoic and Tertiary formations, their maximum elevation in Okinoerabu-jima being about 60 meters above sea level and in Kikaigashima about 207 meters, the thickness varying from 10 to 13 meters.

The reefs in the Okinawa group are underlain by the Palaeozoic or Tertiary formation, the highest point reached in Okinawa-jima being about 180 meters above sea level, and the thickness of the reefs 3–9 meters.

The Miyako Islands in the Sakishima group are composed entirely of the reefs with a few outcrops of the Tertiary formation underlying them. The reefs, which average 30 meters in thickness, have a maximum height of 114 meters above sea level.

In the Yaëyama Islands, the reefs overlie also either the Palaeozoic or the Tertiary formation, or sometimes granite or andesite. The maximum height and the thickness of the reef are respectively 66 meters and 10 meters in Ishigaki-jima.

According to Y. Ōinouye, the Daito group, consisting of three islands, is entirely composed of the reefs of ancient atolls. In Kita-daito island, are three terraces whose heighest point is 70 meters above sea level while in the Rasa island four lower terraces are found, their maximum elevation being only 35 meters above sea level.

S. Tokunaga found the remains of coral, mollusca, brachiopoda, bryozoa, echinoidea, foraminifera and *Lithothamnium nahaense* Heydle in the raised coral reefs of the Ryūkyū Islands.

In Taiwan, raised reefs are developed along the southern and southwestern coasts, including the neighbouring island of Ryukyusho, and also at Takao. At Garanbi, the reefs are said to form a sea cliff several hundred meters high.

According to Yabé and Hanzawa, the reef-forming limestones in the Ryūkyū Islands and Taiwan contain abundant remains of foraminifera of which *Cycloclypeus gumbelianus* var. *carpenteri* Brady, *Operculina bartschi* Cushman var. *Punctata* Y. et H., and *Sideralites* aff. *tetrahedra* Gümbel are common.

As to the geological age of the raised coral reefs of the Ryūkyū Islands and Taiwan nothing definite can be stated; but it is assumed, for the time being, to be Pleistocene.

In the Bonin Islands, according to Akagi, similar reefs are also observed in Haha-jima, Chichi-jima and Minami-jima, their highest point being about 300 meters in Haha-jima and about 150 meters in Minami-jima. The reefs form three terraces in Haha-jima, while in Minami-jima they cover the whole island.

C. RECENT

The lithological character of the Recent alluvial deposits requires little notice. It consists of fluviatile deposits of sand, gravel and clay, besides beach-sand and subaerial secondary deposits of dune-sand and loam.

The seaward shifting of beach-lines due to the increase of Recent within historical times is fully attested by the plains at the mouths of many rivers, the most conspicuous examples being the plains of Tōkyō, Nagoya and Ōsaka.

In the plains of Tōkyō and Shimōsa, and on the coast of the Miura and Boso Peninsulas, the Recent Formation contains abundant shell remains known as the shell layers of Yūrakuchō, Minato, Daitōzaki, Mobara, Inamuragasaki and Zaimokuza.

On the beach near the town of Hosojima in Hyūga, the remains of a Recent coral reef are found in the sand.

Marshy low lands in Saghalien and Hokkaidō, and also in the vicinity of Tanabé and Goshogawara in Mutsu, and of Ishinomaki in Rikuzen, are covered with peat. In the neighbourhood of Chiba in Shimōsa the peat is known to occur in the Recent strata.

CHAPTER II

IGNEOUS ROCKS

BY H. SATO

As is generally characteristic of the Pacific region, the igneous rocks of Japan belong chiefly to the calc-alkalic series. Very exceptionally, several alkali-rocks are found to occur in small areas. The distribution of the alkali-rocks appears to be confined to the two remarkable petrographic provinces, the Inner Zone of South Japan and the Outer Zone of North Japan, especially the northern part of Rikuchū, although a rock similar to teschenite is reported to occur in Tōtōmi.

OLDER IGNEOUS ROCKS

SCHISTOSE GRANITE

As has already been stated, the rocks to be described here comprise all the eruptives belonging to the so-called Gneiss System. As far as we know, these granites occurring near the Ryōké Metamorphics always penetrate the latter in various forms and seem to have metamorphosed sandstones and clayslates into such metamorphics.

The schistose granites embrace schistose hornblende-granite, corresponding to hornblende-gneiss, schistose hornblende-biotite-granite and schistose biotite-granite, corresponding to the so-called granite-gneiss or gneissose granite. The schistose hornblende-granite has the most distinct schistosity and occupies the smallest area among the schistose granites.

Schistose Hornblende-Granite :—The common variety of schistose hornblende-granite consists of hornblende, feldspar and a small quantity of quartz, in more or less parallel arrangement, and often passes into the normal hornblende-granite without showing any abrupt change. Of feldspars, besides the flesh-red orthoclase, there is abundant plagioclase. Occasionally feldspar and quartz are wanting, and then the rock passes into amphibolite. On the south of Takatō in Shinano, a lenticular mass of saccharoidal limestone is found in a schistose granite. The granite contains pyroxene, garnet and tourmaline near its surface of contact with the limestone, that portion being identified as eclogite by Harada, while the limestone contains wollastonite and abundant quartz.

Another variety of the schistose hornblende-granite, which Harada called the Kashio-gneiss, occurs in the upper course of the Tenryū-gawa. The Kashio-gneiss is a dark gray to grayish-green rock with spots of plagioclase and phenocrysts of hornblende in a groundmass consisting of quartz, orthoclase, plagioclase and hornblende. The rock is characterized by the absence of biotite. Harada considered it to be a metamorphosed tuff, but according to M. Ōyu, it is a piezocrystallized igneous rock representing a part of the granitic magma and is not at all paragneiss. The same rock has been observed in Awaji and Hida penetrating the Ryōké Metamorphics.

Schistose Hornblende-Biotite-Granite :—This is the same as the rock which Kotō observed in the Abukuma plateau and classified as schistose amphibole-granite. The rock is dark gray when hornblende predominates and whitish when it lessens. There are different varieties showing different grades of schistosity, and the extremely schistose variety may be well expressed by the name, Augen-gneiss. As usual constituents the rock contains plagioclase and biotite, and under the microscope quartz appears filling the interstices between the other minerals, the same structure being also noticed in the Kashio-gneiss. It seems most probable that a gradual transition is found between this rock and the schistose hornblende-granite.

Schistose Biotite-Granite :—This consists of quartz, feldspar and biotite, and always passes into normal granite. Kotō proposed the name initially for the same rock in the Abukuma plateau. Sometimes it contains diopside and allanite as accessories.

GRANITE

Granites are the most widely distributed of pre-Tertiary eruptives. There is little evidence of the protrusion of granites in the Palaeozoic Era, whereas great irruptions seem to have taken place in the Mesozoic Era. In several places granites exerted contact action on the Cretaceous rocks, suggesting the later age of intrusion.

Granites are found in wide areas throughout the Japanese Islands from Hokkaidō to Kyūshū. In Taiwan, no occurrences is known, except that granite pebbles have been found in a valley to the north of Karen-kō.

There are many varieties of granite, such as biotite-granite, two-mica-granite, hornblende-granite and pyroxene-granite, although the last named is of rare occurrence. The texture also varies from fine-grained to coarse-grained, often being porphyritic. Orbicular granite is of rare occurrence.

Contact phenomena of granite on Palaeozoic clayslate have been observed in several places. Cordierite—and occasionally andalusite and chiastolite—are found in the clayslates of Hidaka, Rikuchū, Shimotsuké, Tamba, etc. Cordierite from Shimotsuké and Tamba has been described by Y. Kikuchi and designated " Cerasite ".

Granite is the best building stone in Japan. The greatest supply comes from the shores of the Inland Sea. It is quarried also in Mikawa, Ōmi, Hitachi, etc.

DIORITE AND GABBRO

These are of common occurrence in small areas, usually as the marginal facies of granite, or as stocks genetically related to granite. The age of irruption was probably the Mesozoic Era in most cases. But the quartz-diorite intruding the Misaka Series seems to belong to the Tertiary age.

Diorites may be classified into quartz-diorite, normal diorite and orbicular-diorite, and the gabbros into normal gabbro, hyperite and norite.

PERIDOTITE AND SERPENTINE

These occur together with gabbros and diorites, intruding crystalline schists, Palaeozoic and Mesozoic Formations. Northern Hitachi and middle Higo are localities noted for peridotite. Serpentines have mostly been derived from peridotite and gabbro. The peridotite of the Machiya district in Hitachi and the ophicalcite of the Chichibu district in Musashi are quarried for ornamental stone.

DIABASE

Typical diabase is found on the south of Tokushima in Shikoku. Thick masses of diabase, found intercalated in the Palaeozoic Formations, and the great developments of variegated schalsteins which accompany them, bear witness to the mighty eruptions of this rock in the Palaeozoic Era. The rock occurs also in the Mesozoic.

QUARTZ-PORPHYRY

This occurs as large masses together with granite in Chūgoku, Hida, Mino, Shinano, etc. Other occurrences are mostly small dykes. In texture the rock often approaches granite-porphyry on the one side and liparite on the other.

PORPHYRITE

Porphyrite commonly intrudes the Palaeozoic and Mesozoic Formations. A tolerably large mass of porphyrite occurs in the Triassic Formation of Nagato. The porphyrite found in the Misaka Series is of later eruption, probably of the Tertiary Period.

YOUNGER ERUPTIVE ROCKS

LIPARITE

The eruption of liparites probably began in the Tertiary Period. Their tuffs form thick sediments in many places and are of especially wide development in North Japan. Three types may be distinguished.

The *first type* has abundant phenocrysts of quarz and feldspar which give the rock its granitic appearance. Such rock occurs at Jōzankei in Ishikari.

The *second type* is usually found as the foundation of volcanoes in North Japan. It is white or light brownish in colour, and has phenocrysts of quartz and plagioclase. Yésan in Ōshima, Hokkaidō, is an active volcano built of this rock.

The *third type* occurs at Ōbora-yama on the boundary of Isé and Yamato. It varies from a light coloured, rough lithoidal rock to the brown or pitch-black porphyritic obsidian.

The liparites of the second and third type are by Kotō called respectively, Plagioliparite, and Rhyodacite or Vitrodacite.

Decomposed liparites furnish materials for porcelain manufacture in numerous places, such as Arita in Hizen, Amakusa in Higo, etc.

ANDESITE

Andesites have erupted extensively since the Tertiary Period. Of all volcanics they have the widest distribution in the Japanese Islands and build up nearly all of the active volcanoes. They are accompanied in most cases by great deposits of tuffs, agglomerate-tuffs and lava-breccias; they sometimes also form interstratified sheets in a series of sedimentaries.

Of andesites, including mica-andesite, hornblende-andesite and pyroxene-andesite, the last mentioned is the most prevalent. Many subvarieties of pyroxene-andesite such as augite-andesite, bronzite-andesite, two-pyroxene andesite, olivine-bearing pyroxene-andesite, etc. are known to occur.

The greater part of augite-andesite, two-pyroxene andesite and olivine-bearing pyroxene-andesite were forced up, forming magnificent volcanoes especially in Central and North Japan; while in South Japan mica-andesite and hornblende-andesite are conspicuous with bronzite-andesite.

Andesites are commonly used as building-stone, being quarried in Sagami, Shinano, Mutsu, Echizen, etc.

BASALT

Typical basalt with titan-augite occurs in Chūgoku and Northern Kyūshū. It crops out in small areas as simple domes and also as sheets and dykes. Another variety is usually dark gray or black, containing chiefly augite and plagioclase. Olivine may, or may not be present. It might be called basaltic andesite from its mineral constituents, but its silica content is always less than 52%. The rock occurs in large volcanoes together with the ordinary augite-andesite.

A unique basalt containing the porphyritic grains of quartz is found in the vicinity of Hagi in Nagato.

VOLCANIC DETRITUS, ETC.

Volcanic detritus and ejecta, including mud-lava, mud-flow, pumice and volcanic ash of recent accumulation are extensively distributed around volcanoes of Oakan-daké, Yatsukōda-yama, Iwaki-san, Yatsuga-také, Fuji-san, Dai-sen, Aso-san and Kirishima-yama. Of these the mud-lava erupted from Aso-san in Kyūshū is remarkable, for it buried the valleys all around the mountain and streamed far down in every direction.

ALKALI-ROCKS

Although of a limited extent, some alkaline rocks have been found to occur in Japan. As they ave of comparatively recent discovery, they seem to be worthy of special though brief description here.

NORDMARKITIC SYENITE

This rock is found in a small mass, intruding the Tertiary Formation at the northeastern foot of Takuhi-yama in Nishinoshima in the Oki Islands.

It is light gray with a somewhat waxy luster, and contains abundant alkali-feldspar and a moderate quantity of barkevikite, with a negligible amount of biotite, quartz, diopside and olivine.

KENTALLENITE

This occurs as a small mass intruding the Palaeozoic Formation near Ichinohé in Mutsu. The rock is dark gray in colour and has a semi-waxy luster. The component minerals are alkaline feldspar, plagioclase, titaniferous augite, olivine, brown mica and magnetite, with apatite as accessory. The geological age of the rock-mass seems to be Cretaceous.

QUARTZ-KERATOPHYRE

This rock intrudes the Palaeozoic Formation near Otobé in Rikuchū. It is bluish gray or yellowish gray in colour, having abundant albite and subordinate biotite or hornblende as the phenocrysts. The groundmass consists mainly of quartz and albite with subordinate biotite, showing microcrystalline or granophyric structure. As accessories, magnetite, ilmenite, titanite, zircon, apatite and allanite are recognized. The age of intrusion is believed to be Cretaceous.

COMENDITE

On Dōgo, one of the Oki Islands, four varieties are found, such as more quartzose comendite, less quartzose comendite, alkali-rhyolite and banded alkali-rhyolite. The age of their effusion is probably Neogene.

The *more quartzose comendite* is found in blocks in a rivulet that runs into the Bay of Iibi. It is light gray with a bluish tone and distinctly exhibits the flow-structure, having abundant phenocrysts of quartz and feldspar with some pyroxene and amphibole such as aegirite, arfvedsonite barkevikite, etc. The groundmass has a pronounced flow structure, due to diversity of crystallinity and arrangement of the constituent minerals, and is composed mostly of quartz and feldspar, with scattered aegirite and aegirite-augite and also magnetite.

The *Less quartzose comendite* is met with on the northeastern sea-cliff at Nakamura in the form of a flow overlying the Tertiary Formation. It is a bluish aphanitic rock with magnophyric glassy feldspar. The phenocrysts are chiefly anorthoclase, rarely aegirite-augite. The groundmass is partly orthophyric and partly trachytic.

The *Alkali-rhyolite* occurs on the higher portions of the mountains, east of the pass from Harada to Nakamura. It is a gray glassy rock having microscopic phenocrysts of sanidine, microperthite and quartz, with a few crystals of oligoclase, magnetite and apatite. Pyroxene occurs only as inclusions in the feldspar. The groundmass is composed of cryptocrystalline devitrified glass.

The *Banded alkali-rhyolite* occupies almost the whole of the western half of the island, overlying the Tertiary Formation. It is pale red with a purple tinge, and shows a marked banded structure. The phenocrysts are soda-potash-feldspar (probably anorthoclase), with a few crystals of titaniferous magnetite. The groundmass consists chiefly of alkali-feldspar, quartz and interstitial glass.

SODA-TRACHYTE

In the Oki Islands, the group of trachytes appears in flows, dykes and sills. The *banded alkali-rhyolite* mentioned above is intruded by a dyke of trachyte, showing that the age of the trachyte is definitely younger than that of the comendites.

This group of trachytes, chiefly composed of alkali-feldspar and soda-pyroxene, is characterized by subordinate amounts of plagioclase, quartz, biotite, diopside and olivine. These minerals are not constant ingredients of all rocks of this group. They may be subdivided into five types as follows: aegirite-augite-trachyte, olivine-bearing glassy trachyte, hornblende-trachyte, biotite-trachyte and hornblende-bearing plagioclase trachyte.

The soda-trachyte of Matsushima and Kakarajima in Hizen occurs as a compact lava, associated with a basaltic rock which contains alkaline feldspar. The rock is blackish gray with a semi-waxy luster, and has abundant phenocrysts of anorthoclase imbedded in an aphanitic groundmass. The age of eruption of this rock seems to have been the close of the Tertiary Period.

RIEBECKITE-BEARING SORETITE-TRACHYANDESITE

This rock is found near Kōzaki in Bungo, where it forms a dyke cutting the metamorphic rocks, consisting of clayslate, chlorite-schist and graphite-schist. It is light gray and appears holocrystalline.

The constituent minerals are hornblende, plagioclase, alkali-feldspar, magnetite and apatite, with pale-coloured augite and olivine in small quantities. Among them, the most conspicuous mineral is hornblende, which is abundantly scattered through the feldspathic groundmass. The hornblende is of three kinds; brown, blue and green. The greater part of the mineral is brown soretite, while the blue riebeckite usually occurs as a fringe or border on the terminal faces of the soretite, but sometimes also as inclusions. The green variety forms the inner part of the brown soretite, the boundary being transitional. In the same locality, a glassy monchiquitic rock occurs as a peripheral facies of the trachy-andesite dyke mentioned above. It is black and compact, containing fairly plentiful quantities of olivine and mica with a few crystals of augite and hornblende.

ALKALI-FELDSPAR-BEARING BASALTIC ROCK AND ALKALI-FELDSPAR-BEARING BASALT

The rock type, associated with olivine-basalt on the one hand and with soda-trachyte on the other, appears to have an extensive distribution over the northern part of Kyūshū. The age of eruption of these rocks is from the close of the Tertiary to the Pleistocene.

The ***Alkali-feldspar-bearing basaltic rock*** occurs at Fukaejima in the Gotō Islands, forming the plateau and some striking dome-shaped hills upon it. It was named *Fukaé-gan* by Professor S. Kōzu from the name of the locality. It is a black and aphanitic rock with magnophyric feldspars scattered in a groundmass consisting of olivine and andesine, with small quantities of alkali-feldspar, augite, magnetite and apatite.

The ***Alkali-feldspar-bearing basalt*** occurs at Madarajima, an islet north-west of the port of Yobuko in Hizen, at Ōshima near the Island of Iki and at Uramino-taki near Ōmura in Hizen. This group differs from the above in having labradorite in the place of andesine as an essential component. It is dark reddish gray or light gray in colour with a semi-waxy luster, and consists of labradorite, alkali-feldspar, augite, olivine, titaniferous iron ores and apatite.

CHAPTER III

VOLCANOES, HOT SPRINGS AND EARTHQUAKES

VOLCANOES:—Volcanoes are widely and regularly distributed in accordance with the geological structure in the long chains of islands from Chishima to Taiwan. The majority of them are located in the Inner Zone and are believed to have been formed in the age extending from Neogene to Pleistocene. They are most abundant in the Chishima Islands, Hokkaidō, northern Honshū and Ryūkyū. The islands of Karafuto and Taiwan contain few volcanoes.

The number of volcanoes already known in Japan is 165, of which 54 are active. Mount Aso in Kyūshū has the largest crater in the world, its diameter measuring 22 km. Mount Fuji is the loftiest of all volcanoes in Japan and attains a height of 3,778 meters above sea level. They are all built up of andesites and their derivatives, which are often basaltic.

The numerous volcanoes of Japan can be grouped into several volcanic zones or chains. Of these the most conspicuous is the Fuji volcanic zone which, running from the Sea of Japan to the Pacific Ocean, divides the island of Honshū into North and South Japan. Beginning on the north, such volcanoes as Myōkō-zan, Togakushi-yama, Tateshina-yama, Yatsugataké, Fuji-san, Hakoné-yama, Amagi-san, etc. culminate in this zone which continues in the Pacific Ocean through Izu Shichito (Seven Islands), Ogasawara-jima (Bonin Islands) and Iwo-jima (Sulphur Islands) and even farther south to the Mariana and Caroline Islands.

The Nasu volcanic chain, which forms the backbone or meridional mountain range of North Japan, comprises the volcanic cones of Osoré-zan, Yatsukōda-yama, Iwaté-san, Zaō-zan, Azuma-yama, Bandai-san, Nasu-zan, Takahara-yama, Nantai-san, Akagi-san, Haruna-san, Asama-yama, etc. The continuation of the Nasu volcanic chain is found in Hokkaidō, giving rise to Komaga-také and the group of volcanoes in Iburi and Shiribeshi.

The Chōkai volcanic chain, also in North Japan, runs parallel to the Nasu volcanic chain along the coast of the Sea of Japan and is studded with the volcanoes, Iwaki-san, Chōkai-san, Gassan, etc.

The Chishima volcanic chain extends from Tokachi-daké in the middle of Hokkaidō through Meakan-daké and Oakan-daké in Kushiro to the volcanic islands of Chishima, and is continued in the Kamtschatka Peninsula.

The Hakusan volcanic chain in South Japan runs along the coast of the Sea of Japan, and comprises the volcanoes, Haku-san, Dai-sen, Sambe-yama, etc.

The Kirishima volcanic chain exists near the western margin of the island of Kyūshū having Kirishima-yama at its center. It extends to Unzen-daké and Tara-daké on the north, and on the south to the volcanic islands of Kuchino-erabu-jima, Suwanosé-jima, Takara-jima, etc. in the Ryūkyū arc.

The group of volcanoes near Aso-san forms another zone with the volcanoes of Unzen-daké and Tara-daké, where it meets the Kirishima volcanic chain and continues eastward in the depressed area of the Inland Sea (Seto-uchi), where several volcanics are found to occur.

The eruptions of Japanese volcanoes for the past half-century have been almost invariably of the Strombolian type. Those of Bandai-san in 1888, Azuma-san in 1893, Adatara-yama in 1900 and Torishima in 1902, were remarkable examples of destructive explosions. Asama-yama, Yaké-yama and Kirishima-yama are famous for their paroxymal explosions, though not violent heretofore. Recently, there have been displayed explosions of five different types, viz.,

(1) The appearance of a new volcanic island on the south of the Bonin Islands in 1904,
(2) The eruption of a new lava-dome in the crater of Tarumai in 1909,
(3) The formation of 45 craterlets on the slope of Mount Usu with a partial elevation of the land near the craterlets in 1910,
(4) The outflow of an enormous quantity of lava on Sakura-jima in 1912,
(5) The ejection of lava blocks from the craters of Asama and Mihara.

HOT SPRINGS:—No country in the world is so blessed with natural hot springs as Japan. All over Japan, especially in the northern and southern parts, numbers of hot springs are found at the top or foot of volcanoes. Just how many, then, constitute the abundant endowment of the country is not known; but 951 hot springs and 155 cold springs are of sufficient importance to be listed, and of these so far as analyses have progressed, over 250 have been found to possess radio-activity, or to be giving off special emanations like radium, as determined by Dr. R. Ishizu and Mr. Y. Kinugawa. The majority of these springs have valuable medicinal qualities, but most of them are unknown to the ordinary tourists by reason of their remoteness, their inaccessibility, and the meagre accommodations available, all of which are unfortunate, because many of springs located in these distant places possess the highest therapeutic properties.

At the source, the temperature of the water of a few springs is extremely high, being over 100°C. The Ō-yu at Atami in Izu, registers 108°C; Unagi-yu at Narugo in Rikuzen, 103°C., Fukiage-yu at Onikōbé in Rikuzen, 100°C. and the Senami-Funto in Echigo, 102°C. A number of springs range between 90°–100°C. Among them, the springs at Noboribetsu in Hokkaidō, Osoré-yama in Mutsu, Furō-sen in Ugo, Futami in Etchū, Nakabusa in Shinano, Yunominé in Kii, Wakura in Noto, Myōban and Kamegawa in Bungo, Ureshino, Obama and Unzen in Hizen and Hokuto in Taiwan are well-known. With temperatures below 90°C. there are hundreds of springs covering the entire range down to 25°C.

The composition of the springs of Japan varies and there are numerous kinds in which simple or salt springs predominate, the greater number of the remainder being sulphur springs, closely followed by alkaline carbon-dioxated springs. Kusatsu, Kannawa, Nasu, Noboribetsu, Kirishima and others carrying free mineral acids are distinctive, especially Kusatsu, Kannawa and Nasu in their alumina and iron content. Springs of bitter, iron-carbonate, simple carbon dioxated, earthy carbon dioxated, acid hydrogen sulphide, alum vitriol and acid vitriol are listed in the classification of Japanese springs, though they are not numerous. Many springs contain small proportions of boric acid, iodine, bromine, lithium, manganese and other compounds.

The quantity of radium emanation of springs in Japan appears to be more closely connected with the geology than with the chemical composition of the water, and the springs of strong radio-activity are found mostly in granite regions.

The mineral springs of strong radio-activity are as follows:

Hot Springs	Mache's units	Cold Springs	Mache's units
Misasa	142.14	Masutomi	1425
,,	102.83	Takayama	281
Sekigané	33.47	Ikeda	187
Tochiomata	25.86	Arima	87
Tōgatta	24.58	Hirukawa	60

EARTHQUAKES:—By plotting 51 epicenters of the destructive earthquakes since 1596, according to data given by Prof. A. Imamura, we may assume six main seismic zones ; (1) Outer, (2) Inner, (3) Inland sea, (4) Lake Biwa, (5) Fuji, (6) Nasu and (7) Ishikari.

(1) The Outer zone runs along the whole length of the Japanese Islands from the east of Hokkaidō to the east of Taiwan, and being about 120 kilometers off the Pacific coast, it lies on the boundary between the continental shelf and the deep. Frequent and intense are the earthquakes occurring in this zone.

(2) The Inner zone runs along the coast line of the Sea of Japan and is parallel to the Chōkai volcanic chain.

(3) The Inland Sea zone coincides with the western part of the depressed area of the Inland Sea.

(4) The Lake Biwa zone corresponds to the depressed tract of land extending from the Bay of Osaka to Tsuruga.

(5) The Fuji zone, as the line of separation between North and South Japan, is of profound significance in respect to earthquakes as well as to the geological structure.

(6) The Nasu zone follows the Nasu volcanic chain which forms the backbone of North Japan.

(7) The Ishikari zone coincides with the depression ef the Ishikari basin in Hokkaidō, running from north to south through the mouth of the Ishikari-gawa.

CHAPTER IV

MINERAL RESOURCES

METALLIC DEPOSITS

BY K. KINOSHITA

Metallic deposits will be described in the following order:

(1) Gold	(6) Tin	(11) Chromite
(2) Silver	(7) Antimony	(12) Mercury
(3) Copper	(8) Manganese	(13) Pyrite
(4) Iron	(9) Tungsten	(14) Arsenic
(5) Lead and Zinc	(10) Molybden	(15) Miscellaneous

A deposit which contains two or more of these is classed under the metal, the production-value of which predominates.

(1) GOLD

The production of mountain and placer gold in 1924 amounted respectively to 7,570 kgr. and 21 kgr. Modes of occurrence are of three types; viz., (a) contact metamorphic deposits, (b) fissure veins, and (c) detrital deposits.

The deposit of the Rokuromi Mine in Rikuchū, representative of the first (a) type, is found in the limestone near the contact zone of the Palaeozoic with granite. The ore is composed of magnetite and auriferous pyrrhotite, associated with garnet, pyroxene and epidote.

(b) Fissure veins have practical importance. They are classified as of two kinds, older and younger gold veins. The former occur in the Palaeozoic formation, granite and gneiss in the Outer Zone of North Japan and the Inner Zone of South Japan, while the latter are found in the igneous and sedimentary rocks of the Tertiary terrain in the Inner Zone of North Japan and the Outer Zone of South Japan. The gold in veins occurs chiefly in the free state and is associated with silver ore, silver and copper ore, or copper ore. The best-known mines of each kind of gold vein are as follows:

	Older gold vein	Younger gold vein
Gold vein.	Shishiori	Kushikino, Serigano
Gold-silver vein.	Nakasé, Bajō	Takatama, Sado, Takeno
Gold-silver-copper vein.		Akabané, Ikuno
Gold-copper vein.		Tamagané, Washinosu

Of these, the Kushikino mine may be taken as representative. It is situated at Kushikino-mura in Satsuma. There augite-andesite is traversed by numerous metalliferous veins, which run in general N E and dip S E. The width of the veins varies from a few centimeters to three meters. The veinstone consists of quartz containing gold and small quantities of argentite, pyrite and chalcopyrite. The yield of gold in 1923 was 831 kgr., valued at 1,113,000 Yen.

In the (c) detrital deposits, shallow placer mining is done on terraces, river-beds and beaches. The chief localities of placer gold are Esashi, the Yūbari-gawa, etc. in Hokkaidō; Setamai, the Abe-kawa, etc. in Honshū; the Yoshino-gawa in Shikoku; the Yabe-gawa, Ōkushi, etc. in Kyūshū; and the Kiirun-gawa in Taiwan. The most celebrated locality is Esashi in Hokkaidō, where a gold nugget weighing 76 grams was found in 1901. The sources of the placer deposit of Esashi are quartz veins in the Palaeozoic formation. In Ishikari and Setamai, gold is often associated with platinum and iridosmin.

(2) SILVER

The production of silver in 1924 was 110,043 kgr., valued at 5,700,205 Yen. The greater part of the output comes from silver veins in Tertiary rocks and argentiferous copper deposits in older rocks. The silver veins in Tertiary rocks are classified as of two types, dry silver veins and copper silver veins. Omui, Todoroki and Shikaribetsu in Hokkaidō, Innai and Handa in Honshū, etc. belong to the first category; and Hisan-ichi, Hatasa and Omodani in Honshū, etc., to the second.

The Handa Mine in Iwashiro lies near the contact zone of the Tertiary strata with liparite. The deposit belongs to fissure veins which run N-S and dip W 40°–70°. The ore is auriferous argentite in quartz gangue accompanied by small quantities of galena, zincblende, chalcopyrite, pyrite and smaller amounts of stephanite and native silver.

Of far greater importance are the silver mines which also produce gold, copper or lead. Some of these are described in connection with the mines of those metals.

(3) COPPER

The production of copper in 1924 was 59,233,052 kgr., valued at 48,541,691 Yen. The modes of occurrence of copper ores may be classified as (A) contact metamorphic deposits, (B) replacement deposits and (C) fissure veins.

(A) CONTACT METAMORPHIC DEPOSITS:—These deposits occur commonly in the Palaeozoic formation, especially at the contact of limestone with granite or allied rocks. They are found in greater abundance in the Inner Zone of South Japan as, for example the deposits of Mochikura, Zōmeki, Kawaiyama, Ofuku and Sannotaké, and rarely in the Outer Zone of North Japan as those of Yaguki and Ōno. In the Yaguki mine, the deposit is found in the Palaeozoic limestone intruded by a granite dyke in close proximity to the deposit. The ore consists of chalcopyrite, pyrrhotite and magnetite with pyroxene and garnet as gangue minerals.

(B) REPLACEMENT DEPOSITS:—These deposits are of two different kinds.

(i) **LENTICULAR OR BED-FORM DEPOSITS OF CUPRIFEROUS PYRITE:**— They occur mostly in crystalline schists and Palaeozoic Slates: very rarely in the Mesozoic. Their distribution is practically limited to the Outer Zone of Japan. Under this category are comprised the deposits of many mines such as Hitachi, Kuné, Iimori, etc. in Honshū; Higashiyama, Takakoshi, Minawa, Sazaré, Shirataki, Besshi, Chihara, Kanayama, Hirota, etc. in Shikoku; and Makiminé, etc. in Kyūshū. Of these the Besshi and Hitachi mines are working particularly large deposits.

At the Besshi mine, the deposit is found in crystalline schists running nearly parallel to the schistosity of the country rock, striking E-W and dipping N 45°. The ore-body is over 1,500 meters long and 0.6–8.0 meters wide, the deepest point explored to date being over 670 meters from the outcrop. Three kinds of ore are found viz., (1) massive pyritic ore containing about 3% Cu and 47% S, (2) banded pyritic ore containing about 4% Cu and (3) massive chalcopyrite ore with some gangue. The average smelting ore contains 3.98% Cu.

At the Hitachi mine five large lenticular masses of ore exist in amphibolite of the Mikabu Series. The Honkō deposit is about 450 meters long and 4 meters wide; the Kamminé deposit, 300 meters long and 7 meters wide; the Chūsei deposit, 400 meters long and 6 meters wide; the Akazawa deposit, 120 meters long and 14 meters wide; and the Takasuzu deposit 150 meters long and 12 meters wide. The average ore now mined contains 0,00001% Au, 0.0011% Ag and 2.46% Cu.

(ii) "**BLACK ORE**" (*Kuromono*) **DEPOSIT**: This is an intimate mixture of galena, zincblende, and baryte. Commonly it contains some gold, silver and copper. The deposit occurs at or near the contact zone of the Tertiary rocks with liparite or andesite. Its distribution is practically confined to the Inner Zone of North Japan, as at Kunitomi in Hokkaidō and Abeshiro, Hanaoka, Kosaka, Yoshino, etc. in North Japan. The Kosaka mine is one of the largest copper mines of the "Black ore" type. The dimensions of the deposit are about 300 meters in length, 40 meters in width and 120 meters in depth. Around the "Black ore", there is a mass of cupriferous pyritic ore which is often siliceous and is used as the flux for smelting *Kuromono*. The oxidized part of *Kuromono*, which is now exhausted was known to contain about 0.02% silver, the silver content gradually becoming less towards the unoxidized portion. The average grade of the ore smelted is 0.00013% Au, 0.010% Ag and 1.90% Cu.

(C) FISSURE VEINS:—The deposits of a large number of important mines belong to this type. They are distributed in the Tertiary rocks along the Inner Zone of the Japan arc. The ores are mostly chalcopyrite and bornite, rarely tetrahedrite and enargite, together with such secondary minerals as malachite, chrysocolla, chalcocite, etc. The copper veins are divided into several kinds by mineral association, viz., copper-tin vein, tourmaline-copper vein, siderite-copper vein and quartz-copper vein. The veins found at Akenobé, Yakuōji, Ōmori and Ashio are good examples of each kind.

The deposit of the Akenobé mine is in the form of fissure veins in Palaeozoic and Mesozoic rocks. They contain argentiferous bornite and chalcopyrite associated with cassiterite and wolframite.

The Yakuōji mine is found at the contact zone of the Palaeozoic formation with quartz monzonite. The ore is chalcopyrite, accompanied by a small quantity of pyrrhotite and pyrite. The veinstone is quartz and tourmaline, sometimes chlorite.

The district around the Ōmori Mine is composed of quartz-bearing hornblende-biotite-andesite and its agglomerate, in addition to the Tertiary strata. The ore deposits are divided into two groups; fissure veins and impregnation deposits. The fissure veins occur in the andesite, their thickness varying between 30 to 60 centimeters. The strike is nearly E-W and dip is to the north at a high angle. The ore is auriferous and argentiferous chalcopyrite with quartz and siderite as veinstone.

The Ashio mine is one of the largest copper mines of the quartz-vein type. The deposit is found in liparite and Palaeozoic sedimentary rocks. There are two systems of parallel veins, one of veins running NE-SW and the other E-W, all with a high dip. The number of veins is known to be over two hundred. The length of the veins varies, that of the longest lode being nearly two kilometers. The breadth is also variable, generally being from 30 cm. to 3 m. The veinstone consists of quartz and calcite, and commonly occurs in small quantities. The ore is chalcopyrite associated with pyrite, galena, zincblende and arsenopyrite. Besides true fissure-veins, irregular chalcopyrite deposits, called *Kajika*, are found at the intersection of numerous radial veinlets.

The deposits of Nagamatsu, Ōarasawa, Furokura, Ani, Osaruzawa, Arakawa, Ogoya, Yūsenji, Obié, etc. in Honshū are of the quartz-copper vein type.

(4) IRON

The production of iron in 1924 was 47,356 metric tons of pig and 27,885 tons of steel. The iron deposits may roughly be classified as (A) contact metasomatic deposits, (B) chemical precipitation deposits and (C) detrital deposits.

(A) CONTACT METASOMATIC DEPOSITS:—The important deposits as far as known, are practically confined to this class. The ore is magnetite or hematite. Contact magnetite deposits occur in the Palaeozoic or the Mesozoic formation at or near the contact with granite or diorite, i. e. in limestone as in the Kamaishi and Kurodaké mines, and in clayslate as in the Kuriki and Nakaozaka mines.

The deposit in the Kamaishi mine is taken as representative. There are a number of deposits occurring in large irregular masses in the Palaeozoic limestone, clayslate and hornstone, within the contact areole of granite. The ore body is enveloped by various contact minerals such as garnet, pyroxene, epidote, etc. One of the largest deposits extends from Takinosawa to Aonoki, being over 5 kilometers in length and one kilometer in breadth.

Contact hematite or micaceous iron ores occurring in the Palaeozoic limestone along or near the zone of contact with granite or diorite are found at Sennin and Akatani. The hematite deposit of the Sennin mine sometimes accompanied by pyrite lies in the contact zone of limestone with gneissose granite, extending from Tōhira to Yatatezawa. It strikes from N N W to S S E and dips steeply toward E N E. Contact minerals such as hornblende, garnet, etc., are often associated in this deposit. The thickness of the deposit is seven meters in the thickest part, but averages about three meters.

(B) CHEMICAL PRECIPITATION DEPOSITS:—These are of two kinds; one, the hematite quartzite as found at Yonai, Ishikawa and Koura, which at present are of no practical importance; and the other, bog iron beds scattered over the country, especially in Hokkaidō, Ugo, Hizen, Higo, Ōsumi and Satsuma.

Bog iron is important both in point of present productivity and future supply. In Hokkaidō numerous deposits of bog iron ore are found crowded together in the middle of Iburi, that of the Abuta mine being representative. The deposit at the Abuta mine consists of bog iron beds intercalating a thin bed of conglomerate. The beds are from 2 to 5 meters in thickness.

(C) DETRITAL DEPOSITS:—Iron sand is chiefly found in the mountainous region of Chūgoku, being usually derived by disintegration from granite, diorite and basic volcanic rocks. The sands derived from diorite and volcanic rocks are mixed with titaniferous iron and bisilicates, so that the quality is inferior to those from granite. The principal localities of mountain iron sand are Hōki, Mimasaka, Iwami Izumo and Bingo. Besides these, iron sand is also found in the Pleistocene terraces and sand beaches throughout Japan, especially in Hokkaidō, Mutsu, Rikuchū, Iwaki, Chikuzen and Satsuma.

(5) LEAD AND ZINC

There are three kinds of deposits; fissure veins, metasomatic deposits and contact metamorphic deposits. All of them are of equally frequent occurrence, but the deposits worked at present are chiefly of the third type.

In the Takata mine, well known from early times for its silver and lead, galena and zincblende occur in VEINS traversing the Tertiary tuff intruded by andesite and propylite. The veins run irregularly some from N E to S W and others crossing them. In thickness they vary from 60 cm. to 3 m. The veinstone consists of calcite, quartz, fluorite and clayey substances. The ore is chiefly argentiferous galena and zincblende mixed with chalcopyrite and pyrite. Feather-ore is frequently met with. To the same type belong the deposits of Daira, Budō and Kuratani.

The METASOMATIC DEPOSITS are of two kinds: to the first belong those which yield the "BLACK ORE" containing low percentages of zinc and copper, as mentioned under the heading of copper. The ore of the Karatoya, Kanō and Wanibuchi mines is of this kind. The second kind consists of the COMMON REPLACEMENT DEPOSITS which are distributed mainly in the Inner Zone. Yasuda and Sasu are two adjacent mines on the island of Tsushima. The ore-body in these mines is of bed-form in the

Mesozoic shale near a sheet of quartz-porphyry. The ore is a compact zincblende associated with pyrrhotite and argentiferous galena. It contains almost no gangue mineral. The deposits of the Okita, Bunmuro, Nakatenjō and Shinryō mines belong to the same category.

The Kamioka mine is the largest lead and zinc producer at present. The two ore-boides occur as deposits of the CONTACT METAMORPHIC TYPE, one lying in the N - S direction with a steep inclination toward the east, and the other striking E-W with a high dip toward the south. The thinner portions of the deposits measure from 30 to 60 centimeters, and the thicker, from 3 to 15 meters. The ore sometimes occurs in the form of irregular pockets. The gangue consists of hedenbergite, garnet and epidite, often with calcite and quartz. The ore is a mixture of argentiferous galena, chalcopyrite and zincblende, associated with crysocolla, malachite, pyrite, arsenopyrite and native bismuth. The deposit of the Kawaiyama mine is of the same type, being an occurrence at the contact of limestone and an andesite dyke.

The output of lead and zinc in 1924 was 2,937,762 kgr. and 14,051,221 kgr. respectively.

(6) TIN

In 1924, the output of tin amounted to 346,158 kgr., valued at 864,900 Yen. The ore is cassiterite, always associated with several sulphides such as pyrite, chalcopyrite, etc., and is often accompanied by the ore of tungsten. The modes of occurrence are fissure veins, detrital deposits and contact metamorphic deposits. Of these the first kind is the only one worked at present.

The only tin veins now worked are those at the Akenobé, Mitaté and Suzuyama mines. The Suzuyama mine in Satsuma has been well-known from ancient times. The deposit in this mine occurs as parallel veins in the Mesozoic shale and sandstone, and the ore is accompanied by several sulphides, such as pyrite, pyrrhotite, and zincblende, together with chlorite, siderite, quartz and calcite as gangue minerals.

Placer tin was worked at Naegi in Mino, where the cassiterite is found in the Pleistocene strata. The source of the tin sand may be the decomposed pegmatite of the neighbourhood. It is associated with magnetite, topaz, quartz, feldspar, beryl, wolframite, sapphire, naegite, fergusonite, etc.

(7) ANTIMONY

Of late, the production of antimony has greatly diminished, owing to the scarcity of good ore. The deposits are commonly fissure veins in the Palaeozoic and Mesozoic formations. Those of the Ichinokawa and Kano mines are good examples. At the Ichinokawa mine, there are four principal veins in the crystalline schists and conglomerate, running E-W and dipping S 80°. The ore is stibnite in quartz gangue, and in druses, beautiful crystals of stibnite have often been found, but now they are almost exhausted.

(8) MANGANESE

The output of this ore during 1924 amounted to 7,575 metric tons, valued at 218,544 Yen. The ore of economic importance is almost invariably a mixture of various manganese oxides. It occurs in the forms of veins, beds, nodules or irregular masses in sedimentary rocks varying in age from the Palaeozoic to the Tertiary, and also in younger eruptive rocks. Of these, the metasomatic deposits of the Tertiary age, which are mainly distributed in the Inner Zone of North Japan, and the residual deposits in the Palaeozoic and Mesozoic formations, have practical importance.

The typical manganese deposit of metasomatic origin is that of Birika in Hokkaidō. There a black earthy manganese ore occurs in the tufaceous sandstone, shale and conglomerate of the Tertiary age. The deposit has the strike N 70° E and the dip N W 25°. The deposits of Toshibetsu, Fukaura, Ōwani, Iwasaki, Searashi, etc. belong to the same type.

In the Palaeozoic formation, manganese oxides are found as lenticular masses or beds along the bedding plane. The ore occurs only near the surface, and on the deeper horizon gradually changes into rhodonite or manganiferous quartzite, but in rare cases, it continues down to 150 meters or more below the surface. This kind of manganese deposit may be formed by weathering action on the mangano-quartzite or siliceous manganese ore previously deposited as a chemical precipitation. Its distribution is almost wholly limited to the Palaeozoic terrain of the Outer Zone of the Japan arc, but in rare cases it is found in the Mesozoic terrain also. The Nakayama mine in Tamba was the only one working the ore of this kind in 1923, the output being reported as 886 metric tons, valued at 23,273 Yen.

(9) TUNGSTEN

Wolframite and scheelite deposits were formerly mined in several localities, but many of these mines are now abandoned. According to their modes of occurrence the deposits are classified as of two kinds; fissure veins and contact metamorphic deposits.

The deposit of the Takatori mine is representative of the fissure veins. In the upper part of the vein, wolframite occurs abundantly with quartz, but lower down chalcopyrite, arsenopyrite and pyrite make their appearance in place of wolframite. The veinstuff is chiefly fluorite, muscovite and topaz. At Kurasawa and Yaku-jima, small wolframite-quartz veins are found.

The Kiwada is a good example of a mine working a deposit of the contact metamorphic type. Here the scheelite is found together with copper ore in the Palaeozoic rocks, near a granite mass. The deposits traverse the alternating beds of slate, sandstone and quartzite of the Palaeozoic. The Kuga mine belongs to the same category.

(10) MOLYBDEN

Molybden ore is known to occur at several places, but very little has been prospected. Molybdenite is the most common ore of molybden, and is occasionally associated with tungsten and tin ores. The ore-bedies of all the workable molybden mines belong to the fissure vein type as in the Toyama, Kokurobé, Ita, Shirakawa and Yamasa mines. In the Yamasa mine the ore is found in massive and platy form in a pegmatite vein which intrudes granite.

(11) CHROMITE

The output of this ore during 1924 amounted to 5,356 metric tons, valued at 177,873 Yen. It occurs commonly in serpentine or allied rocks as a magmatic differentiation deposit, in irregular masses which are often of considerable size. In some cases it also occurs as detrital deposits derived from the disintegration of magmatic chromite deposits. Though chromite deposits have been reported to occur in several localities, the mines in actual operation in 1924 were only those at Kasuga and Nittō in Hokkaidō, and at Wakamatsu and Hino in Honshū.

The deposit of the Wakamatsu mine is the largest in Japan. The ore is found in serpentine or peridotite as irregular or lenticular masses, the diameter varying greatly from several to several hundred meters. The average content of Cr_2O_3 is as much as 40 %.

(12) MERCURY

The ore is mainly cinnabar, occasionally associated with metacinnabarite. It occurs in fissure veins in several localities such as Shamani, Meiji and Aibetsu in Hokkaidō; Komagaeri and Tōnominé in Honshū; and Chichinokawa, Suigin and Suii in Shikoku; but many of these mines are already exhausted. The veins of the Suigin mine in Awa are found along the planes of faults in the Mesozoic limestone. The ore is cinnabar accompanied by bituminous calcite gangue. At the Meiji mine, cinnabar is disseminated in the quartz vein together with metacinnabarite and marcasite.

(13) PYRITE

The output of pyrite and pyrrhotite in 1924 amounted to 220,555 metric tons, valued at 3,030,076 Yen. The greater part of this amount was contributed by the former mineral. These minerals occur in contact metamorphic deposits, metasomatic deposits and fissure veins.

In CONTACT METAMORPHIC DEPOSITS, the ore is commonly pyrrhotite, Yoshioka mine in Bitchū being representative of this type. The district is composed of Palaeozoic slate, sandstone and schalstein traversed by porphyry dykes. The ore deposits with skarn minerals usually occur in the form of veins, and lie in both igneous and sedimentary rocks near the contact zone. The veins generally strike E N E–W S W with the dip toward N N W. The ore consists of chalcopyrite, pyrrhotite, pyrite, zincblende and arsenopyrite. The Mihara mine belongs to the same category.

The METASOMATIC DEPOSITS are the most important, and are of three different kinds, (a) "Black ore" (*Kuromono*), (b) lenticular or bed-form deposits, and (c) simple metasomatic deposits, their distribution being similar to that of copper.

Under "**BLACK ORE**" deposits are included the ore-bodies of many mines such as Kosaka, Hanaoka, Yoshino, Takara and Suwa. The Takara mine is taken as representative. The district is made up of the Tertiary, consisting of shale, tuff, tuff-breccia and sandstone, intruded by dykes of liparite, andesite and diabase. The deposit of pyrite is found in the liparite as a lenticular mass, which is 80 meters long with a width of 25 meters at the depth of 70 meters from the outcrop.

A large number of important mines such as the Hitachi, Kuné, Iimori, Higashiyama, Takakoshi and Besshi mine are working the **LENTICULAR OR BED-FORM DEPOSITS** which are described under the heading of copper. The Iimori mine is a good example of this type. The rocks are crystalline schists, and the deposit extends for a long distance with a width of about 30 cm. The ore is a compact cupriferous pyrite, containing about 2 % Cu and 40 % S.

The ore-body of the Yanahara mine is the largest of the SIMPLE METASOMATIC DEPOSITS. The mining district is composed of Triassic slate, hornfels, etc., with dykes of diabase, porphyry and porphyrite.

The deposit consists of a large mass of compact pyrite altered to limonite near the outcrop. The pyrite contains more than 48 % S.

The FISSURE VEINS are of slight importance. The vein of the Kanayama mine in Kii is an example. Several veins occur in sandstone and shale near the zone of contact with andesite. The length of the largest vein is 300 meters, the breadth varying from 1 to 2 meters. The ore is iron pyrites associated with zincblende and galena.

(14) ARSENIC

In 1924, the production of arsenical compound amounted to 3,745,675 kgr., valued at 1,146,210 Yen. Arsenic ore occurs mainly in the contact metamorphic deposits and fissure veins, only the former being of practical importance.

The ore body of the Sasagatani mine is a good example of CONTACT MOTAMORPHIC DEPOSIT. The deposit in this mine forms an irregular mass between the Palaeozoic limestone and a dyke of quartz-prophyry. Arsenopyrite is found associated with some chalcopyrite, zincblende, galena and pyrite with pyroxene as gangue mineral. The deposits of Naganobori, Kamioka, etc. are of the same type.

The FISSURE-VEIN type is represented by that of the Kanagatao mine in Nagato. The district is made up of Palaeozic sandstone intruded by dykes of hornblende porphyrite. The sandstone is traversed by a metalliferous vein, one meter thick. The general strike of the vein is N 20° W, with a steep dip toward the east. The veinstone is mainly quartz, often mixed with calcite. The ore is arsenopyrite associated with chalcopyrite and pyrrhotite. The Takumi and Kashikanaidani mines belong to this category.

(15) MISCELLANEOUS

Besides the above-mentioned metals, small quantities of platinum, bismuth, nickel and cobalt occur in several localities.

The output of PLATINUM in 1924 was 4.5 kgr., valued at 48,064 Yen.

The ore occurs in detrital deposits and is mined in river beds. In Hokkaidō the prospecting for placer is comparatively advanced, the Teshio-gawa and the Yūbari-gawa being the chief centers, where the platinum occurs as flat grains associated with gold and iridosmin.

Various BISMUTH minerals are found in association with copper and gold ores in several localities, notably at Ikuno, Ashio, Kosaka, Kamioka, etc. At the Ikuno mine in Tajima, the mineral occurs with chalcopyrite and iron pyrites in fissure veins traversing liparite.

A small amount of COBALT is usually associated with the ore of some cupriferous pyrite deposits, such as those of the Iimori and Besshi mines. Though no cobalt minerals can be distinguished with the naked eye in the ore of these mines, yet the base bullion is found to contain about 0.2 % Co and cobalt was formerly extracted as a by-product. The cobalt ores also occur in some contact metamorphic deposits as in those of the Eboshi mine in Nagato. The rocks in the district are granite-porphyry penetrating the Palaeozoic limestone. The ore-deposit which consists of cobaltite, bismuthinite and tungsten ore, occurs in irregular masses in the contact zone of limestone with granite-porphyry, and are enveloped by such contact minerals as hedenbergite, garnet, etc.

NICKEL ore is found in fissure veins. At the Natsumé mine in Tajima, niccolite and gersdorffite associated with pyrrhotite, chalcopyrite and chromite, occur in two clayey veins traversing serpentine. The ore contains about 30 % Ni. Nickel is also contained in cupriferous pyrite in small quantities and at Hitachi, Besshi and Saganoseki, it is obtained as a by-product in the electrolytic refining of copper.

COAL AND PETROLEUM

BY G. KOBAYASHI

(A) COAL

Coal is known to occur in the Palæozoic, the Mesozoic and the Tertiary, and may be classified as 1) anthracite and semi-anthracite, 2) bituminous and sub-bituminous coal, 3) black lignite and 4) lignite. The coal in the Palæozoic and the Mesozoic belongs to the anthracite and semi-anthracite varieties; that in the lower Tertiary, considered as the Eocene and the Miocene, is mostly bituminous and sub-bituminous coal and black lignite; while that in the upper Tertiary, probably the Pliocene, is lignite. The Ōmine and Tsubuta Coal Fields, are important occurrences of the Jurassic coal in Japan; while those of the Triassic in Bitchū and of the Jurassic in Tamba are not so well known. Of far greater importance are the coal seams in the Tertiary, which are most extensive and valuable in the coal fields of Kyūshū and Hokkaidō. As regards coal reserves, the Ishikari Coal Field ranks first; while as to production the Chikuhō Coal Field far exceeds the others. Accordingly the center of coal production is in Northern Kyūshū, which yields about sixty percent of the total output of Japan. Of the coal fields in Northern Kyūshū, the Chikuhō Coal Field is the largest and yields about seventy two per cent, while the famous Miike Coal Field ranks next both in respect of its coal reserves and its output. The Karatsu, Sasebo, Sakito, Matsushima and Takashima Coal Fields are also important and yield good bituminous coal. In Hokkaidō, the coal mining industry is in course of development, so that the output is rather small in comparison with the reserves. The Jōban Coal Field, extending over Hitachi and Iwaki, ranks next to those of Kyūshū and Hokkaidō, but the coal is much inferior in quality and less in quantity. The coal fields in the southern part of Nagato, known as the Ubé Coal Field, are of much less extent and the coal is also inferior in quality. The other coal fields scattered throughout the country and yielding varieties from bituminous coal to black lignite, are less important both in reserves and output. The only Tertiary coal fields yielding anthracite and semi-anthracite lie in Kii and Higo, both the output and reserves being small. Lignite-bearing Tertiary is scattered throughout central and northeast Japan, though its extent is limited. The coal fields extending over Owari and Mino, known as the Nōbi Coal Field, yield lignite and are the most important of the lignite districts. The coal fields in the northern part of Taiwan, known as the Taiwan Coal Field, are the only source of coal in Taiwan, the production exceeding the demands of the island. The coal fields of Karafuto are not thoroughly explored but are considered to contain a large amount of coal, only two coal fields, the Naibuchi and Notoro Coal Fields, having been roughly estimated. Most of the coal fields in Karafuto have not yet been opened, so that the annual output of coal is very small.

The following table shows the analyses of coals from the principal coal-fields of Japan.

TABLE XIII

Age	Locality	Kinds of Coal	Water	Volatile matter	Fixed Carbon	Ashes	Sulphur	Calorific Power	Sp. G.
Upper Trias	Ōmine (Nagato)	Semi-Anthracite	3.04	8.74	68.74	19.48	0.62	6.042	—
Eocene	Naibuchi (Karafuto)	Low grade Bituminous	5.12	43.35	40.84	10.69	0.33	6.209	1.336
„	Bibai (Ishikari)	„	3.25	39.49	47.90	9.36	0.38	7.024	1.335
„	Horonai (Ishikari)	„	4.56	41.63	49.14	4.57	0.49	6.655	1.311
„	Yūbari („)	„	2.28	41.20	50.41	6.11	0.44	7.371	1.284
Miocene	Kushiro (Kushiro)	„	7.54	39.60	45.30	7.56	0.35	5.957	1.352
„	Jōban (Iwaki)	Black lignite	10.83	41.76	35.98	11.43	1.58	5.476	1.349
Eocene	Onga (Chikuzen)	Low grade Bituminous	2.38	40.99	47.79	8.84	0.94	7.017	1.317
„	Fukuoka („)	„	3.00	42.03	47.29	7.68	1.07	7.130	1.324
„	Miike (Chikugo)	„	0.68	40.07	48.08	11.17	3.61	—	—
„	Karatsu (Hizen)	„	3.40	42.17	45.39	9.04	2.08	6.874	1.332
„	Takashima („)	„	1.19	38.34	52.44	8.03	0.67	7.110	1.348
„	Amakusa (Chikugo)	Semi-Bituminous	2.65	11.75	78.88	6.83	1.60	6.780	1.480
Miocene	Kiirun (Taiwan)	Low grade Bituminous	4.33	38.08	54.28	3.28	4.16	6.875	1.240

Production of coal in Japan :—

1920............................29,245,384 metric tons
1921............................26,220,617
1922............................27,701,731
1923............................28,948,820
1924............................30,110,826

(B) PETROLEUM

The principal oil-yielding belts in Japan extend from Hokkaidō to Echigo, almost parallel to the coast of the Sea of Japan, and from Echigo south into Shinano, disappearing near Nagano City, but reappearing on the Pacific coast of Tōtōmi.

Petroleum deposits in Japan are found exclusively in the Tertiary formations. These formations have been studied in detail by many geologists, and it is clear that, although there are certain different peculiarities in the oil-bearing strata in the various districts, they have, on the whole, similar characteristics and are of the same geological horizon. Correlation of the Tertiary sediments of the important oil fields in Japan such as Echigo, Akita, and Hokkaidō, is as follows:

TABLE XIV

<table>
<tr><th colspan="2">Hokkaidō Oil Fields.</th><th colspan="2">Akita Oil Fields.</th><th colspan="2">Echigo Oil Fields.</th></tr>
<tr><td>(a) Lower Tertiary (Eocene-Oligocene)</td><td>Coal Measure</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>(b) Middle Tertiary (Miocene)</td><td>Black Shale Series (Poronai Series)</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td rowspan="4">(c) Upper Tertiary (Miocene-Pliocene)</td><td>1) Sandstone and Conglomerate Series</td><td rowspan="2">Lower Division</td><td rowspan="2">Green Tuff
Siliceous Shale
Black Shale
Gray Shale</td><td rowspan="2">Lower Division</td><td rowspan="2">Black Shale and Tuff
Alternation of Shale and Sandstone</td></tr>
<tr><td>2) Dark Gray Shale Series (Wakkanai Series)</td></tr>
<tr><td>3) Gray Shale Series</td><td>Middle Division</td><td>Sandy Shale</td><td>Middle Division</td><td>Gray Sandy Shale</td></tr>
<tr><td>4) Sandstone Series</td><td>Upper Division</td><td>Sandstone</td><td>Upper Division</td><td>Shale, Sandstone Conglomerate</td></tr>
<tr><td>(d) Uppermost Tertiary (Pliocene)</td><td>Sand, Gravel and Clay</td><td></td><td>Clay, Sand</td><td></td><td>Clay, Sand, Gravel</td></tr>
</table>

(1) THE HOKKAIDŌ OIL FIELDS

Geologically Hokkaidō is divided into two parts by the so-called Central Zone of Depression. The oil-bearing Tertiary formations differ in character in each district. In the western part they contain much pyroclastic material, and in some cases it is difficult to make a comparison with those of the eastern part.

The Tertiary formations in Hokkaidō overlie Cretaceous formations, for the most part unconformable. The Lower Tertiary strata show many signs of oil in the provinces of Teshio and Ishikari, but no important deposit has been found in them. The Middle Tertiary formation contains oil in many places in Iburi and Ishikari, but no important deposit has been found up to the present. Many oil seepages are found in 1) Sandstone and conglomerate Series of the upper Tertiary, but no rich oil deposit has been met with. The principal oil-containing strata in Hokkaidō are found in 2) Dark gray shale Series, and 3) Gray shale Series of the upper Tertiary and rich oil deposits occur in Ishikari, Kitami, and Teshio.

In the area occupied by the Upper Tertiary formation there are many oil districts along anticlinal folds. In Ishikari there are two principal anticlinal axes running almost parallel from north to south. The easternmost, called the Toshibet anticline, has an axis about 13 miles long, and dips on either side of less than 20 degrees. Some of the many oil wells bored along the anticline produced as much as 250 barrels a day. The western anticline, called the Atsuta anticline, runs along the shore line of Atsuta and has a length of six miles. The strata which, like those of the Toshibet anticline, are dark gray and gray shales, dip not more than 20 degrees on either side of the axis. Several test borings were made on this fold, but no rich oil deposit was struck.

There are two long anticlinal folds extending south from Kitami to Teshio. The Koitoi anticline on the east has a length of 17 miles and is composed of dark gray and gray shales. The inclination on either side of the axis ranges from 10 to 20 degrees. Several wells have been drilled on it and some of them less than 1,100 feet deep reached oil pools. The Wakkanai anticline on the west is principally composed of the Wakkanai Series and is 8 miles long. The inclination on either side of the anticline does not exceed 20 degrees. Two or three wells have been bored on it and fairly rich oil pools were found at a depth of 2,500 feet.

In addition, in the provinces of Iburi, Hitaka and Oshima there are many anticlines along which test borings have been made, but as no rich oil pool was found all were abandoned.

The total production of oil in Hokkaidō did not exceed 7,000 barrels annually.

(2) THE AKITA OIL FIELDS

Like the Echigo oil fields, the Akita oil fields are important in Japan. They are in Ugo, having the city of Akita in their center, in the northwestern part of Honshū, facing the Sea of Japan. The oil fields parallel the coast line for about 128 kilometers.

The surface of the oil districts is occupied by hills or low mountains not over 300 meters in height, which have a general northeasterly trend. These hills and mountain ranges usually coincide with the anticlinal folds in the Tertiary strata and the valleys between them are mostly synclinal.

Oil deposits are found in the lower and middle divisions of the Upper Tertiary formations. In the lower division, the upper parts of the siliceous shale series and the lower parts of the gray shale series contain oil.

Tufaceous sandstones and fractured parts of the siliceous shales provide rich oil bearing zones. In the black shale series, tuff and tufaceous sandstones are important oil bearing strata. Oil seepages are numerous in the lower part of the Middle Division, but oil in commercial quantity has not been obtained.

The most productive oil zones are found in the lower part of the black shale series and in the upper part of the silicious shale series. Oil deposits are confined to the anticlinal or domal structures.

Volcanic rocks are met with in the lower and middle divisions. They consist of basalt, andesite, dacite and liparite; these volcanic rocks caused lithological changes in the character of the Tertiary sediments and in some cases it is believed that they have had some influence on the accumulation of oil.

There are many oil fields in Akita district, and among them, the Kurokawa, Toyokawa, Michikawa and Uchimichikawa fields are the most important.

The general strike of the Tertiary formations in the Akita Oil Fields is NNE; the strata in most cases are gently folded with dips not exceeding 30 degrees. The Kurokawa Oil Field is three miles south of Akita city, and is famous for a gusher which produced 10,000 barrels a day. The oil field is surfaced by gray shale and has an elongated dome structure; the inclination of the strata averages 20 degrees. The Toyokawa Oil Field is in black shale. The structure is that of a terrace, and the oil occurs in fractured zones of the rock. The Michikawa Oil Field is in gray shale which forms an elongated north-trending dome; the oil deposits being found in the domal structure at many depths. At Uchimichikawa Oil Field, there is found the alternation of sandstone and shale of the middle division; the structure is anticlinal.

(3) THE ECHIGO OIL FIELDS

The oil-bearing strata of the Echigo oil fields belongs to the Upper Tertiary formations and is divided into four divisions as shown in Table XIV.

Some oil is found in almost all the Tertiary formations, but rich oil deposits are found in the lower and middle divisions.

The geological structure of the Tertiary formation in the Echigo oil fields is, generally speaking, simply due to folding, and there are no great faults affecting the general trend of the strata. The general direction of the strike is from NNE to SSW, parallel to the sea coast. In the districts lying on the western side of the Shinano River there are four anticlines together with subordinate wrinkles, all running parallel from NNE to SSW.

The Amaze anticline, in the far west, extends northward over the sea as far as Teradomari, forming low longitudinal undulations. The Amaze Oil Fields are at its southern end. The Oginojō anticline lying on the east of the Amaze anticline extends slightly west for a great distance along the crest of that range, its western wing being greatly disturbed, with many faults and foldings. The Ojiya Oil Field is developed along the same anticline, and has regular and gentle inclinations of strata. The Higashiyama range represents an anticlinal fold, the axis of which traverses the entire range. Its western wing is greatly disturbed with numerous faults and folds. The Higashiyama Oil Field, one of the oldest oil fields in Japan, is developed along an anticline. To the northwest of the Higashiyama anticline lies the Ōmo anticline, running north and south, the Ōmo Oil Field being located along the axis of the anticline.

The Niitsu anticline runs from north to south, forming a gentle arch, and a low undulation like a terrace structure lies on its western wing. In the southwestern part of the Echigo oil fields, in the Kubiki district, there are many anticlines, all parallel and most of them short. Some are steeply inclined, but others are gently inclined, though all generally have steep sides on the western side. The most prominent anticline in the district runs from Gendōji to the north of Yasuzuka through Iwagami. All the oil districts scattered throughout the districts are on the anticlines, especially on those having an elongated dome structure.

The production of oil in Japan during recent years was as follows :

1916	3,008,818 barrels.
1917	2,883,300 barrels.
1918	2,449,531 barrels.
1919	2,380,730 barrels.
1920	2,227,360 barrels.
1921	2,447,000 barrels.
1922	2,004,000 barrels.
1923	1,791,300 barrels.
1924	2,210,853 barrels.

NON-METALLIC MINERALS (EXCEPT COAL AND PETROLEUM)

BY Y. OINOUYE

(1) **PRECIOUS STONES**:—The ruby, sapphire, beryl and topaz have become known in comparatively recent times. Tourmaline, axinite, garnet, vesuvianite, etc. are also found, but they are neither fit for ornamental purposes nor abundant. These minerals occur in pegmetitic dykes or in sedimentary rocks metamorphosed by granite intrusion. Agate, opal and chalcedony are found filling cavities in volcanic rocks.

(2) **GRAPHITE**:—This occurs in two forms, crystalline and amorphous. Two types of deposits, beds and fissure veins, are found, of which the former are numerous, while the latter are very rare. In Hida and Etchū, scaly graphite occurs as a constituent mineral of gneissose granite.

(3) **ASPHALT**:—Akita is the only locality where this mineral is produced. It occurs usually as asphalt earth, which seems to be a natural residue of petroleum that impregnated the soil covering the oil-bearing Tertiary strata.

(4) **STONES FOR BUILDING AND MONUMENTS**:—Triassic slate occurring in the north-eastern part of Rikuzen, the Cretaceous Izumi-sandstone and various Tertiary sandstones and tuffs are important sedimentary rocks useful for building and decorative purposes. For gravestones and monuments, rocks of common occurrence are quarried, such as granites, andesites, tuffs and Triassic slate.

The building stones most widely used in Tōkyō are granites and andesites, together with andesitic tuffs and breccia. The granites are brought from Hitachi, Mikawa and the islands of the Inland Sea. The andesites come from Izu, and their tuffs and breccia from Awa (in Honshū), Kōzuké, etc.

Ornamental stones are granite, diorite, porphyrite, serpentine (ophicalcite), limestone and schalstein. The Carboniferous marble of Mino, the crystalline limestone of Nagato and Hitachi, and the serpentine of Higo and Hitachi are the most beautiful of the ornamental stones.

(5) **FULLER'S EARTH**:—This is found in liparite, liparitic tuff and tufaceous shale of the Tertiary age. The Fuller's earth of Echigo is chiefly an alteration product of liparite and is most profitable. It is used for bleaching mineral oils and manufacturing soap, and also as an absorbent.

(6) PORCELAIN CLAY:—As rocks bearing potash-feldspar such as granite, porphyry and liparite, are widely distributed in Japan, the argillaceous materials for the manufacture of porcelain and earthenware are abundant. The porcelain clays of Yamashiro, Ōmi, Owari and Iwaki are the products of decomposition of granite and porphyry, while those of Amakusa, Arita and Izushi come from weathered liparite. Less commonly, decomposed sedimentary rocks are used in making porcelain such as the " Bizen-yaki " and " Banko-yaki."

(7) DIATOM EARTH:—This is found embedded in the Tertiary and Pleistocene strata in several localities in Hokkaidō, Honshū and Kyūshū; but it is not of economic importance at present.

(8) FIRE CLAY:—A hydrous silicate of alumina, sometimes known as " Rōseki " in Chūgoku, occurs either as veins in acid volcanics or in tufaceous rocks. Adjacent to the Tertiary coal seams, there are often found beds of carbonaceous fire clay, besides beds of clay with abundant quartz, so useful as refractory clay, the latter being especially produced in Owari.

(9) " TATAKI " EARTH:—" Tataki " earth is a natural mixture of sand and earth, of which a kind of concrete is made by adding a certain quantity of lime. The natural mixture is formed from the decomposition of granite or sandstone and clayslate, in such a stage of weathering that the feldspar in the rocks can be dissolved most effectually by hydric chloride, though it is not completely kaolinized. It occurs in Owari, Isé, Ōmi, Yamashiro, Aki and Nagato.

(10) NATURAL CEMENT:—A certain variety of marl or calcareous clay convertible into cement by roasting is known as natural cement. For the manufacture of a cement of good quality, however, it is necessary to add a certain quantity of clay and lime to the quarried earth. It occurs in Etchū and Higo.

(11) VOLCANIC ASHES:—Some volcanic ashes found in Hokkaidō, northeastern Honshū and Kyūshū are often used as an admixture in Portland cement.

(12) ABRASIVE MATERIALS:—For millstones and mortars, compact varieties of granite, diorite, andesite or basalt are chiefly used. The Nagura-do of Mikawa, a well-known stone for horing swords, is a fine-grained liparitic tuff. Ochre and *tonoko* derived from decomposed clayslate, are used in the polishing of metals. Diatom earth ranks next in importance to garnet sand as a polishing material. *Bōshū* sand which occurs in abundance in Bōshū or Awa (in Honshū) is derived from a pumiceous tuff. It is largely used in finishing moderately hard materials and for polishing wheat and rice.

(13) **INKSTONE OR INK-BASIN**:—The Inkstone is the stone on which the solid cake of Japanese ink is rubbed to make a solution. These stones are made of shale, clayslate or schalstein of a compact and homogeneous texture. Liparite, though very coarse in texture in comparision with the rocks mentioned above is still used for the same purpose in schools of lower grades on account of its cheapness.

(14) **LYDIAN STONE**:—This is used as touchstone, and also serves as the material for the black pieces in the game of *Go*. The best lydian stone known as *Nachi-guro* comes from the Nachi-gawa in Kii.

(15) **SLATE**:—Certain kinds of slate in the Palaeozoic and Mesozoic formations are used for roofing and also for school-slates. The chief localities for such slate are Rikuzen, Suruga and Tosa.

(16) **LITHOGRAPHIC STONE**:—A marly limestone of the Tertiary formation can be used in lithographing. It is, however, not compact enough to serve for fine printing. The occurrence of the rock is limited to Sannai in Musashi and Kamewaki in Sado.

(17) **STEATITE AND AGALMATOLITE**:—These occur chiefly in liparite regions, or as secondary products of the alteration of ultra-basic eruptive rocks. Agalmatolite is sometimes found interbedded in Mesozoic schalstein.

(18) **ASBESTOS**:—Asbestos is found as a secondary decomposition product of serpentine and peridotite. The mineral found in Hizen, Kii, Higo and Iwaki is of good quality and is employed for technical purposes.

(19) **GYPSUM**:—This occurs in mineral veins, or in sedimentary or volcanic rocks acted on by hot springs. In the Tertiary tuff of Kai, gypsum is found in the form of beds or veins. Important deposits of gypsum are distributed in the " black ore " districts. Kanō in Iwashiro, Wanibuchi and Udo in Izumo, Matsushiro in Ōmi and Isotakė in Iwami are the chief localities of the mineral. It is used for plastering walls, pottery moulds, statuary, cement, paint and fertilizer.

(20) **LIMESTONE**:—This is widely distributed in all geological formations and occurs throughout the country. Palaeozoic limestone is abundant in Japan and is quarried chiefly for the manufacture of lime, though certain varieties are used for building or decorative purposes.

(21) **FLUORSPAR**:—This occurs in veins in acidic eruptives, also at the contact of granitic rock with quartzite, slate and limestone of the Palaeozoic ; but the quantity is not large.

(22) **TALC**:—Talc occurs in decomposed serpentine, in pyroxenite and in the schists.

(23) **MICA**:—Mica occurs chiefly in pegmatitic dykes in granite and sometimes in sericite-schist. Large crystals are very rare.

(24) **QUARTZ**:—Quartz occurs in the Palaeozoic quartzite and weathered acidic eruptives, as well as in sand of young formations. It is used for the flux for iron ores and also for making glass.

(25) **PORCELAIN-GLAZE**:—In Japanese potteries some glazes used are very often natural products of the weathering of liparite, as for example the glaze of the Arita porcelain.

(26) **MINERAL PIGMENTS**:—The mineral pigments used in Japan from remote times comprise cinnabar, malachite, azurite, red lead, realgar, orpiment, lead carbonate, iron oxides, *benigara* (a mixture of ferric oxide and clay derived from the decomposition of pyrites), ultramarine, etc.

(27) **MEDICAL MINERALS**:—The important medical minerals are arsenopyrite, iron oxide, alum, gypsum, copper vitriol salt, cerussite and alabaster ; but the output is not remarkable.

(28) **SULPHUR**:—The mode of occurrence of sulphur in Japan is of the "Solfatara type" and some of the deposits are of bed-form in the old solfatara lakes, having more or less circular boundaries. The thickness of the deposits sometimes exceeds 30 meters, but their horizontal extent is comparatively small. They are found in volcanic districts, extending from Chishima (Kurile Islands), through Hokkaidō, Honshū and Kyūshū, down to Taiwan. The chief localities are as follows : Atosanobori, Okujiri, Iwaonobori, Horobetsu, Kumadomari and Esan in Hokkaidō ; Matsuo, Numajiri, Takai and Nasu in Honshū ; Kujūsan in Kyūshū.

(29) **PHOSPHATES**:—Phosphates occur in the Palaeozoic formations in Shima, in the Tertiary formations in Uzen, Ugo, Noto and Hyūga, and in the coral reefs of younger age in the Daitō and Rasa islands, as well as in the Pelew islands, mandated to the Empire. Nodules or beds in the Palaeozoic and Tertiary formations, and veins or irregular masses in coral reefs are the modes of occurrence of phosphatic rocks in Japan. Phosphoric mineral in the former takes usually the form of apatite or vivianite, while in the latter it is amorphous tricalcium phosphate occasionally with aluminium phosphate. The quality of the latter in most cases excels that of the former.

The phosphates of Rasa, one of the Daitō Islands, cover the entire surface of the coral island and attain a thickness of about 20 meters. Rasa is the most productive source of phosphates in Japan.

PART II
GEOLOGY AND MINERAL RESOURCES OF KOREA

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CHAPTER I

GEOLOGY

The results of the geological survey of Korea, in 1911–1925, have been given in some detail in the publications already issued. Here they are treated in the form of a systematic geological summary with additional informations from other sources.

The Korean Peninsula, formerly called Haetung[1], is a part of the Asiatic continent as are the peninsulas of Shantung[2] and Liautung[3], but it differs from them in that it forms a land-bridge between the continent and the Japanese Islands. Accordingly, the geological study of the peninsula can not be carried out without referring to them, but it is beyond the scope of this paper to enter into the subject in detail.

The geological features of the peninsula agree in general with those of North China and South Manchuria, and differ in many respects from those of the Japanese Islands.

Synopsis of Stratified Rocks

Pre-Cambrian
  Pre-Cambrian Sedimentaries
    Igneous contact
  Pre-Cambrian Gray Gneisses
    Unconformity of dip
Chosen[4] System (Lower Cambrian to Middle Ordovician)
    Parallel unconformity
Heian[5] System (Upper Carboniferous to Earlier Triassic)
    Unconformity of dip
Daido[6] System (Lower Jurassic to Cretaceous)
  Lower Daido Formation (Lower Jurassic)
    Unconformity of dip
  Middle Daido Formation (Middle ? Jurassic)
    Relation unknown

1) 海東　2) 山東　3) 遼東　4) 朝鮮　5) 平安　6) 大同

Lower Keisho[1] Formation (Upper Jurassic)

Apparent conformity

Upper Keisho Formation, Upper Daido Formation, etc. (Earlier Cretaceous)

Unconformity by denudation

Fukkokuji[2] Formation (Cretaceous ?)

Unconformity of dip

Tertiary

Palaeogene

Unconformity of dip

Neogene

Unconformity by denudation

Quaternary

Pleistocene (?)

Unconformity by denudation

Recent

PRE-CAMBRIAN

The Pre-Cambrian rocks in Korea are divisible into the metamorphosed sedimentaries and the Gray Gneisses, the latter being regarded as metamorphosed granite, in some cases abounding in xenoliths caught up from the intruded sedimentaries. In North China and South Manchuria the Pre-Cambrian rocks are divided by unconformity, probable or inferred, into the Archaean and the Proterozoic; and the latter again into Eoproterozoic and Neoproterozoic, following Willis and Blackwelder. In some cases, the Gray Gneisses of the peninsula petrographically come very near to some of the Archaean rocks and our metamorphosed sedimentaries to some divisions of the Proterozoic in China; but we can not correlate them, because in China there is most probably great unconformity between the Archaean and the Proterozoic, while in Korea they are in igneous contact so far as our observation shows. It may here be remarked that some of our Gray Gneisses, that is, the Gray Granite-Gneiss and the Augen-Gneiss seem to be analogous respectively to the Granitoid Gneiss and the Augen-Gneiss, which in N. China associate with the Proterozoic sedimentaries, probably in intrusive contact.[3] In the Japanese Islands there are also metamorphosed rocks, gneisses and schists, which resemble

1) 慶尙 2) 佛國寺

3) Willis, B. and Blackwelder, E. (1907) Research in China, Vol. I, Pt. 1, pp. 105, 106; Willis, B. (1907) Research in China, Vol. II, pp. 5, 6.

Yamane, S. (1924) Jap. Journ. Geol. Geogr. Vol. III, No. 3-4, pp. 66, 67.

the Pre-Cambrian metamorphosed rocks of Korea, but we have no evidence on which to correlate them ; for the only thing that we are able to say of the old rocks of Japan with regard to their geological age is that they are Pre-Carboniferous. Thus the oldest rocks of the peninsula, being unconformable in dip with the overlying Lower Cambrian rocks, are grouped together under the Pre-Cambrian.

PRE-CAMBRIAN SEDIMENTARIES

The Pre-Cambrian sedimentaries in the peninsula still remain for the most part uninvestigated, and some areas tentatively included in this category may be of a much younger age. In respect of their separate distributions and their petrographical natures, but not of their stratigraphical relations, the Pre-Cambrian sedimentaries may be divided into the following three formations :—

1 Matenrei[1] Formation
2 Rensen[2] Formation
3 Yokusen[3] Formation.

The Matenrei Formation consists mainly of metamorphosed limestone, commonly with calc-silicate minerals, and mica-schist, in some cases with garnet or staurolite[4], associated with biotite-gneiss, hornfels-gneiss, amphibolite and pyroxenite. In the Matenrei district, Kankyo-Do, it attains a thickness of 13,000 m. The strata are highly folded and intensely deformed, the minutely contorted silicious laminae in the metamorphosed limestone being a notable characteristic of the Formation. It is intruded by reddish granite and other igneous rocks of unknown age.

The Rensen Formation crops out typically in the vicinity of Rensen in Keiki-Do, the rocks resembling those of the Matenrei Formation, but calcareous rocks are much less frequent and amphibolite predominates. The lower part is made up of white quartzite, metamorphosed limestone, hornfels-gneiss and amphibolite ; the upper part, of mica-schist, in some cases with cyanite, and phyllite. The thickness attained is about 28,000 m. The Gray Gneisses and gabbro of the Pre-Cambrian and porphyritic granite are observed intruding the Formation.

The Yokusen Formation is extensively developed in the Yokusen district, North Chusei-Do, and is composed of rocks less metamorphosed than those of the above two formations, viz., phyllite, graphite-phyllite, mica-schist, quartzite and amphibolite, of which phyllite predominates.

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1) 摩天嶺 2) 漣川 3) 沃川

4) Chitani, Y. (1918) Journ. Geol. Soc. Tokyo, Vol. XXV, p. 55.

It is noteworthy that in the Formation deposits of graphite of an amorphous nature are of importance, while in the two preceding formations the graphite is crystalline.

GRAY GNEISSES

The Gneisses are various in composition and structure, the typical one, being banded, fluidal or schistose in structure and made essentially of dark gray feldspar, dark bluish quartz and biotite often of golden colour and accessorily of cordierite and garnet, often in abundance. In these Gneisses, the peculiar banding which consists of a rough alternation of lighter and darker coloured bands, irregularly thinned, thickened and fluidal, is analogous to that of the Archaean or the Taishan Complex in China. Besides the highly schistose variety, there are some of a distinctly granitic texture, viz., the Gray Granite-Gneiss and the Augen-Gneiss. In some cases these are observed to pass into one another.

The Gray Gneisses are commonly rich in xenoliths of the Pre-Cambrian sedimentaries, and the marginal portion of the xenoliths is assimilated by, and passes into, the host.

The Gray Granite-Gneiss and the Augen-Gneiss may, in petrographical respects, be compared to the Granitoid-Gneiss and the Augen-Gneiss in N. China ; but it seems to be not yet clearly determined whether they are Archaean or intrusive in the Sitsui Series of the Proterozoic. By Willis and Yamane they are considered to be intrusive rather than Archaean. It is, however, extremely unsafe to attempt the correlation of metamorphosed rocks in regions so widely separated. The Gneisses occur as batholiths or stocks in the Pre-Cambrian sedimentaries and are considered their genesis due largely to the assimilation of the stoped Pre-Cambrian sedimentaries.

PALAEOZOIC

The Palaeozoic in Korea is distinctly divided into two systems by an immense hiatus as in North China. The lower division has been named the Chosen System and the upper, the Heian System. The Chosen System, corresponding to the Upper Sinian of v. Richthofen and to the Sinian of Willis and Blackwelder, includes the strata from the Lower Cambrian up to the *Actinoceras* horizon of the Ordovician ; and the Heian System, from the Upper Carboniferous up to the Triassic. The contact between the base of the Heian System and the top of the Chosen System has been observed by various authors to be distinct and apparently conformable.

CHOSEN SYSTEM

This System, also known as the Korean System, is exposed in a wide area covering the greater part of S. Heian-Do and Kokai-Do and a part of S. Kankyo-Do. It is also found, though less extensively, in Kogen-Do and in small patches in the upper course of the Oryok-ko which forms the boundary between Korea and South Manchuria. The provisional divisions of the System are as follows :—

Great Limestone Series	Thick limestone intercalating one or two shale beds; total thickness in Kogen-Do, 1,270 m. Cambrian and Ordovician marine fossils.
Conformity	
Yotoku Series	Red shale or slate, intercalating thin limestone, on the basal quartzite; total thickness in Kogen-Do, 550 m. Lower Cambrian Trilobite.

The red shale in the Yotoku Series has the characteristic Lower Cambrian Trilobite, *Redlichia chinensis* Walcot, so that the shale corresponds to the Mant'o shale in North China. The shale intercalates thin limestone beds in the upper horizons and passes into the overlying Great Limestone Series. The quartzite underlying conformably the shale or slate and overlying unconformably in dip the Pre-Cambrian rocks is of variable thickness, in some regions being about 500 m. or much more, and thinning out in others. In North China and South Manchuria, the red shale with the leading Lower Cambrian Trilobite covers directly and unconformably in dip the Pre-Cambrian rocks, the Taishan Complex, the Wutai or the Huto System, in some regions, but in most cases overlies conformably and directly or indirectly a sandstone or quartzite bed which rests unconformably upon older rocks. The sandstone or quartzite is considered by several authors[1] to be of the Lower Cambrian, or of the Proterozoic. In Korea we have no evidence, either positive or negative, on which to cut it off from the Lower Cambrian and it is accordingly regarded as representing the basal sediments of the Cambrian transgression.

Oölitic, vermicular and Cryptozoon limestones are common in the lower part of the Great Limestone Series. The fossils in the Series are *Ptychoparia kochibei*, *Anomocallera chinensis*, *Anomocare* sp., *Olenoides* sp., *Lingulella* sp., *Acrotreta* sp. and *Blackwelderia cilix* from the lower part; and *Maclurea* sp., *Raphistoma* sp., *Actinoceras* sp., *Orthis calligramma*, *Asaphus* sp., etc. from the upper part; *Graptolite* was also found in shale

1) v. Richthofen, Willis, B., Aoji, O., Yamane, S., etc.

intercalated in the limestone in Kogen-Do. Whether or not the Chosen System represents a continuous sedimentation with no hiatus must be decided by future investigation.

HEIAN SYSTEM

This System is mostly of terrigenous deposition and ranges in age from the Upper Carboniferous to the Triassic. It is divided into the following four Series in descending order :—

(4) Green Series	Green shale and sandstone, no coal and no fossils ; thickness 1,000 m.
Conformity	
(3) Kobosan Series	Shale and sandstone, generally with thin coal seams; Permo-Triassic plant fossils; thickness 364–580 m.
Conformity	
(2) Jido Series	Sandstone, Shale and workable coal seams; Permo-Carboniferous plant fossils ; thickness 80–150 m.
Conformity	
(1) Koten Series	Red shale, sandstone, limestone and rarely thin coal seams ; imperfect plant remains, and Upper Carboniferous and Permian animal remains; thickness 80–270 m.

Among the above four Series (1), (2) and (3) may respectively be roughly compared with the Tayuang, the Shansi and the Shihhotse Series including the Ginkgo zone, in China.[1]

KOTEN SERIES

This Series, the lowest division of the Heian System, is made up of terrigenous and marine deposits. The basal bed is commonly red shale, which has often ottrelite as its ingredient mineral and haematite concretions arranged in layers. In some cases, a thin conglomerate layer comes between the red shale and the underlying limestone of the Great Limestone Series, these three being apparently conformable.

The limestone in the Series occurs generally in thin beds or lenses, which vary in thickness and number, there being five or more in some

1) Norin, E. (1922) Bull. Geol. Surv. China, No. 4, p. 7.
Grabau, A. W. (1924) Stratigraphy of China, p. 254.

cases. The fauna recorded by Yabe from the limestone of a horizon in the middle of the Series is as follows :—

Schwagerina princeps Ehrb., *Chaetetes asiaticus* Yabe et Hayasaka, *Caninia muratai* Yabe et Hayasaka, *C.* sp., *Cystophora dubia* Yabe et Hayasaka, *C. kikkawai* Yabe et Hayasaka, *Archnastraea coreanica* Yabe et Hayasaka, *Productus* sp., *Spirifer* sp., *Uncrinulus* sp. and *Dalmanella* sp.

The following are recorded by E. Konno from a limestone probably of the same horizon :—

Productus cora Diener, *Fusulina* sp. and *Tetrataxis* cf. *maxima* Schelwien.

The fauna recorded from the limestone of an upper horizon by Yabe and Konno is as follows :—

by Yabe

Fusulina sp. indet. aff. *richthofeni* Schwager and *F.* sp.

by Konno

Fusulina subcylindrica Deprat and *Schwagerina* sp.

Ozawa describes a new species, *Fusulinella konnoi* Ozawa from the Series.

The name 'Koten' was originally applied to the formation in the Heijo[1] district from the basal red shale up to the limestone with *Schwagerina princeps.* Here it is adopted to designate roughly similar formations throughout the peninsula, but extending it a little upward to the uppermost limestone bed, including the lower Jido formation, in the Heijo district, because the limestone beds are thin or lenticular and not persistent, and in districts other than Heijo no foraminifera distinctly identified with the leading species has yet been found.

JIDO SERIES

This is a terrigenous formation rich in anthracite seams and in Permo-Carboniferous flora. The common plants in the flora are as follows :—

Mariopteris muricata Schloth., *Pecopteris candollei* Brongn., *P. polymorpha* Brongn., *P. oreopterida* Schloth., *P. cyathea* Schloth., *P. orientalis* Schenk, *Lonchopteris alata* nov. sp., *Callipteridium koraiensis* (Tokunaga) *Callipteris conferta* Schloth., *Taeniopteris multinervis* Weiss, *Mixoneura subcrenata* Rost, *Calamites cisti* Brongn., *Sphenophyllum emarginatum* Geinitz, *S. oblongifolium* Germ. et Kauf., *S. thoni* Mahr., *Annularia inequifolium* Tokunaga, *Lepidodendoron oculis-felis* Abbado, *Lepidostrobus* sp., *Sigillaria* sp., *Stigmaria ficoides* Sternbg., *Cordaites principalis* Germ., *C.* sp., *Noeggerathia acuminifissa* Krasser, *N. kikkawai* Tokunaga, *Pterophyllum carbonicum* Schenk and *Lagenospermum* cf. *oblongum* (Kidston).

1) 平壤

Professor Yabe also gives sixteen other species of plants and Tokunaga describes a new species, *Sphenophyllum macrophyllum*. The flora is a mixture of Carboniferous and Permian plants, but is regarded by Yabe as Lower Permian, because the Series overlies the Koten Series bearing *Schwagerina princeps*. Without doubt the Jido Series corresponds to the Shansi Series in North China.

KOBOSAN SERIES

This is also a terrigenous formation and rich in plant remains. The anthracite seams are generally thin, though locally thickened as in the Tokusen district in S. Heian-Do. The plants determined are as follows :—

Pecopteris integra Andrae, *P. orientalis* Schenk, *Desmopteris* sp., *Taeniopteris spatulata* McClell., *Sphenophyllum speciosa* (Royle), *Annularia inequifolium* Tokunaga, *A. papilioides* nov. sp., *A. mucronata* Schenk, *A. maxima* Schenk, *Schizoneura heianensis* Kodaira, *Neocalamites meriani* (Brongn.), *Gigantopteris nicotianaefolia* Schenk, *G. rarinervis* Konno, *G. elongata* nov. sp., *G. dentata* Yabe, *Chiropteris reniformis* Kawasaki, *Thinnfeldia* cf. *incisa* Sap. and *Conchophyllum richthofeni* Schenk ; besides these *Annulariopsis inopinata* Zeiller and *Sphenophyllum sino-coreanum* Yabe are described by Yabe. Thus the flora includes fairly many Triassic types.

GREEN SERIES

This is the uppermost and thickest member of the Heian System, and consists of sandstone and shale, which are prevalently green in colour and calcareous in composition. Though no fossils are known, it is considered Triassic, because of its stratigraphical relation to the Permo-Triassic Kobosan Series.

MESOZOIC

The oldest Mesozoic rocks have been referred to above as the Kobosan and the Green Series, which are continuous members of the Heian System. Here the other Mesozoic rocks, which are much younger than them and separated by a considerable unconformity from the preceding System, are treated under the name of Daido System.

The Daido System lies with unconformity of dip upon the Heian System and other older rocks, and underlies, also with unconformity of dip, the Tertiary or other younger rocks. It is divided stratigraphically and palaeontologically into five members by unconformable contact, distinct or probable.

In descending order they are as follows :—

(5) Fukkokuji Formation	Agglomerate, tuff, flows of quartz-porphyry and felsophyre, and granite ; thickness (except granite) 900 m.
Unconformity by denudation	
(4) Upper Keisho Formation or Upper Daido Formation	Conglomerate, sandstone, shale, tuff, agglomerate, flows of porphyrite ; thickness 1,000 m. or more ; plant and animal remains rare.
Parallel unconformity	
(3) Lower Keisho Formation	Conglomerate, sandstone, shale and thin coal ; thickness 28,000 m.; plant remains abundant, animal remains scanty.
No direct contact	
(2) Middle Daido Formation	Conglomerate, sandstone, shale and thin coal ; thickness 1,300 m.; plant and animal remains.
Most probable unconformity of dip	
(1) Lower Daido Formation	Conglomerate, shale, sandstone and thin coal ; thickness 1,600 m.; plant fossils abundant, animal fossils not abundant.

DAIDO SYSTEM

LOWER DAIDO FORMATION

This Formation occurs chiefly on the lower courses of the Daido-ko and the Reisei-ko, and in a comparatively large area in S. Chusei-Do, other smaller areas being found in S. Kankyo-Do, Keiki-Do and Kogen-Do.

The Formation is much more intensely disturbed than the overlying younger formation. The direct contact between the Formation and the adjacent and younger Middle Daido Formation can not be observed, as it is covered by a narrow area of Quaternary deposits, about 100 m. across ;

but the latter is in gentle inclination in contrast to the intense foldings of the former.

Animal remains already recorded are *Hildoceras inouyei* Yok. which is of the Liassic in the Japanese Islands and *Estheria koreana* Ozawa et Watanabe and *E. kawasakii* Ozawa et Watanabe.[1] The plants are as follows :—

Laccopteris polypodioides (Brongn.), *Clathropteris meniscoides* Brongn., *Cladophlebis denticulata* Brongn., *C. raciborski* Zeill., *C. nebbensis* Brongn., *C. haiburnensis* (L. et H.), *C. nanpoensis* Kawasaki, *C. williamsonis* Brongn., *C. whitbiensis* Brongn., *Marattiopsis muensteri* (Goepp.), *Taeniopteris stenophylla* Kryst., *T. eurychoron* (Schenk), *T. mc'clellandi* (Oldh. et Morr.), *T. superba* Sap., *Neocalamites carrerei* (Zeill.), *Schizoneura nanpoensis* Kawasaki, *Anomozamites nilssoni* (Phill.), *Nilssonia pterophylloides* Nath., *Ginkgoites sibirica* (Heer), *Baiera phillipsi* Nath., *B. gracilis* Bunb., *B. concinna* (Heer), *B. lindleyana* Schimper, *Phoenicopsis angustifolia* Heer, *P. speciosa* Heer, *Pityophyllum longifolium* Nath.. *Podozamites distans* (Presl), *P. lanceolatus* (L. et H.), *P. schenki* Heer and *Spirangium* sp., etc.

The flora of the Quichou Series[2] in Central China and that of the Mongugai Series[3] near Vladivostok, both of which are regarded as Liassic, may be comparable with the Korean flora.

MIDDLE DAIDO FORMATION

This is observed at Heijo city and its suburbs in S. Heian-Do, the lowest rock thus far exposed being a limestone-conglomerate, but its contact with the older rocks has not been observed. Fish bones were found in the sandy shale in the lower horizon, and *Cyrena* shells in the shale in the upper horizon. The plants from the shale and sandstone in the upper horizons are as follows :—

Coniopteris hymenophylloides Brongn., *Eboracia lobifolia* (Phill.), *Cladophlebis raciborski* Zeill., *C. argutula* (Heer), *Baiera gracilis* Bunb. and *Podozamites lanceolatus* (L. et H.).

From the marked contrast in movement of strata between the present Formation and the preceding Lower Daido Formation, as referred to above, and from the Jurassic type of the present flora, the Middle Daido Formation is considered to be younger than the Lower Formation, most probably with an intervening diastrophism between them.

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1) Ozawa and Watanabe (1923) Jap. Journ. Geol. Geogr., Vol. II, No. 2.
2) Willis, B. and Blackwelder, E. (1907) Research in China, Vol. I, Pt. I, p. 280.
3) Kryshtofovich (1923) Rec. Geol. Com. Russ. Far East, No. 22.

LOWER KEISHO FORMATION

This Formation occupies an extensive area covering almost all of N. and S. Keisho-Do, covering Pre-Cambrian rocks and granite probably of the Mesozoic, and being covered in apparent conformity by a thick conglomerate bed of the Upper Keisho Formation. The strata dip slowly and are disposed in gentle undulations, forming low hilly land·

Animal remains are found generally in the upper part, while plants abound in the lower. The animal remains are *Ceromya*, *Pholas*, *Tellina*, *Melania*, *Posidonomya*, *Neritina*, *Oxyrhima*, etc. The plants are as follows:—

Coniopteris hymenophylloides Brongn., *C. heerianus* (Yok.), *Eboracia lobifolia* (Phill.), *Onychiopsis mantelli* (Brongn.), *Adiantites sewardi* Yabe, *Cladophlebis denticulata* Brongn., *C. dunkeri* (Schimper), *C. geyleriana* (Nath.), *C. koraiensis* Yabe, *Ruffordia goepperti* (Dunk.), *Sagenopteris bilobata* Yabe, *S. Phillipsi* (Brongn.), *Equisetites ushimalensis* (Yok.), *E. naktongensis* Tateiwa, *Ptilophyllum pecten* (Phillip), *Dictyozamites falcatus* (Morris), *Otozamites klipsteini* (Dunker), *Nilssonia orientalis* Heer, *N. schauburgensis* (Dunker), *Podozamites lanceolatus* (L. et H.), *P. reini* Geyler, *Ginkgoites sibirica* (Heer), *Czekanowskia murrayana* (L. et H.) and *Pinus* sp.

The above flora named the Naktong flora by Yabe[1] shows close affinity to the Tetori flora in Japan and the Nikanian flora in the beds near Vladivostok, both of which are regarded as of the Malm age.

UPPER KEISHO FORMATION or UPPER DAIDO FORMATION

This Formation is distributed mainly in South Korea, i. e. N. and S. Keisho-Do, N. and S. Zenra-Do and N. Chusei-Do. It also occupies a wide area on the lower courses of the Daido-ko and the Sainei-ko. As mentioned above, the Formation lies with parallel unconformity or apparent conformity upon the Lower Keisho Formation, where it is in contact with the latter, that is, in N. and S. Keisho-Do. In the other regions, it rests upon the other older rocks in unconformity of dip, always with a basal conglomerate bed. In N. and S. Keisho-Do, it is covered by the Fukkokuji Formation, the basal agglomerate and tuff of the latter resting on its denudated surface, but not with unconformity of dip. The Formation is characterized by its reddish shale, indurated flinty shale and repeated flows of porphyrite and its agglomerate.

Organic remains are rare in the Formation, only the following few having been found :—

1) *Brachyphyllum* cf. *spinosum* Seward, 2) *Frenelopsis* sp., 3) *Elatides* cf. *curvifolia* (Dunker), 4) *Otozamites* sp., 5) *Pinus* sp., 6) *Zamites* sp.,

1) Yabe, H. (1905) Journ. Coll. Sci. Imp. Univ. Tokyo, Vol. XXIII, Art. 8.

7) *Cunninghamites* sp., 8) *Platanus* sp., 9) *Ptilophyllum* sp., 10) *Equisetites* sp., 11) *Viburnum* cf. *montanum* Knowlton, 12) *Populophyllum* sp., 13) *Ficus* (?) sp., 14) *Nelumbo* sp., 15) *Tapeiridium* (?) *undulatum* (Hall) and 16) *Zamiophyllum buchianum* Ett.

1) & 2), in the lower-course district of the Sainei-ko, Kokai-Do, Eido district, N. Chusei-Do and the Chinan district, N. Zenra-Do ;

3) & 4), in the lower-course district of the Sainei-ko ;

5)–15), in the Chinan district ;

16) in the Wajun district, S. Zenra-Do.

Though few in number, these plants seem to indicate the Cretaceous age of the Formation.

FUKKOKUJI FORMATION

This Formation consists mostly of flows of quartz-porphyry and felsophyre with intrusive granite and masanite. Agglomerate and tuff in small proportions are associated as its basal bed, covering the denudated surface of the underlying Upper Keisho Formation. The Formation is well exposed in N. and S. Keisho-Do, especially in the vicinity of the famous temple of Fukkokuji[1] in N. Keisho-Do, where it is covered by the older Tertiary in unconformity of dip. The granite and its marginal facies, masanite,[2] are intrusive through the flows of quartz-porphyry and felsophyre. The Formation seems to be comparable with the widely exposed quartz-porphyry under the Red Formation in south-eastern China.

CAINOZOIC

The Cainozoic is of limited extent compared with any other group, and is found along sea coast and rivers, forming low hilly lands.

TERTIARY

Most of the Tertiary areas are scattered along the eastern coast of the peninsula, in which the meridional watershed runs near to the coast, while on the other side only two small areas of the Tertiary are found near the mouth of the Seisen-ko and on the east bank of the Sainei-ko. The Tertiary is built up of terrigenous or coastal deposits accompanying flows and dykes of volcanic rocks. It is divided by unconformity of dip and its palaeontological character into Palaeogene and Neogene.

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1) 佛國寺

2) Kotô, B. (1909) Journ. Coll. Sci. Imp. Univ. Tokyo. Vol. XXVI, Art. 2, pp. 190–192.

PALAEOGENE

The areas investigated in some detail are those of Choki[1] coal field in N. Keisho-Do and the Kisshu-Meisen[2] coal field in N. Kankyo-Do. In the former, the Tertiary rocks are grouped under the Choki Series and are divided by an unconformity of dip into the Lower and the Upper Choki Series, these two representing the Palaeogene and Neogene respectively. The Lower Choki Series is in the following sequence in descending order :

Senpoku[3] conglomerate (the base of the Upper Choki Series)	
Unconformity of dip	
(2) Bonkokuri[4] group	Tuff, conglomerate and flows of andesite ; thickness of the sedimentaries 1,000 m.; plant remains.
Unconformity of dip	
(1) Choki group	Conglomerate, shale, sandstone, tuff, coal and flows of andesite and trachyte ; thickness of the sedimentaries 1,470 m.; plant remains.
Unconformity of dip	
Fukkokuji Formation	

In the Kisshu-Meisen coal-field, the Tertiary is in the following sequence in descending order :—

Shichihosan[5] group (Neogene ?)	
Unconformity of dip	
Kisshu-Meisen Series	
(4) Upper Sandstone and Conglomerate	With shale and coal ; thickness 1,000 m.; animal remains.
Conformity	
(3) Shale	Thickness 200–300 m.; plant and animal remains.
Conformity	
(2) Lower Sandstone and Conglomerate	With basaltic conglomerate and tuff, shale and coal ; thickness 800–1,200 m.; animal remains.
Unconformity by denudation	
(1) Ryudo Series	Sandstone, shale, coal and alkali-basalt flows ; thickness of the sedimentaries 80 m.; plant remains.

1) 長鬐　2) 吉州明川　3) 川北　4) 凡谷里　5) 七寶山

Unconformity by denudation

Granite.

The fossils from the Lower Choki, the Kisshu-Meisen and the Ryudo Series are as follows :—

Animal remains from the Choki group (by I. Tateiwa);

Natica sp., *Cerithium* sp., *Dosinia* sp., *Arca* sp., *Pectunculus* sp., *Ostrea* sp. and *Solen* sp.

Animal remains from the Kisshu-Meisen Series (by J. Makiyama, Kyoto Imp. Univ.);

(Lower Sandstone and Conglomerate)

Potamides (*Cerithidea*) *kanpokuensis* nov. sp., *Battilaria tateiwai* nov. sp., *B. yamanarii* nov. sp., *Polinices* (*Euspira*) *meisensis* nov. sp., *Acila submirabilis* nov. sp., *Arca* (*Anadara*) *daitokudoensis* nov. sp., *A. abdita* nov. sp., *Phacoides* cf. *saxorum* Lamark and *Cyclina* (*Cyclinorbis*) *lunulata* nov. subgen. et nov. sp.

(Shale)

Leda sp., *Yoldia laudabilis* Yokoyama, *Thyasira* aff. *bisecta* Conrad, *Pitaria itoi* (?) nov. sp., *Chione tateiwai* nov. sp., *Cardium* sp., *Macoma* sp. and *Mya crassa* Grew.

(Upper Sandstone and Conglomerate)

Genota cryptoconoides nov. sp., *Polynices* (*Neverita*) *coticazae* nov. sp., *Pectunculus cissensis* nov. sp., *Arca* (*Anadara*) *ogawai* nov sp., *Pecten* (*Chalamys*) *meisensis* nov. sp., *Diplodonta ferruginata* nov. sp., *Chione tateiwai* nov. sp., *Phacoides* cf. *acutilineatus* Conrad, *Pitaria itoi* nov. sp., *Macoma inquinata* Desh. and *Panope* sp.

Makiyama regards the fauna of the Lower Sandstone and Conglomerate as probably Upper Eocene, and those of the Shale and the Upper Sandstone and Conglomerate as Oligocene or Lowermost Miocene.

Plant remains from the Choki group of the Lower Choki Series, from the Ryudo Series and from the Shale bed of the Kisshu-Meisen Series (by I. Tateiwa);

	Choki	Ryudo	K.-M.
Aspidium meyeri Hr.	,,		
Sequoia langsdorfii (Brongn.)	,,	,,	,,
S. disticha Hr.	,,		
Pinus cf. *larico thomasiana* (Goep.)		,,	
P. hepios (Ung.)		,,	
P. palaeostrobus (Ett.)		,,	
Alnus serrulata Willd.	,,		
A. kefersteinii Goep.		,,	
Betula brongniarti Ett.	,,	,,	

	Choki	Ryudo	K.–M.
Betula. cf. *ermannii* Cham.			,,
Fagus antipofii Hr.	,,	,,	
F. macrophylla Hr.	,,		
F. ferruginea Ait.			,,
Fagophyllum gotschei Nath.	,,		
Castanea kubinyi (Kovats)	,,	,,	
Carpinus grandis Ung.	,,	,,	,,
Corylus macquarrii Hr.	,,		
Quercus furcinervis Ung.		,,	
Q. cf. *pseudocastanea* Goep.			,,
Juglans acuminata A. Br.	,,		
J. bilinica Ung.	,,		
J. nigella Hr.	,,	,,	,,
Carya serraefolia (Goep.)			,,
Pterocarya cf. *denticulata* (Web.)			,,
Salix lavateri Hr.	,,		
S. varians Goep.	,,		
Populus gaudini Fisher-Ooster			,,
P. cf. *zaddachi* Hr.			,,
Ficus tiliaefolia A. Br.	,,		
Ulnus braunii Hr.	,,	,,	
U. cf. *elegantior* Nath.		,,	
U. cf. *longifolia* Ung.		,,	
Planera ungeri Ett.	,,	,,	,,
Acer cf. *hilgendorfi* Nath.	,,		
A. palmatum Thunbg.			,,
A. trilobatum Stb.	,,		
A. cf. *pictum* Thunbg.	,,		,,
Rhamnus gaudini Hr.	,,		
Tripetaleja cf. *almovisti* Nath.			,,
Hamamelis cf. *japonica* Sieb. et Zucc.			,,
Cornus cf. *submacrophylla* Nath.	,,		
Tilia cf. *cordata* Mill.			,,
Zanthoxylon serratum Hr.	,,		
Z. cf. *ailanthoides* Sieb. et Zucc.	,,		
Glyptostrobus europaeus (Brongn.)		,,	,,
Prunus cf. *serrulata* Hr.		,,	
Amygdalus (?) *persicifolia* Web.		,,	
Dryostrobus (?) *sternbergii* (Goep.)			,,

Tateiwa regards the three floras as Oligocene-Eocene, and considers the Choki flora to be Oligocene rather than Eocene, the Ryudo flora not younger, and the Kisshu-Meisen flora not older, than the Choki flora.

NEOGENE

The younger Tertiary, considered palaeontologically Pliocene or later Miocene, are the Upper Choki Series covering the Lower Choki Series with unconformity of dip, and the sandstone bed covered by trachytic lava on the southern coast of the island of Saishu[1] (Quelpart).

The sequence of rocks in the Upper Choki Series in descending order is as follows :—

Basalt flow (probably Quaternary), horizontal

Unconformity by denudation

(2) Ennichi[2] Shale	Shale and sandstone, the former prevalent; thickness 400 m.; animal and plant remains.
Conformity	
(1) Senpoku Conglomerate	Conglomerate and sandstone; the former prevalent; rarely thin coal; thickness 200 m.; animal remains.

Unconformity of dip

Bonkokuri group (Lower Choki Series).

The fossils from the Upper Choki Series are as follows :—

Animal remains from the Senpoku Conglomerate ;

Cardium, *Mactra*, *Solen*, *Potamides* and *Ostrea*.

Animal remains from the lower part of the Ennichi Shale ;

Pecten, *Leda*, *Cardium*, *Mactra*, *Ostrea* and fish bones.

Plants from the upper part of the Ennichi Shale ;

Quercus cf. *lonchites* Ung., *Q.* cf. *stuxbergi* Nath., *Q.* cf. *neriifolia* A. Br., *Cinnamomum* cf. *Scheuchzeri* Hr. and *Sapindus* cf. *falcifolius* A. Br.

From these plants and the stratigraphical relation, Tateiwa considers the Series to be the Lower Pliocene or Upper Miocene.

The fauna from the sandstone bed on the southern coast of the island of Saishu, according to Yokoyama,[3] comprises the following :—

Turritella saishuensis nov. sp., *Natica* sp., *Dentalium weinkauffi* Dkr., *Pholas fragilis* Sow., *Dosinia* sp., *Meretrix* (*Callista*) *chinensis* Chem.,

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1) 濟州島 2) 延日

3) Yokoyama, M. (1923) Journ. Coll. Sci. Imp. Univ. Tokyo, Vol. XLV, Art. 7.

Saxidomus purpuratus Sow., *Cardium* sp., *Diplodonta semiaspera* Phil., *Lucina lorealis* L., *Venericardia cipangoana* Yok., *V. ferruginea* Ad., *V. nakamurai* nov. sp. *Myodola fluctuosa* Gld., *Thracia pubescens* Pult., *Mytilus* sp., *Anomia lunula* Yok., *Pecten laqueatus* Sow., *P. laetus* Gld., *P. tokyoensis* Tok., *P. cosibensis* Yok., *Pectunculus vestitus* Dkr., *Nucula insignis* Gld., *Terebratella coreanica* Ad., *T.* (?) *excelsa* nov. sp., *T.* (?) sp. and *Endesia* (?) sp.

From these mollusca and brachiopoda, Yokoyama deems the shell-layers to be of the Musashino Age in the Japanese Islands, that is to say, of the Upper Pliocene.

In the Kisshu and Meisen districts, there are two volcanic groups lying horizontally upon the eroded surface of the gently dipping Kisshu-Meisen Series. They are the Shichihosan group and the Kenzan[1] group, and though their direct contact is unknown because of their separated areas, they seem to be of the same age, judging from their stratigraphical and petrological characters. They consist of repeated lava flows intercalating breccia, tuff, conglomerate, sandstone, shale and, in some places, peat. The volcanics are mostly alkalic, such as comendite, hakutoite, alkalic moonstone-rhyolite, alkalic granite-porphyry, olivine basalt and oölitic pitchstone. There are some two planes of unconformity of denudation among them. The groups are considered provisionally to be of the younger Tertiary. The sequence of the Shichihosan group is as follows :

Meisen district	Kisshu district
Conglomerate (probably Pleistocene)	Basalt flow (probably Pleistocene)
Unconformity by denudation	*Unconformity of denudation*
(7) Alkalic moonstone-rhyolite	(7) Alkalic moonstone-rhyolite; thickness 0–100 m.
Conformity	
(6) Volcanic breccia with thin sheets of alkalic moonstone-rhyolite ; thickness 180 m.	(6) Comendite ; thickness 0–300 m.
Unconformity by denudation	*Unconformity by denudation*
(5) Alkalic granite-porphyry	(5) Glassy alkalic rhyolite ; thickness 0–200 m.
	Unconformity by denudation
(4) Alkalic rhyolite	(4) Hakutoite ; thickness 400 m.
Unconformity by denudation	*Unconformity by denudation*
(3) Alkalic rhyolite with glassy phases	(3) Alkalic trachyte ; thickness 0–250 m.

1) 劍山

(2) Pumiceous tuff with conglomerate; thickness 20 m.

Apparent conformity

(1) Alkalic basalt

Unconformity of dip

Upper sandstone and conglomerate of the Kisshu-Meisen Series.

(2) Oolitic pitchstone; thickness 20 m.

(1) Tuff; thickness 30 m.

Unconformity by denudation

Granite of unknown age.

The sequence of the Kenzan group is as follows:

Basalt and its clastics (probably Pleistocene)

Unconformity by denudation

(2) Hakutoite and its clastics; thickness of the latter 0–160 m.

Unconformity by denudation

(1) Hakutoite and its clastics, shale and sandstone; *Ostrea* bed in the lower part; thickness of the sedimentaries 0–400 m.

Unconformity of dip

Shale of the Kisshu-Meisen Series.

TERTIARY OF UNKNOWN AGE

The other Tertiary areas have not yet been well studied nor it is able to consult about their geological informations. Some of these Tertiary formations have afforded abundant plant and animal remains, and also intercalate promising coal seams. Most of them are tentatively referred to the older Tertiary. In the Hozan[1] coal-field, the teeth and bones of a mammal were found in a coal seam.

QUATERNARY

This System is divided by its present altitude into the older and the younger Quaternary, the former generally forming plateaus or remaining as the flat tops of mountains or hills; while the other always occupies low lands along rivers or seacoasts. The older Quaternary consists of horizontal beds of conglomerate, sand, clay and basalt-flows, in some cases intercalating peat or diatom beds, and covers older rocks unconformably. It may be referred to the Pleistocene. The younger or Recent has no volcanic flows nor their detritus, except on the island of Saishu in Tsushima Strait, where we have the record of a volcanic eruption in the tenth century.

1) 鳳 山

CHAPTER II

MINERAL RESOURCES

The useful minerals in the peninsula are gold, silver, copper, zinc, lead, iron, molybdenum and tungsten in metals, and brown coal, anthracite, graphite, alunite, kaolin, mica, barite and quartz sand in nonmetals.

Among these, the gold, iron, graphite, anthracite and brown coal are of the most importance. The value of the annual mineral production of Korea for the fourteen years, 1909–1922, was reported by the government to have varied from 6,067,000 to 30,838,000 Yen. In 1922, the production was 17,326,000 Yen, of which 38% was of gold, 33% of pig iron, and the remaining 29% of coal, iron ore, graphite, arsenic oxide, quartz sand, silver, kaolin, mica and copper. Most of the gold comes from N. Heian-Do, the iron from Kokai-Do and S. Heian-Do, the anthracite from S. Heian-Do, the graphite from S. Kankyo-Do, N. Keisho-Do and N. Chuesi-Do and the brown coal from N. Kankyo-Do, Kokai-Do and S. Heian-Do.

An examination of the occurrence of minerals in Korea shows generally that gold is restricted to the area of the Gray Gneisses, iron to the Great Limestone, graphite to the Pre-Cambrian or the Heian System in contact with granite, anthracite to the Heian System, and brown coal to the Older Tertiary.

Gold occurs in quartz veins, contact deposits and placers, of which the first is the most important. Auriferous quartz-veins are mostly rich in sulphide minerals—pyrite, pyrrhotite, galena, zincblende and arsenophyrite being common—the pyrite and arsenopyrite being the important gold-bearers. In contrast to the case in the Japanese Islands, it is noteworthy that there are no auriferous deposits in the Tertiary of Korea.

Iren ore is magnetite, titaniferous in certain cases, haematite or limonite. Titaniferous magnetite occurs always in, or at the margin of, a basic plutonic rock, while non-titaniferous magnetite is found in the Pre-Cambrian sedimentaries in bedded form, and haematite and limonite mostly in the Great Limestone Series also in bedded or lenticular form, in some cases showing that it is an alteration product of siderite or pyrite.

There are two kinds of graphite viz., crystalline or scaly, and non-crystalline or earthy. The former occurs in veins, in beds, or in dissemination in the Pre-Cambrian rocks, and the latter in the metamorphosed sedimentaries of the Pre-Cambrian, or those of the Heian System.

Anthracite is found in the Jido Series of the Heian System and in the Lower Daido Formatien of the Daido System, that in the former being by far the more important. The anthracite is mostly of the dusty kind and is used for briquet coal; but in certain localities hard lump coal is also found. The brown coal has much moisture and on long exposure crumbles into pieces and fine dust; but that in contact with intrusive basalt is of finer quality and does not so easily crumble. The coal near Kisshu, N. Kankyo-Do, in the Lower Sandstone and Conglomerate, is characteristic and yields the most tar, about 20%, in low-temperature distillation.

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ERRATA

Page	Line	Read	For	Page	Line	Read	For
1	8 (from below)	where	and where	65	12	OR	OF
5	17	System	Series	65	8 (from below)	Teshio	Teshiro
6	12 (from below)	Carboniferous	Palaeozoic	66	10 („)	andesitic	andestic
14	1	quartzite	quarzits	69	3 („)	Tellina	Telina
15	8	also	alse	70	2 („)	platform of	platformof
15	16	Spirifer	Spiri er	76	18	Oshima	Ōshima
20	11	Carboniferous	Palaeozoic	81	8	Kyūshū	Ryūkyū
26	Table V.	Pectunculus	Pectuncias	84	19	of	ef
27	7 (from below)	Sanchū	Sanshū	85	4 (from below)	Outer and Inner	Outer
28	4 („)	Ebisugahana	Eisugahama	87	9	Yoshioka	Mochikura
29	2	Ebisugahana	Ebisugahama	89	15	metamorphic	metasomatic
30	8	Plesiosaurus	Plesisaurus	89	17	METAMORPHIC	METASOMATIC
32	13 (from below)	dicksonianum	dicksoniamum	91	12	epidote	epidite
36	19	representative	representive	94	11 (from below)	Susaki	Suwa
37	9	fusca	usca	94	4 („)	mines	mine
43	18 (from below)	basin	besin	96	18	is	are
50	8 („)	Liquidambar	Liquidamber	105	3 (from below)	Matsushiro	Matsushiro in Ōmi
53	18	the Older	theOlder	113	18	Walcott	Walcot
53	3 (from below)	Taxus	Tauxus	117	15	2,800	28,000
53	2 („)	Thuja	Thuya	119	17	schaumburgensis	schauburgensis
58	14 („)	Liquidambar	Liquidamber	122	6 (from below)	laricio	larico
59	5	L.	Y.	123	10 („)	almqvista	almovisti
59	8	hypohippoides	hyphipopoides	125	14 („)	by	of
59	2 (from below)	E. et H.	Et. H.	127	13 („)	Iron	Iren
61	8 („)	littoral	litteral	127	2 („)	Formation	Formatien

Table VI.

Plant-fossils of the Ryōseki-Series.

	Kō-zuke.	Kii.	Awa.				Tosa (Ryōseki District).								Tosa.				Formations in which species of the Ryōseki Series are found.
	Kagahara.	Yuasa.	Sakamoto.	Fujikawa.	Tanno.	Mitani.	Kataji.	Ishiseki.	Tōgodani.	Yakyō.	Ueno.	Torikubi.	Otani.	Hagino-tani.	Kaiseki-yama.	Yoshida-yashiki.	Monobe-gawa.	Shiraishi-gawa.	
FILICES.																			
Thyrsopteris sp.	−	−	−	+															
Dicksonia tosana	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	
Dicksoniopteris naumanni	−	−	−	−	−	−	+	+	−	−	−	−	−	−	−	−	−	−	
Onychiopsis elongata	+	+	−	+	−	+	+	+	+	+	+	−	+	+	+	−	+	−	Middle Jurassic of Kaga, Hida, etc.
„ *elegans*	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	
Adiantites yuasensis	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	
Pteris (?) sp.	+	?	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	
Sphenopteris tenuicula	+	+	−	−	−	−	−	−	−	+	−	−	−	−	+	−	+	−	
Pecopteris browniana	−	−	−	+	−	−	+	−	+	−	−	−	−	?	+	+	?	+	Wealden of Europe, Potomac of America.
„ *geyleriana*	−	+	−	+	−	−	+	−	−	−	−	+	−	−	+	−	+	−	
„ cf. *virginiensis*	−	−	−	+	?	−	−	−	−	−	−	−	−	−	−	−	−	−	Potomac of America.
Chladophlebis nathorsti	−	+	−	−	−	?	+	+	+	−	+	−	−	−	+	−	+	−	
LYCOPODIACAE.																			
Licopodites sp.	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	
CYCADEACAE.																			
Podozamites sp.	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	
„ *lanceolatus* var. *minor*	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	Rhaetic, Jurassic and Cretaceous of Europe.
„ „ „ *latifolia*	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	Middle Jurassic of Kaga etc.
„ *pusillus*.	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	Cenomanian of Bohemia.
Zamiophyllum buchianum	+	+	+	−	+	−	+	+	+	−	+	+	+	−	+	−	+	−	Urgonia of Europe, Potomac of America.
„ „ var. *angustifolia*	−	+	−	−	−	−	+	−	−	−	−	−	−	−	+	−	−	−	Potomac of America.
„ *naumanni*	−	+	−	−	−	−	+	+	+	−	−	−	−	−	+	−	+	−	
Glossozamites parvifolius	−	+					−	−	−	−	−	−	−	−	−	−	−	−	
Nilssonia johnstrupi	−	−	−	−	−	−	+	−	+	−	−	−	−	−	−	−	−	−	Kome beds of Greenland.
„ *schaumburgensis*.	+	+	−	−	−	+	+	+	+	−	−	−	−	−	−	−	+	−	Wealden of Europe.
„ *pterophylloides*.	−	+	−	−	−	−	+	−	−	−	−	−	−	−	−	−	?	−	
Ptilophyllum cf. *cutchense*.	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	Kajmahal of India.
CONIFERAE.																			
Cyparissidium (?) *japonicum*	+	−	−	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	
Torreya venusta	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	