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Introduction to the Paleontology of the Tertiary Marine Mollusca from the Joban Coal-field, Japan

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INTRODUCTION

Although there have been published numerous works concerning the geology and paleontology of the Cenozoic deposits in the Joban coal-field distributed in northeast Ibaraki and southeast Fukushima Prefectures since the later part of the nineteenth Century, very little has been published with regard to the systematic classification of the rich molluscan fauna occurring from the different lithological units hitherto recognized in the said coal-field. The first purpose of the present work is to make a systematic classification and monographic study of the large marine molluscan fauna occurring from the respective stratigraphical units in the coal-field.

The previous works on the geology of the mentioned coal-field had been primarily undertaken from the reasons of economical value of the coal deposits developed in the lower horizons, and very little has been accomplished concerning the detail stratigraphy of the respective rock units so far as variations in lithofacies, laterally as well as vertically, structurally as well as paleontologically. This is the second purpose of the present work and it is felt that the relationship between the lithofacies and molluscan fauna, laterally as well as vertically, should be undertaken to clarify the stratigraphic value of those fossils.

Aside from the paleontological studies published on the plant leaves, pollen, mammals, shark's teeth, echinoids, fish remains and foraminifers, the papers concerning the molluscan fossils seem to have been restricted either to certain groups, local areas, limited stratigraphical units, on small collections, to the descriptions on only the new species, discussions on particular elements with those from the present area merely employed as supplementary, and to their modes of occurrence. Thus, the third purpose of the present work is to make a biostratigrahic study of the molluscan fauna distributed chiefly in the central more important and classical area of the Joban coal-field. This purpose is particularly necessary because it includes the problems

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related with paleoecological characters of the molluscan fauna, from which the nature of the sedimentary basin and the relation between the molluscan fauna and lithology may be known.

Since various views have hitherto been expressed concerning the geological ages of the respective Cenozoic stratigraphical units developed in the coal-field and attempts for a correlation of them with other areas in Japan undertaken with different results, it is thought that the time for a reconsideration of the two problems is appropriate. This is the fourth subject of the present article.

The present work which incorporates the problems outlined as mentioned in the above paragraphs is concentrated to the molluscan paleontology, and for this reason, remarks on the stratigraphy and geological structures of the Joban coal-field will only be briefly stated. For the reason that indetermined species should not be considered important when a large number of species have been identified, they are omitted from the present work, but it should be added that they will be given attention at another oppotunity.

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HISTORICAL REVIEW OF THE WORKS CONCERNING THE MOLLUSCAN FAUNA OF THE JOBAN COAL-FIELD

As already stated in the Introduction, there have been published papers on the mammals (H. Yabe, S. Tokunaga, F. Takai, T. Shikama), shark's teeth (S. Tokunaga, I. Ishiwada, H. Yabe), echinoids (S. Tokunaga, S. Nisiyama), plant leaves (G. Nathorst, S. Endo, S. Endo and H. Morita), pollen (Sh. Tokunaga), foraminifers (K. Asano, T. Inomata and Y. Higuchi), fish remains (S. Tokunaga, F. Takai), brachiopods (I. Hayasaka, K. Hatai), and decapod crustaceans (R. Imaizumi), they will not be reviewed in this work. In the following lines will be given a review of the works concerning the molluscan fauna, because this group forms the scope of the present project.

The first work on the molluscan fauna of the Tertiary rocks of the Joban coal-field was by C. Kochibe (1883), who listed the fossil molluscs which he collected from the rocks building the upper part of the Tertiary deposits. He also gave lists of the Recent shells which he collected from the sea-shore of northern Ibaraki Pre-

fecture. He also listed the brachiopods from the upper Tertiary rocks. Besides the lists he also gave drawn illustrations of the more outstanding forms. Although the work, so far as identification is concerned, should be fully revised, but from another view, this is important in being the first publication on the molluscan fauna of the Joban coal-field. It is from this work that subsequent geologists visited the fossil localities to collect specimens which were later studied by several authors.

Three years later, M. Yokoyama (1836) revised some of the species previously identified by Kochibe. This work is not systematic, but it progressed the studies of Kochibe.

Many years later, J. Makiyama (1921) based on the fossils colleted chiefly from the sea-cliff at Yotsukura-machi in the northeastern part of the coal-field, discussed on *Mya crassa* Grewingk. He gave emphasis as to the variation and pointed out that the name was preoccupied and renamed it as *Mya grewingki* Makiyama.

In 1923, M. Yokoyama as a preliminary report, reported on the molluscan fossils occurring from the lower part of the Tertiary sequence of the Joban coal-field. This work is not sytstematic, but merely listed some of the fossils and stated that the geological age may be Pliocene.

In 1924, M. Yokoyama published the first systematic work on the molluscan fauna of the Joban coal-field, giving particular attention to those occurring from the lowest part of the Tertiary sequence, namely, the Iwaki and Asagai formations. He reported nine species from the Iwaki and 26 from the Asagai, among which two of both formations were considered to be doubtful. According to his analyses of the fauna, among the 42 fossil forms, six have not been exactly determined, 36 were specifically identified, ten species were considered to extend their range to the present, and as great as 70 per cent of the species are now extinct in the seas of the world. From such analyses he arrived to the conclusion that the geological age of both formations is Miocene. The work contains the descriptions of the new species and their illustrations. Although many of his species have been revised by subsequent workers as to generic names and specific positions, the work is important and the first of importance concerning the Tertiary rocks of the Joban coal-field.

In the following year, M. Yokoyama (1925) described and illustrated the molluscan fossils occurring from the uppermost part of the Tertiary rocks in the Joban coal-field. From the four localities he treated, he distinguished a total of 96 species, among which 12 are not specifically determined and of the remaining 84,17 are con-

sidered to be extinct. Thus about 20 per cent of the whole fauna are extinct, and of those species, 13 are known to him to occur in other parts of Japan, namely, five in the Musashino formation in the vicinity of Tokyo, seven in the Pliocene of Totomi (Shizuoka Prefecture), Kii (Wakayama Prefecture) and Izumo (Shimane Prefecture), and one in the lowest part of the Joban coal-field, while four are said to be entirely new forms. Also he stated that among the stated 17 species, four species are unknown from the seas surrounding Japan. As the result of his comparisons with other regions in Japan and from the percentage of the extinct species, he concluded that "it they are Tertiary at all, must be looked upon as Upper Pliocene, and not older".

His Pliocene of Kii is now middle Miocene, and his Pliocene of Izumo is generally accepted at present day also as middle Miocene, and his lowest part of the Joban coal-field is Oligocene, while the rocks mentioned by him for Totomi is Pliocene.

M. Yokoyama's next work (1925) was based on the fossils derived from the middle part of the Tertiary sequence of the Joban coal-field. In this paper he described and figured some new species, listed the entire fauna and stated that the age is Miocene.

In the same year (1925), M. Yokoyama published three short notes on the molluscan fauna of the lowermost and lower parts of the same coal-field. These three papers contain no systematic descriptions, but remarks as to the occurrences of the fossil molluscs and the geological ages they represent.

S. Tokunaga (1927) in his work on the stratigraphy of the Joban coal-field, classified the Tertiary rocks into three series of older, middle and younger, and three groups of lower, middle and upper in the younger series, and into these he incoporated his newly proposed lithological units. (see Table 1) The molluscan species mentioned by Tokunaga are based upon the identification of M. Yokoyama and formed the foundation of his discussions. He mentioned the characteristic species of each unit and gave their upper and lower limits, determined the faunal breaks, gave remarks on the important species distributed in the Japanese Tertiary deposits, noted the relation between fauna and lithofacies, and concluded that there are four horizons of the *Thyasira-Lucina* fauna in the Tertiary rocks of the Joban coal-field.

Besides the molluscan fossil he also discussed and illustrated those of shark's teeth, echinoids, cephalopods and others found by him during his geological studies in the area.

The greatest advance in the molluscan paleontology of the Joban coal-field commenced with the publication of J. Makiyama's (1934) work on the Asagaian molluscs

of Yotsukura and Matchgar. In this work Makiyama gave detail descriptions of 24 species distributed among 14 genera, among which 15 species comprise the pelecypods and the remaining the gastropods. From detail discussions on the affinity of the Asagai formation fauna with other areas along the northern Pacific borderland, Makiyama concluded that the geological age is Upper Oligocene or Aquitanian. He also pointed out that the stratigraphical position of the Asagai should not be confused with the typical Miocene.

In 1935, J. Makiyama gave an account of his previous work on the Asagai fauna in Japanese, but the work is not a systematic account of the molluscan fauna and seems to contain no data additional to his previous article.

In his work on the Miocene shells from the Joban coal-field, K. Kanehara (1937) described the molluscan fossils from the Kamenoo-, Mizunoya- and Asagai formations, all of which were obtained during the process of digging two shafts for the purpose of coal-mining in the said coal-field. He listed the occurrences of 29 species of molluscs according to their respective horizons measured from the mouth of the shafts above mentioned. As the entire fauna known from the Iwaki formation up to the Honya, he listed a total of 46 species, giving their respecitve distributions in the coal-field. He also discussed in detail and concluded that the Asagai is Oligocene in age and the formation superposed on its are of Miocene age.

The results of the just mentioned work was briefly summerized by K. Kanehara (1937) and introduced to the assembly on the occasion of the Annual Meeting of the Geological Society of Japan, held in Tokyo, 1937.

In a short paper concerning *Cardium* (*Cerastoderma*) *shinjiense* Yokoyama, K. Kanehara (1937), recorded the occurrence of that species from the Asagai formation of the Joban coal-field, and also that of *Cardium* (*Cerastoderma*) aff. *ciliatum* Fabricius from the Iwaki formation. In this paper he considers the Asagai formation to be either Upper Oligocene or Lower Miocene, and the Iwaki formation to be also of the same age, contrary to his previous opinion that the Asagai is Aquitanian as once stated by J. Makiyama.

Y. Otuka (1937) in his work on the middle Tertiary molluscs from North Hokkaido and the Joban coal-field, several new species are described and figured from both areas and brief discussions are presented as to their geological ages.

H. Yabe and K. Hatai (1938) in their descriptive work on the Japanese species of *Vicarya*, mentioned on the occurrence of the genus in the Joban coal-field and also

described a new genus which they called *Vicaryella*.

S. Nomura (1940) made a detail study of *Meretrix iizukai* Yokoyama, originally from the Tertiary deposits of the Joban coal-field. Nomura was successful in obtaining a large number of topotype materials, broke many of the specimens to study their dentition and internal features. As the result, Nomura changed the generic name to *Clementia* (*Comsomyax*), and stated that Yokoyama's species is close *Clementia* (*Compsomyax*) *subdisphana* Carpenter from the west coast of America. As associated with the mentioned species, Nomura gave a list of 27 molluscan species, which included such as *Cardium* (*Clinocardium*) *shinjiense* Yokoyama, *Cultellus izumoensis* Yokoyama, *Pecten kimurai* Yokoyana, *Dentalium yokoyamai* Makiyama, *Phalium yabei* Nomura and Hatai and *Surculites yokoyamai* Otuka. From the associated species, Nomura stated that the fauna may be Upper Miocene in age.

K. Hatai and S. Nisiyama (1949) described and figured some new species of molluscs from the Tertiary deposits of the Joban coal-field, ranging from Oligocene to Miocene in age.

T. Kotaka (1951) in his work on the new species of the genus *Turritella* from northern Japan, described *Turritella iwakiensis* Kotaka from the Miocene Nakayama formation. This species is additional to the fauna of the coal-field.

Y. Kamada (1951) in his address on the Asagai formation of the Joban coal-field presented to the Annual Meeting of the Geological Society of Japan, mentioned the important species from the formation, the faunal assemblages recognized, the thickness and lithological details of the formation, and the important geological structures of the field.

K. Ida (1952) in his monographic work on the *Turritella* of Japan, mentioned on the occurrence of six species of the genus from the coal-field. From the Takaku group he described *Turritella numanouchiensis*, from the next older Shirado, *T. iwakiensis*, from the Mizunoya such as *T. kaneharai*, *T. omurai* and *T. s-hataii*, and from the Shiramizu group which is the oldest, he records *T. tokunagai* and *T. importuna*. Thus it may be known that the different formations developed in the coal-field have their own characteristic species. His work is of importance so far as concerns the biostratigraphy of the Joban coal-field, although it is to be added that with the publications of other monographs on the molluscan fauna, probably more details will be brought to light.

Y. Kamada (1952) in his study on the *Cyclina* from Japan, described two new

species, *Cyclina japonica* Kamada from the Kunugidaira formation and *Cyclina asagaiensis* Kamada from the Asagai formation.

In 1953, K. Masuda described a new species of *Patinopecten* from the southern part of the Joban coal-field. The same species has been found to occur also in the northern part of the same coal-field but not in the intermediate area.

The molluscan fauna described by S. Aoki (1954) from his Kabeya formation situated in the middle part of the Joban coal-field, comprised a total of 21 species, which included five new species, five indetermined species and only two which extend their range to the Recent. This formation name is not recognized by the writer in the present work because it is merely a facies of the Honya formation as will be mentioned in another article.

M. Omori (1954) in his paper on *Conchocele compacta* Ishizaki and *C. compacta minor* Omori from the Tertiary deposits of Japan, also mentioned on the occurrence of the subspecies from the Joban coal-field.

Y. Kamada (1954) described a new and interesting species of *Patinopecten* named by him *P. kobiyamai* Kamada from the Miocene of the Joban coal-field. This species is interesting because it shows considerable resemblance with the genus *Vertipecten*.

K. Hirayama (1955) in his work on the geology and molluscan paleontology of the Asagai formation distributed in the northern part of the Joban coal-field, described a total of 55 species from the formation. Among the 55 species, 15 species were specifically indetermined, 13 were described as new to science, 35 are pelecypods, one scaphopod, and 18 gastropods. Of the 55 species, 20 genera are pelecypoda, one genus Scaphopoda and 11 genera gastropods, thus showing that the generic number of pelecypoda exceed that of the gastropoda as is the general case among the molluscan fossils of the Tertiary in Japan. Besides giving detail discussions to certain genera and species, his work is interesting in that he have particular emphasis to the mode of occurrence of the fossils, thereby recognizing several different types to which he gave names. Also the stratigraphic positions of the fossils within the sequence established by him is indicated. As to the geological age, Hirayama is in the opinion that the Asagai fauna is late Oligocene.

In his study of the Tertiary species of *Thracia* from Japan, Y. Kamada (1955) described those occurring from the Joban coal-field. These consist of two species, namely, *Thracia kidoensis* Kamada from the Oligocene Asagai formation and *Thracia hataii* Kamada from the Miocene Nakayama formation.

As the first work on the non-marine shells from the Joban coal-field, Y. Kamada (1955) described two species, namely, *Corbicula tokudai* (Yokoyama) and *Anodonta subjapanensis yokoyamai* (Suzuki). This is the first record of non-marine shells from the coal-field and serve in interpreting the paleoecological conditions at the time the sediments entombing them were deposited.

A large and interesting species of *Japelion, J. yabei* was described as new to science by Y. Kamada (1955) from the Joban coal-field. This specimen is well preserved, supplemented with good illustrations and is additional to the fauna of the coal-field.

Y. Kamada (1955) when dealing with the fauna of the lower Uchigo group of Paleogene age recognized several molluscan assemblages, which he named the *Glycymeris-Pitar* assembalge, *Cyclina-Ostrea* assemblage and *Spisula-Euspira* assemblage. Although the distributions of these assemblages are different, their associations are important in interpretation of the conditions then prevailing.

S. Hayasaka (1956) described the molluscan fauna occurring from the Pliocene sediments developed in the northern part of the Joban coal-field. Although comprising only 23 species among which two were left indetermined, three are described as new to science. The work deals with the geology of the area, paleoecology, correlation and age considerations.

A. Mizuno and S. Fujii (1958) in their paper on the Miocene shells from the so-called Taki formation in the Joban coal-field, described *Cerithidea sugaii* as new to science.

Y. Kamada and S. Hayasaka (1959) in their article on the marine molluscan fauna from Tateishi in the northern part of the Joban coal-field, gave details to each of the distinguished species, remarks on the singnificance of the fossils since there were derived from rocks previously considered to be early Miocene in age, although the distinguished fossils indicate the Pliocene age.

In his biostratigraphical study on the associated occurrence of *Vicarya* and *Vicaryella* in the Japanese Tertiary, Y. Kamada (1960) found two *Vicarya*-bearing beds separated one another by thick marine sediments in the Joban coal-field. He described the occurrence of *Vicarya yokoyamai* Takeyama and *Vicaryella ishiiana* (Yokoyama) from the upper *Vicarya* bed in the Kadono district and also that of *Vicarya yokoyamai* Takeyama and *Vicaryella jobanica* Kamada from the lower *Vicarya* bed in the Kunugidaira formation in the coal-field. In this paper he emphasized that the brackish

water *Vicarya*-bearing beds occupy two distinct horizons in a single sedimentary basin is an outstanding feature of the Japanese Tertiary.

From the brief historical review of the papers treating the molluscan fauna from the different Tertiary formations of the Joban coal-field there are several outstanding features, such as given below. From 1833 through the 1920's, the molluscan fauna of Japan was compared chiefly with the Tertiary fauna of England, a very remote region. However, in 1920-1922 since Yokoyama distinguished in the Kwanto Region, the Upper and Lower Musashino Series, his comparisons were chiefly with the fauna of those two units. From about 1930, all workers on the molluscan fossils except for M. Yokoyama refrained from using the percentage method established by C. Lyell, and their comparisons were made with the fauna of the northwest coast of America instead of with the Tertiary fossils of England. Although systematic molluscan paleontology commenced from the time of M. Yokoyama (1924) so far as con-

Table. 1. Correlation of the Stratigraphic Sequences of the Joban Coal-field, Established by Different Authors.

S. NAKAMURA 1914		J. MAKIYAMA 1920	H. YABE and R. AOKI 1918, 1921, 1924		S. TOKUNAGA 1927			K. WATANABE 1926, 1927, 1929 1932, 1934	
UP. TERTIARY	SHIRADO Tuffite	TAGA SERIES	TOKIWA SERIES		YOUNGER JOBAN SERIES	UP. GR.	TENPISAN	SHIRADO TAGA	USUISO
							TAGA		ONA
							TOYOMA		KAMAMAYE
						MID. GR.	KAMADO		
							KOGACHI		
							TATSUZAWA		NAKAYAMA
							NAKAYAMA		
MID. TERTIARY	MISAWA S.S.	TAIRA SERIES	KAMENOO SERIES	MISAWA		LOW. GR.	YOSHINOYA		MISAWA
							YANOKURA		
							TAIRA		HONYA
	KAMENOO Sh.			KAMENOO	MIDDLE JOBAN	KAMEZAWA		YUNAGAYA	KAMENOO
	MIZUNOYA Sandstone / Shale			MIZUNOYA		MIZUNOYA			MIZUNOYA Sandstone / Shale
	GOYASU S.S.			GOYASU		GOYASU			GOYASU YOTSUNAMI GOYASU Basal cgl.
LOW. TERTIARY	SHIRASAKA Sh.	ASAGAI SERIES	ASAGAI SERIES	SHIRASAKA Shale	OLDER JOBAN	SHIRASAKA		SHIRAMIZU	SHIRASAKA
	ASAGAI S.S.			ASAGAI Sandstone		ASAGAI			ASAGAI
	IWAKI S.S.	IWAKI SERIES	IWAKI SERIES			ISHIKI			IWAKI
	coal bearing beds Basal beds		SHIRAMIZU SERIES						Coal-bearing Basal conglo.&ss.

Boundaries: ——— Conformity; ~~~~~ Unconformity

cerns the molluscan fossils of the Joban coal-field, detail discussions, paleontologically as well as geologically, can said to have begun since the time of J. Makiyama (1934). Subsequent to Makiyama's work considerable emphasis has been given to the relation of the molluscan fossils to the lithological characters of the sediments which yielded the fossil fauna, in other words, paleoecological considerations have increased. Also the mode of occurrence of the fossil fauna has been given attention because it is nesessary to determine whether the fossils are representative of the rocks in which they were found. Thus, it can be seen that from the early days to present the trends in paleontological research are gradually decomming more fine cut.

OUTLINE OF THE GEOLOGY OF THE JOBAN COAL-FIELD

A historical review of the stratigraphy of the Joban coal-field distributed in the northeastern part of Ibaraki Prefecture and the southeastern part of Fukushima

K. HATAI and Y. KAMADA 1950	K. SUGAI and H. MATSUI 1953	S. HANZAWA 1954	K. SUGAI et al. 1957	Y. KAMADA 1960
		IWASAWA	TAGA: TOMIOKA / HIRONO	SENDAI: FUTABA-TOMIOKA
		TENPISAN		TENPISAN
	TAKAKU: SHIMO-TAKAKU (HAMAMACHI / USUISO / KAMIYASAKU)	TAGA: SHIMOTAKAKU	TAKAKU: SHIMOTAKAKU	TAGA: SHIMOTAKAKU (KOKOZURA)
	TAKAKU: NUMANOUCHI	TAGA: NUMANOUCHI	TAKAKU: NUMANOUCHI	TAGA: NUMANOUCHI (KOKOZURA)
	TAKAKU: KAMITAKAKU	TAGA: KAMITAKAKU	TAKAKU: KAMITAKAKU	TAGA: KAMITAKAKU (KOKOZURA)
	SHIRADO: NAKA-YAMA (NAKAYAMA / YOSHINOYA)	NAKAYAMA	SHIRADO: NAKA-YAMA (MINAMI-SHIRADO / YOSHINOYA)	SHIRADO: NAKAYAMA
	YUNAGAYA: TAIRA (MISAWA / HONYA / KAMIYADA)	MISAWA / HONYA	YUNAGAYA: TAIRA (MISAWA / HONYA / KAMIYADA / ISHIMORI)	MISAWA / HONYA / ISHIMORI
YUNAGAYA GROUP	YUNAGAYA: KAMENOO	YUNAGAYA: KAMENOO	YUNAGAYA: KAMENOO	YUNAGAYA: KAMENOO
	YUNAGAYA: MIZUNOYA	YUNAGAYA: MIZUNOYA	YUNAGAYA: MIZUNOYA	YUNAGAYA: MIZUNOYA
	YUNAGAYA: GOYASU	YUNAGAYA: GOYASU	YUNAGAYA: GOYASU	YUNAGAYA: GOYASU
		YUNAGAYA: KUNUGIDAIRA	YUNAGAYA: TAKI Coal-bearing	YUNAGAYA: KUNUGIDAIRA
UCHIGO: SHIRASAKA	SHIRAMIZU: SHIRASAKA	UCHIGO: SHIRASAKA	SHIRAMIZU: SHIRASAKA	UCHIGO: SHIRASAKA
UCHIGO: ASAGAI	SHIRAMIZU: ASAGAI	UCHIGO: ASAGAI	SHIRAMIZU: ASAGAI	UCHIGO: ASAGAI
UCHIGO: IWAKI	SHIRAMIZU: IWAKI	UCHIGO: IWAKI	SHIRAMIZU: IWAKI Coal-bearing	UCHIGO: IWAKI
UCHIGO: SHIRAMIZU		UCHIGO: SHIRAMIZU		UCHIGO: SHIRAMIZU

Prefecture is shown in Table 1. From this table the relationships between the stratigraphical sequence established by the different authors according to both year and area can be readily understood.

It is noticed from the Table that Nakamura (1914) recognized no unconformities within the thick Tertiary deposits developed in the Yumoto area, the central part of the Joban coal-field, but in 1918, R. Aoki noticed two significant ones, one between the Lower Tertiary and another between the Middle and Upper Tertiary deposits of Nakamura's classification. Since then the unconformities have been accepted by all subsequent workers on the geology of the Joban coal-field. However, as may be noticed from the table, the positions of these two unconformities differed according to workers because of misinterpretations of the geology of the local areas in which they undertook stratigraphical researches. For example, the unconformities between the Middle Joban series and the Upper Joban series of S. Tokunaga (1927) does not agree in position with that previously recognized by both R. Aoki (1918) and H. Yabe (1921), this is because the number of stratigraphic units developed in the area studied by Tokunaga differs much from that in the Yumoto area studied by Nakamura, Aoki and Yabe. Also it should be noticed that S. Tokunaga recognized three unconformities in the Upper group of his Younger Joban series, and only the one between Tenpisan formation and Taga formation is accepted by subsequent workers, while the ones between the Taga and Toyoma (=Tozenji) and between the Toyoma and Kamado formations are not accepted or recognized by subsequent workers.

The many works of K. Watanabe (1926, '27 '29, '32, '35) in various parts of the Joban coal-field lead him to the recognition of several important unconformities. One between the Shiramizu and superposed Yunagaya groups, one between the Yunagaya and next younger Shirado groups, and another between the Shirado and youngest Taga groups. These groups were called the Yunagaya series by Watanabe. These three unconformities are accepted by all subsequent workers in the coal-field geology.

Also to be noticed from the Table is the different usage of stratigrahic names particulary between Nakamura (1914), Makiyama (1920) and Tokunaga (1827), and the general uniformity thereafter. The lithological unit names designated by Tokunaga are often not based upon geographical names but their combination and so do not actually prevail, and his names are often more of lithofacies nature than of stratigraphic meaning. The present writer, from his studies in the coal-field has recognized the names given in the right column of the Table.

From the results of the writer's works on the geology of the central to northern parts of the Joban coal-field as included in the present article, the stratigraphic sequence given in Table 2, with thickness in meters of each of the stratigraphic units.

Table 2. Stratigraphic Classification of the Tertiary Deposits of the Joban Coal-field in Fukushima and Ibaraki Prefectures.

Group	Formation	Thickness in meters
Sendai	Futaba-Tomioka	150+
----------Unconformity----------		
Taga	Shimotakaku	150+
(=Kokozura Formation)	Numanouchi	70
	Kamitakaku	100
----------Unconformity----------		
Shirado	Nakayama	130
----------Unconformity----------		
	Misawa	120
	Honya	150
	(Ishimori tuff breccia)	
Yunagaya	Kamenoo	100
	Mizunoya	80
	Goyasu	70
	Kunugidaira	95
----------Unconformity----------		
	Shirasaka	150
	Asagai	60
Uchigo	Iwaki	250
	Shiramizu	80
----------Unconformity----------		
Foundation (Futaba Cretaceous sedimentaries, Paleozoic sedimentaries, and metamorphic and ignerous rocks.)		

AREA STUDIES AND THE FIVE DISTRICTS (Figs. 1,2)

The area from which the molluscan fossils treated with in the present work were collected extends from Tomioka in Futaba-gun, Fukushima Prefecture in the north southwards to Isohara in Kita-Ibaraki City in Ibaraki Prefecture, covering a distance of about 65 kilometers. This broad area from geolgical structure and stratigraphic classification is divided into five provinces, which from the north to south are named as, Futaba district, Ishimori district, Yumoto district, Kadono district and Nakoso district. The Futaba is separated from the Ishimori by the Futatsuya fault of K. Watanabe (1930) and the Yotsukura fault of H. Yabe and R. Aoki (1924), the Ishimori is separated from the Yumoto by the physiographic line extending along the southern foot of Akai-dake Mountain eastwards to along the lower course of the

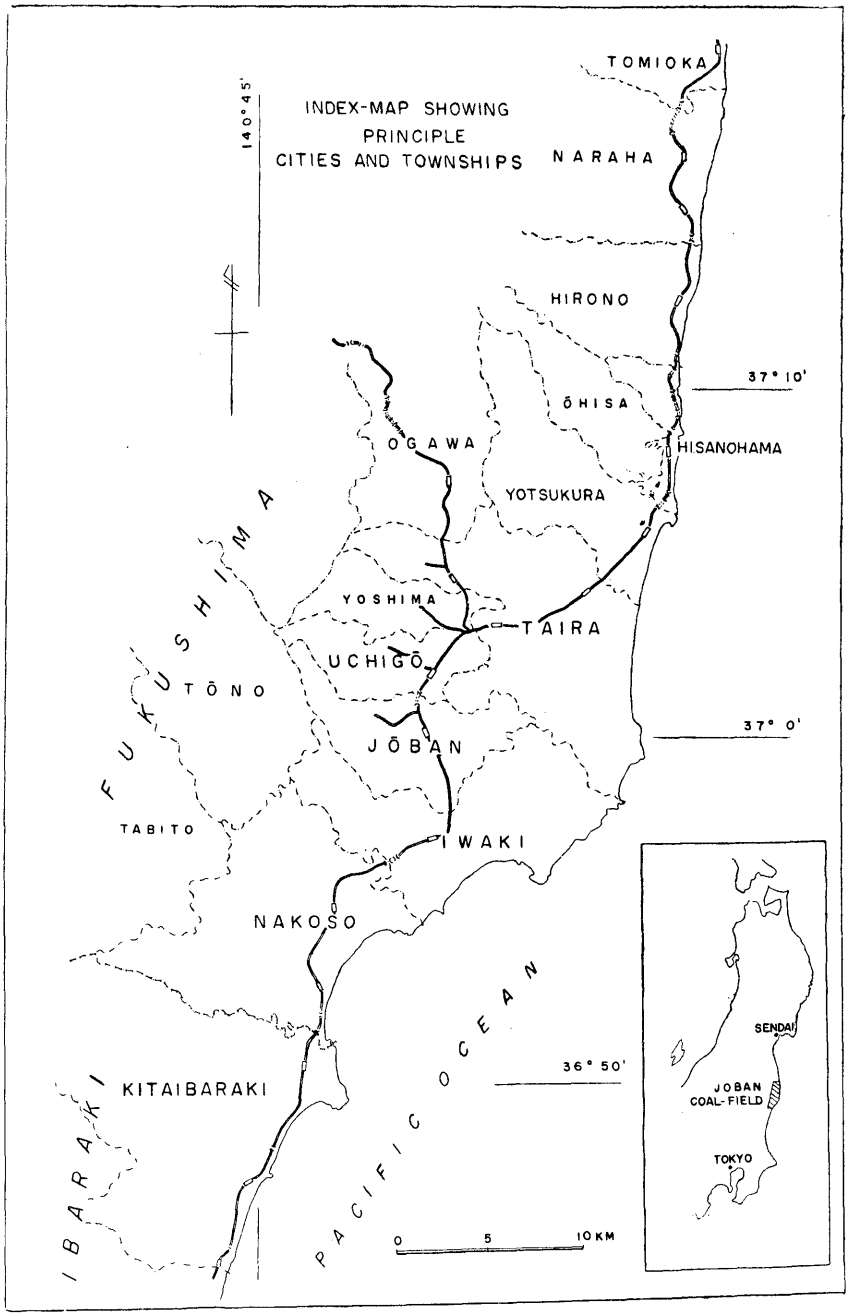
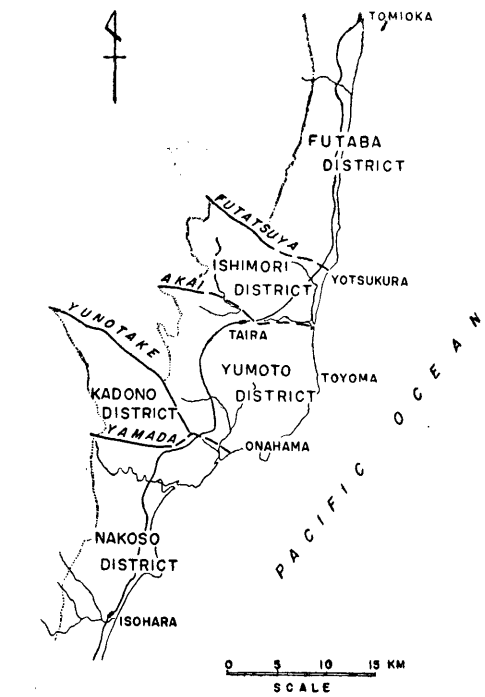


Figure 1. Index Map of the Joban Coal-field.

Natsui River and also by the Akai fault of K. Watanabe (1930) structually. The Yumoto is bounded from the Kadono by the fault scarp of the Yunotake fault (K. Watanabe, 1934) extending from northwest to southeast in distinction from the southern foot of Yunotake Mountain southeastwards throught the south of the Izumi

Station on the Joban line and eastwards into the Pacific Ocean. This fault separates the foundation rocks from the Tertiary sediments and is also extends to the Tabasaka-Ishigamiyama fault of K. Watanabe (1934). The Kadono district is separated from that of the Nakoso by the Yamada fault of K. Watanbe (1934) which extends from east to west in approximate direction and by which the Kadono district is bounded by faults to make a triangular form with the apex directed towards the east.

The five districts being separated by faults of large scale and thereby have different development of the stratigraphic units, a general correlation table showing their interrelationship is given in the Figure 2, which also shows the distribution of the different sedimentary units, the positions of the above mentioned faults and the extensions of the respective districts.



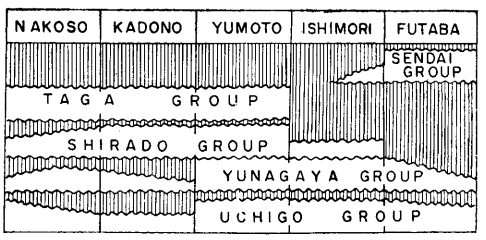


Figure 2. Index Map Showing the Five Districts and Correlation of the Groups

BRIEF NOTE ON THE TERTIARY MARINE MOLLUSCA FROM THE JOBAN COAL-FIELD

The molluscan fossils derived from the respective stratigraphical units developed in the Joban coal-field of Fukushima and Ibaraki Prefectures were studied systematically and analysed as to paleoecology and geological significance. The present work is the first monographic study of the molluscan fossils occurring from the Joban coal-field.

The Joban coal-field was divided into five provinces from geological structure and the molluscan remains from the stratigraphic units developed in each of the different provinces was studied separately because of the differences in lithofacies, degree in development of the respective formations developed and because the area studies is longitudinally exten-

sive. This procedure was done in order that the differences in the faunal assemblages could be studied to clarify the sedimentary conditions under which the different parts of the sedimentary basin was subjected to during the deposition of the different rock units.

The molluscan remains studied systematically resulted in the discrimination of a total of 138 species distributed among 83 genera, of which 86 are pelecypoda, one scaphopoda, and 51 gastropoda. The species found to be undescribed, that is to say, new to as science comprise a total of 21, among which 15 are pelecypods and six gastropoda. Also one new genus and one new subgenus were distinguished among the molluscan fauna. The number of specifically determined mollucs from the Iwaki formation (including the Shiramizu formation) amounted to 19, the Asagai formation totaled 42, and Shirasaka formation yielded two. These formation are referred to the Uchigo group. From the Yunagaya group, seven species were found in the Kunugidaira formation, four from the Goyasu formation, 11 from the Mizunoya formation, eight from the Kamenoo formation, and 35 from the Honya formation. These stratal units including the uppermost unfossiliferous Misawa formation are included into Yunagaya group. The next younger formation, the Nakayama yielded only 23 species. The Taga group, in the central part of the Joban coal-field studied in this article, yielded from the Numanouchi formation a total of 27 species, and only three from the Shimotakaku formation. In the southern part of the coal-field treated in this article, the Kokozura formation yielded a total of 37 species. The youngest stratigraphic unit in the area studies is represented by the Futaba-Tomioka formation and this yielded a total of 20 species, among which only one is found in the Miocene deposits of the Joban coal-field.

A study of the species of molluscs from the Iwaki formation up to and including the Futaba-Tomioka formation resulted in interesting features such as follows, 1) the stratigraphic break separating the Uchigo group from the next younger Yunagaya is considered to be a very important one because the species of molluscs collected from the Uchigo group do not extend up into the Yunagaya, thus proving the existence of a rather long time break, 2) the molluscan species found in the Yanagaya, Shirado, and Taga major stratigraphic units are intimately related with one another regardless of the stratigraphic breaks separating each the mentioned three units, 3) the majority of the important and characteristic extinct species of molluscs not only cross the physical breaks but also show varied chronological ranges from which the

relationship between each of the respective formations incorporated into those major rock units can be proved, 4) from the respective stratigraphical ranges of the molluscan remains, it is inferred that the Yunagaya group, the Nakayama formation, and the Taga groups, although separated with unconformities, their magnitude in time can be almost neglected, and the molluscs in being intimately related with one another form a rather concrete time unit ranging from early to middle Miocene.

Judging from the molluscan fossils, that is to say, their implications as to paleoecology, relationship with the strata in which they occurred, changes in stratigraphic sequence, and geographical distributions, it is inferred that the temperature of the seas in which the early to middle Miocene molluscs once lived was influenced by warm water, contrary to the cold water conditions indicated by the Futaba-Tomioka molluscan assemblages. Compared with the molluscan assemblages of the Uchigo group, those of the Yunagaya group, Nakayama formation and Taga group are contrasting in several respects. First the number of extinct species decreased in the Yunagaya and younger units compared with that of the Uchigo group, second the paleoecological conditions are quite different, there being lagoonal facies well developed in the Uchigo but much less so in the younger rock units, and none of the important fossils cross the unconformity to enter the Yunagaya.

The relationship between the molluscan assemblages and stratigraphical sequence of the different rocks making up the Joban coal-field point to that several small cycles of sedimentation existed during the early to middle Miocene, but when viewed from the genral features, all may be included into a major cycle in good agreement with the sedimentary-paleontological cycle phase developed nearly throughout the early to middle Miocene in the Japanese Islands.

(To be continued)

BIBLIOGRAPHY

See : Sugai, K. et al., 1957, Geological Map and Explanatory Text of the Joban Coal Fields : Geol. Surv. Japan ; Geological Maps of the Coal Fields of Japan, I, pp.1-143. (With full references on the geology and paleontology of the Joban coal-field, Should be referred to by readers).