SEDIMENTOLOGICAL STUDY OF THE PALEOGENE BASIN OF KUSHIRO IN HOKKAIDO, JAPAN

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Contents

Abstract

The Kushiro coal basin is situated on the south side of the eastern part of Hokkaido, the northernmost main island of Japan. Until the present, there have been many contributions regarding the stratigraphy of the Paleogene formations in this basin, including the author's own studies.

In the present paper, the results of these studies will be briefly outlined at first. Then the development of the Paleogene basin will be described in detail. The most remarkable facts observed in the course of this study are as follows:

1) In the initial stage of the coal basin, the general trends seem to have

been in a West-East direction, in respect to the direction of isopach lines of formations, the boundary line of heterofacies in rocks and fossil-assemblages. This is named the Early Urahoro stage.

2) Various kinds of bio-facies and sedimentary facies can be recognized in 2nd stage too. Their general trends in arrangement, however, tend to be NNE to SSW. The deepest part of the basin is situated in the eastern part. This is denominated the Later Urahoro stage.

3) In the next stage the basin becomes deeper than it was in the former stage as a whole. Further, the basin seems to have been more uniform throughout, from the view point of bio- and sedimentary facies. In spite of this, the sediments show local differences in thickness. The general trend of isopach lines extends nearly NNE to SSW like the preceding stage. The deepest part of the basin seems to have been shifting far from east to west. This is the Early Onbetsu stage.

4) In the Later Onbetsu stage, the thickest part of the basin has been much moved towards the west, lying nearly at the edge of the former sedimentary basin. Volcanic products were developed along the lines of the deepest part of the basin of the preceeding stage.

5) The characteristic of the migration of the thickest part of the basin towards the west from the east is not only observable in the Paleogene sedimentary basin but also it continues from the Cretaceous to Pliocene or Recent. This condition implies the existence of and some effect of the "Paleo-Nemuro land" which was located on the south-eastern edge of this sedimentary basin.

Lastly the relation between tectonic and sedimentary facies as well as thickness of formation will be discussed briefly. Structural movements during the process of sedimentation such as occurrence of intraformational foldings, planeless faults and sandstone dykes, are evidenced in areas and horizons where the most sudden disturbances in sedimentation took place. Furthermore, the geological structure of this field has been influenced by the features of sedimentation, namely the direction and position of faults and axes of foldings are in coincidence with the sedimentational features of this basin as above stated.

§ 1. Introduction

Since 1951, the writer, aiming at a complete geological study of the Kushiro coal field in Hokkaido, has been carrying on these ten years' studies and investigation regarding the various portions of that field in cooperation with Messrs. Tsutomu FUJIE, Yasukuni FURUHATA, Jiro ISHII, and Katsutoshi MITANI under the very kind and most careful guidance of Dr. Masao MINATO, Professer of Hokkaido University.

What the writer intends to present briefly in this paper is nothing but a clarification of the features of the sedimentation in relation to the geological structure of the Kushiro coal-field sedimentary basin, simultaneously with developing a theory on the relations between the various characters of sedimentation and the formation of the sedimentary basin of which Dr. Shoji IJIRI (1958) and Prof, Masao MINATO (1953) have already written. Based on the facts proved so far by many previous writers and the observations of the present writer and others, the writer of this paper should like to clarify the characters and the changes of the thickness of lithologic-facies and fossil-biofacies of the various formations belonging to the Urahoro group and Onbetsu group of Paleogene which are developed in the Kushiro coad-field, and to refer to the different problems which arise in connection with the sedimentation and subsidence movements of this sedimentary basin*). Moreover the writer wishes to discuss how the characters of these movements changed and developed through the ages. He proposes then to refer to these movements and the formation of pyroclastic dykes, intraformational foldings and planeless faults, and lastly to consider the general relations, which are recognizable among the characters of structural movement such as folding or faulting which developed on a large scale in the later stages**). Here the writer humbly awaits the criticisms of the honorable readers.

§ 2. Acknowledgments

The writer is sincerely indebted to Prof. Masao MINATO in the Geological and Mineralogical Institute, Hokkaido University for his kind instructions through the whole course of studies and for kind revision of this thesis. At the same time he fully appreciates the kindness of Messrs. Tsutomu FUJIE, Yasukuni FURUHATA, Jiro ISHII and Katsutoshi MITANI who were willing to cooperate with the writer in both field investigations and laboratory studies. The writer also gratefully acknowledges the receipt of valuable materials from these people, also from Dr. Satoru UOZUMI and Dr. Toshimasa TANAI to whom most hearty thanks are expressed.

§ 3. Pre-Tertiary topography and geology of the Kushiro sedimentary basin

The Kushiro Paleogene sedimentary basin extends from the outer zone of eastern Hokkaido westward to the inner zone. It covers the Nemuro group

* The geology and stratigraphy concerning the Kushiro coal field have hitherto been studied by ASANO, K. (1952, 1954, 1955), FUJIE, T. et al. (1957), HASHIMOTO, W. (1958), HAYASHI, I. (1955, 1957), HAYASAKA, I. & UOZUMI, S. (1954), FUJIOKA, K. (1941), IIJIMA, A. (1959) IMAI, H. (1920, 1924, 1925), ISHII, J. (1957), KAWAI, M. (1958), KIZAKI, K. (1959), MATSUI, M. (1950, 1951a, 1951b, 1953, 1957, 1958, 1959, 1960), MINATO, M. (1950, 1952, 1957a, 1957b), MITANI, K. (1954, 1948, 1959, 1960), MIZUNO, A. (1960), MURATA, S. (1930) ODA, Y. et NEMOTO, T. (1959), OGASAWARA, K. (1955), OTATSUME, K. (1943, 1950), SAITO, R. (1953, 1955, 1956, 1958), SAKAKURA, K. (1954), SASA, Y. (1940, 1941, 1942, 1956, 1957), SATO, S. et al. (1950), SHIBATA, I. (1957, 1958), SHIMOGAWARA, H. (1953), SUZUKI, T. (1952), TAGAMI, M. (1933), TAKAO, S. (1952), TANAI, T. (1957), TASHIRO, S. (1951), TESHIMA, J. (1955, 1958), UOZUMI, S. (1955, 1957), YABE, H. (1951a, 1951b).

** Published contricutions concerning the relations between tectonic and sedimentary facies and the thickness of strata are as follows: BELOUSOV, V. V. (1953), FUJITA, Y. (1953), IJIRI, S. et al. (1955, 1958), IWAI, T. (1953), KOIKE, K. (1955), KRUMBEIN, W. G. (1951, 1956), KUENEN, Ph. H. (1950), MII, H. (1953), PETTIJOHN, F. J. (1957).

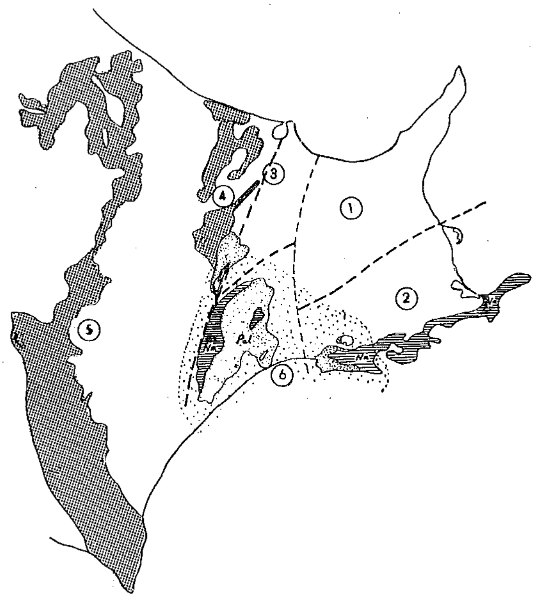


Fig. 1. Index map of Paleogene Kushiro Basin.

Pal: Onbetsu & Urahoro groups
Nm: Nemuro (Cretaceous) Groups
1) inner zone of Kurile Arc.
2) outer zone of Kurile Arc.
3) Toyokoro-Kitami Tectionic Zone.
4) Oikamanai zone
5) Hidaka zone
6) Kushiro coal field

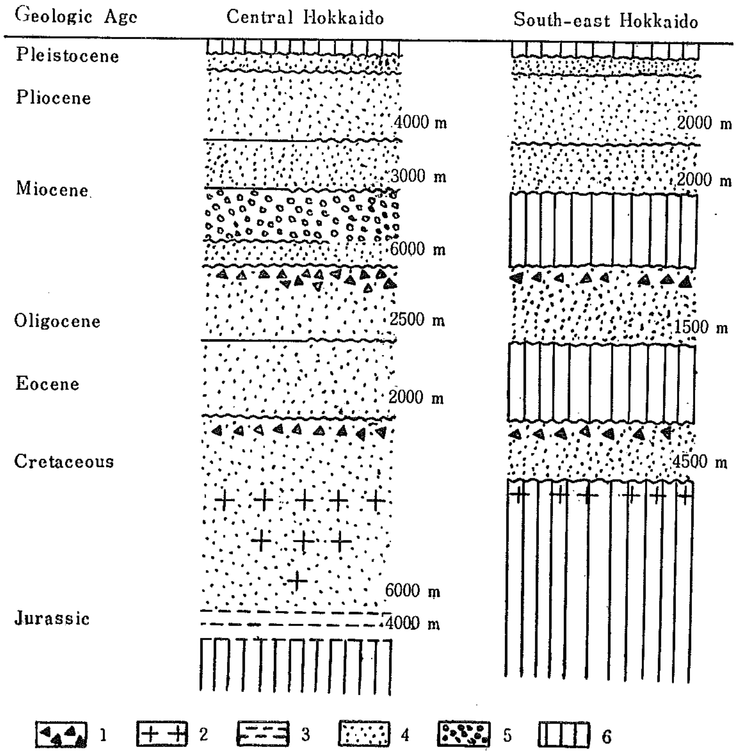
as its direct basis and spreads to the pre-Cretaceous area in an overlapping way. It extends at the present time to the coast of Akkeshi bay, Senposhi peninsula in the east, and to the areas of the Ashoro, Honbetsu and Nisei rivers in the west; on the north it stretches to the southern side of the Akan volcanoes and to the southernmost points of the Pacific coast in the south. Through the Rikubetsu valley to the middle course of the Honbetsu river, the Urahoro fault extends having a north-south strike as a boundary of the Cretaceous and pre-Cretaceous areas. The pre-Cretaceous group, composed chiefly of schalestein, red chert and green chert including pillow lava in some parts, which have a general strike N 30°E, is exposed as the basis on the western side of the Urahoro fault.

In the inner zone of the Kurile Arc, which is geologically an extension to the north-east of eastern Hokkaido, there is found in various places the same basic granitic rock, for example in Kunashiri and Etorofu islands. The distribution of pre-Cretaceous deposits which are seen on the extension of the line connecting the Rikubetsu and Honbetsu rivers clearly runs obliquely to the main trend of the Hidaka orogenic zone. It is clear that the pre-Cretaceous deposits provide the composition of the Oikamanai zone which extends to the inner zone of eastern Hokkaido, the Kurile Islands and Kamchatka.

As above mentioned, the basis formed of pre-Cretaceous deposits does not appear at all in the outer zone of eastern Hokkaido, east of the Urahoro fault, while in the chief parts of the Kushiro sedimentary basin, the Nemuro group of the Urakawa transgression, is widely exposed as the direct basis of Paleogene groups.

The formation of the Cretaceous sedimentary basin in south-eastern Hokkaido was later than that of middle Hokkaido due to the fact that the formation of the Paleogene sedimentary basin was slow in its beginning and the formation of the Miocene sedimentary basin was slow, too. This phenomenon is evidenced by the imperfectness of growth which the Oikamanai zone had from the beginning, and by the poverty of its geological history and sedimentation because not only is it situated in the hinterland of the Hidaka orogenic movement which is characterized by overthrusting upheaval to the west, but also at the north-west edge of "Paleo-Nemuro land" area which existed through these ages.

TABLE 1. Geohistorical Development of Central and South-eastern Hokkaido in Mesozoic and Cenozoic Era.



After M. Minato et al 1956)

1. Igneous activity of the final stage.
2. Igneous activity of the orogenic stage.
3. Igneous activity of the initial stage.
4. Depositional stage.
5. Sedimentation of molasse type.
6. Erosional stage.

TABLE 2. Correlation Table of the Nemuro Group (upper Cretaceous) in Southeast Hokkaido

Honbetsu-Ashoro (Mitani, Hasegawa et al 1959)	Tokomuro (Oda & Nemoto 1959)	Kushiro (Kawai, 1956)	Nemuro (Hasegawa & Fujiwara, 1959)	Shikotan Islands (Sasa, 1957)
	Tokomuro: silt & fine sandstone 400m	Konbumori 360m	Nemuro: Ochiishi andesite, sandstone & conglomerate 870m	Augite andesite, lava, sandstone 600 m
Kawaruppu: fine sandstone, siltstone, medium-coarse sandstone & conglomerate 1400m	Tokomuro: sand & silt alternation 500m	Akkeshi: Shiomi (Basalt 800 m	Nemuro: Choboshi sandstone siltstone 770m	Shikotan: dark grey siltstone & sandstone gabbro intrusion basalt dyke 2100m
Kawaruppu: alternation 350m	Tokomuro: grey sandstone & silt stone. 600m	Akkeshi: Senposhi tuff & sandstone 200 m	Nemuro: Nemuro tuffaceous sandstone & siltstone (Dolerite) 1900m	Matakotan volcanics
Katsuhira: sandstone, siltstone & white tuff 800m	Katsuhira: dark grey siltstone 600m	Akkeshi: Monshizu 200 m	Nemuro: Notsukamappu agglomerate, pillow lava	

OUTLINE OF THE SEDIMENTOLOGY OF THE NEMURO GROUP

Studies of the Cretaceous groups of the Nemuro and Kushiro areas have been carried out by many authors. It is still unknown on what foundation the Nemuro group developed; but from the fact that a zone of unusually high gravitational anormarly is found in the Nemuro area, it is thought that the distribution of the basaltic layer is very shallow.

When the Nemuro group is viewed from the sedimentological point of view it is seen to be composed of thick formations of alternating dark gray mudstone, siltstone and sandstone with very few fossils; that is, its noteworthy characters are that it is predominantly composed of geosynclinal deposits, which are occasionally of coarse grains in the uppermost part; thick formations are developed, and developments of intraformational foldings and sandstone dykes exist in the uppermost formation of this group in the Nemuro and Konbumori areas. The considerably thick formations in the lower Nemuro and Senposhi groups are found along the line connecting Nemuro and Habomai, and it is recognized that the position of the thick formation in the upper Shiomi, Tokoro and Kawarufu formations moves more to the north-west than does that of the lower formations.

The geosynclinal thick deposits of Cretaceous are folded in NEE–SWW strike direction, and include a large quantity of andesitic or basaltic lavas, pillow lavas, dykes and agglomerates. It can be safely said, that the Cretaceous sediments have been deposited in geosynclinal environments, that were newly produced in the upper Cretaceous.

The structural zone which consists of pre-Cretaceous Schalsteine as the basis, and is the boundary of the pre-Cretaceous area and the area of the Cretaceous Nemuro group, is called the Toyokoro-Kitami tectonic zone. In the west of the Kushiro sedimentary basin, this structural zone which has NEN–SWS strike like the Honbetsu, Rawan and Urahoro faults, has a deep significance in its construction, too. It is evident that this tectonic zone was in activity even before the deposition of the Paleogene group of this coal-field and it has been continuing its activity off and on till Miocene, Neogene Tertiary.

§ 4. Stratigraphy of the Paleogene Groups in the Kushiro basin

When one considers the general geology of the Paleogene Kushiro sedimentary basin, he finds that the Urahoro group, including coal-bearing formations in the lower part, covers the Cretaceous Nemuro group unconformably. The Urahoro group, through the whole area of the Kushiro coal field, shows principally fresh or brackish water facies with one or two formations bearing shallow sea facies in their several horizons. From the viewpoint of lithologic-facies, the Paleogene deposits are divided into six formations as listed in Table 3.

The Onbetsu group, marine water facies whice covers the Urahoro group is widely distributed in the western part of this sedimentary basin and extends farther to the west. Outside the distribution area of the Uraharo group, it lies unconformably on the pre-Cretaceous group.

Among the formations of the Urahoro group, coal bearing formations are characterized by alternation of sandstone and siltstone, but in the Beppo formation and Tenneru formations is developed a spectacularly characterized conglomerate which bears thin layers of sandstone. Shitakara is a brackish and marine formation featuring sandstone and sandy siltstone. But the characters of thickness and lithologic facies of every formation are varied according to the areas, and there are not a few cases in which the differentiation of the

TABLE 3. General Stratigraphy of the Paleogene Groups in the Kushiro Basin

Formation			Colm.	Facies	T. (m)	Lithology	Main Fossils	Volc.
Onbetsu Group	Nuibetsu			Marine	300	Dark gray tuffaceous sandstone, containing pyroclastic grains, intercalated thin agglomerate in middle & upper.	*Yoldia laudabilis* Yok. *Malletia poronaica* (Yok) *Neptunea onbetsuensis* Mat. *Ancistrolepis japonicus* (Tak.) *Callianassa muratai* Nag.	Basic Andesite
	Charo form	Charo memb.		Brackish	30-400	Dark gray siltstone intercalated marly layers & nodules, calcareous bands, thin white tuff.		
		Omagari			0-120	Green sandstone.		
Urahoro Group	Shakubetsu				280-	Gray siltstone, sandstone, thin conglomerate at basal part; upper parts becomes fine grained	*Corbicula tokudai* (Yok.) *Batissa sitakarensis* (Suz.) *Ostrea* sp.	Liparitic tuff.
	Shitakara				130-230	Dark gray siltstone platy greenish grey sandstone with grey thin conglomerate.	*Nemocardium yokoyamai* Tak. *Neptunea shitakarensis* Mat.	
	Yubetsu			Terrestrial	300-	Grayish sandstone, dark gray siltstone reddish conglomerate, intercalating coal seams.	*Batissa sitakarensis* (Suz.) *Corbicula tokudai* (Yok.) *Ostrea praegravitesta* Tak.	Acidic tuff.
	Tenneru				120-	Reddish conglomerate with gray sandstone patches and thin coal seams.	*Mya grewingki* Mak. *Nemocardium yokoyamai* Tak.	
	Harutori				120	sand-siltstone.		
	Beppo				50	Black conglomerate.		

formations is not distinct. Generally every formation considerably increases in its coarse-grained part towards the west, and in the area of Rushin in the western portion of this sedimentary basin, the whole formations become considerably conglomeratic through the whole Urahoro group. The Urahoro group, as indicated in Table 3, starts with the Beppo conglomerate formation and Harutori coal-bearing formation of fresh water facies, and extends to the Tenneru conglomerate formation. In this formation, in the Senposhi peninsula area, the eastern end of this coal-field shows evidence of the intergression of sea water. The characters of facies in the formations of the Urahoro group, which change periodically and spaciously as illustrated in Table 3, will be discussed in a later chapter.

The Onbetsu group is of marine sediments throughout with the exception of brackish fossils included in the lowest part; it commonly produces marine molluscan and foraminiferal fossils, excepting the Omagari member which is found at the base of this group, and predominates in sandstone and contains pebbles, the Charo formation predominantly exhibits dark gray siltstone. The Nuibetsu formation, upper half of the Onbetsu group, consists of dark gray or black sandstone, andesitic agglomerates and tuff layers.

No volcanic rock is found in the Urahoro group, but between the coal layers or in the coal layer itself are found white and fine grained tuff or tuffaceous clay layers. Especially in the Shakubetsu formation there are contained white liparitic pebbles in a large quality, the conglomerate of this material is called "Hatokuso". In the areas of Tokomuro and Rushin, the Onbetsu group bears andesitic sheet or agglomerate between the Omagari and Charo members. It has been already mentioned by previous studies, that the Nuibetsu formation contains a large quantity of basaltic or basic andesitic tuff, agglomerate and coarse-medium grained tuffaceous sandstone in the whole area of this basin.

Molluscan fossils and the minor foraminiferal fossils found in the Shitakara formation and Onbetsu group include the species which are contained in the "Poronal fossil fauna"; the Shitakara formation and the Onbetsu group can be safely correlated with the Poronai formation of the Ishikari coal-field. The brackish or marine water facies in a part of the Tenneru formation of the Urahoro group, produces molluscan fossils which are commonly found in the Shitakara formation. The stratigraphical relation between the marine formations of the Urahoro group and Akahira and Hiragishi formations which include brackish or marine water facies, presents a problem, but as the paleontological study of these formations advances a close relationship will probably clarified. When the age of the Onbetsu-Urahoro groups is considered in the correlation of the Poronai formation and the upper part of the Ishikari group, their age will probably be found to be from lower to upper Oligocene. This can be fully understood by a comparative study of the Yakataga formation of Alaska and the formations of Blakeley, Lincoln and Keasey from the Pacific coast of North America, by means of materials for paleontological study, such as mollusca or minor foraminifera.

The geological structure of the Kushiro coal field generally consists of four anticlinal zones running NE-SW, and three synclinal zones occupying the space between two anticlinal zones. There are (from NW to SE)

1) Ukotakinupuri—Rushin anticlinal zone.
2) Kamicharo—Tokomuro synclinal zone.
3) Yubetsu—Shakubetsu anticlinal zone.
4) Kamishoro—Onbetsu synclinal zone.
5) Akan—Shoro anticlinal zone.
6) Otanoshike synclinal zone.
7) Senposhi—Harutori dome zone.

Each of these structural zones is divided into several small units, and further they are rendered structurally complex by many foldings and faults. Gradual changes in the various characters of these structural units are recognized

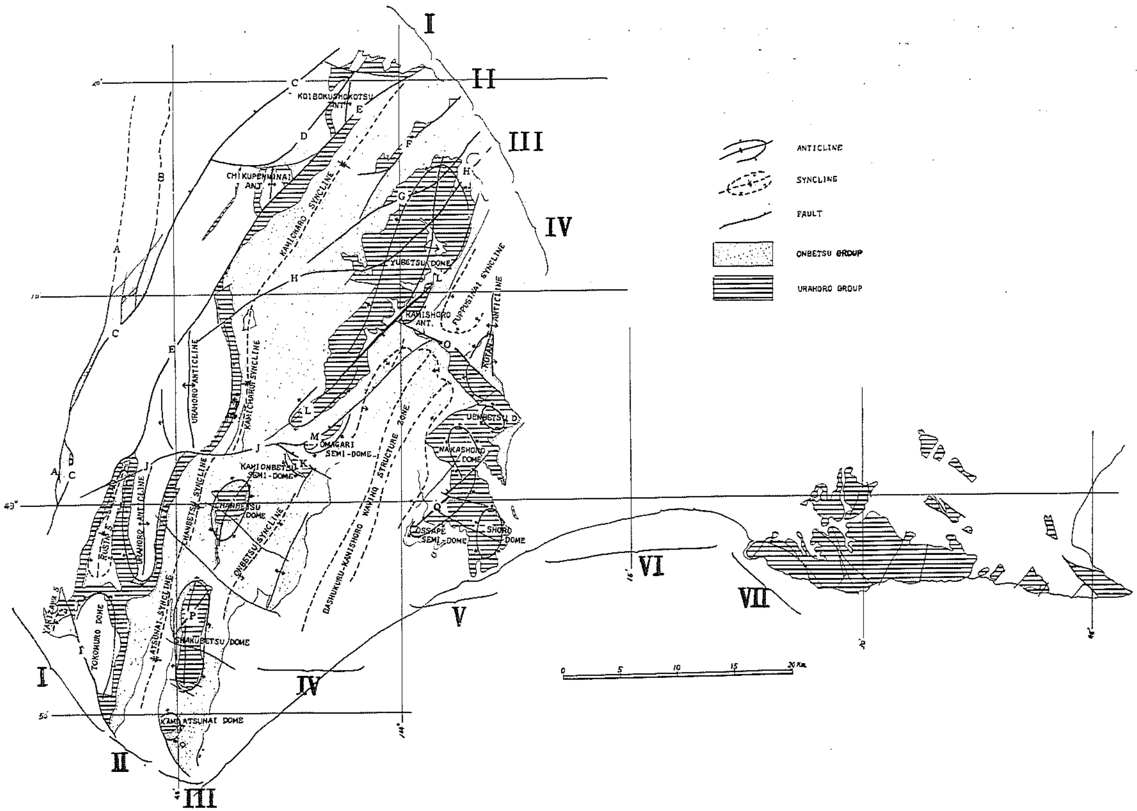


Fig. 2. Structural map of Kushiro Basin.

I): Ukotakinupuri-Rushin anticlinal zone, II): Kamicharo-Tokomuro synclinal zone, III): Yubetsu-Shakubetsu anticlinal zone, IV): Kamishoro-Onbetsu synclinal zone, V): Akan-Shoro anticlinal zone, VI): Otanoshike synclinal zone, VII): Senposhi-Harutori dome zone.
A: Rawan fault, B: Honbetsugawa fault, C: Urahoro fault, D: Chikupenninai fault, E: Kamicharo fault, F: Hokuyo fault, G: Teshibetsugawa fault, H: Nagasakisawa-Irobetsu fault, I: Tokomuro fault, J: Nupukibetsu fault, K: Onbetsugawa fault, L: Yubetsu fault, M: Omagari fault, O: Fuppushinai fault, P: Shibeshizawa fault, Q: Osappe fault.

towards the south-east from the north-west, that is all the way from zones 1) to 7).

To the north-west, the direction of the extension of each structural unit draws nearer to NS ; in the south-east area, the direction becomes more unclear. The general dip of the foldings in each anticlinal structural zone decreases toward the east from the west; the general dip of each zone is 80°–60°, 40°–30°, 20°, and 10° in zones 1), 3), 5), 7) respectively.

As to the faults, in zones 1) and 2) there are several large scale vertical faults which are the same or nearly same in direction as that of the structural units. In zones 3) and 4), there are conspicuous cross faults perpendicular to the axis, besides the same faults as in zones 1) and 2) above mentioned. In zones 5)–7) the differences between two kinds faults disappear gradually, especially in zone 7) there are conspicuous block faults which cross the lower dipped dome structure.

§ 5. Changing of lithologic-facies, bio-facies and thickness of the Urahoro group through the ages

The subdivisions of the lithologic-facies of the Urahoro and Onbetsu groups are shown in Table 1, but when these formations are considered from the viewpoint of the history of the growth and development of the Kushiro coal-field, they are grouped into the following four divisions.

(1) The lower part of the Urahoro group : including the Beppo, Harutori and Tenneru formations.

(2) The upper part of the Urahoro group : including the Yubetsu, Shitakara and Shakubetsu formations.

(3) The lower part of the Onbetsu group : Charo formation (including the Omagari member in its basal part).

(4) The upper part of the Onbetsu group : Nuibetsu formation.

In this chapter are to be discussed the characters of the lithologic-facies, bio-facies and thickness of every formation of the Urahoro group and the changes in them through the ages. The areas examined are shown in Table 4 and Figure 3. The locality numbers in Table 4 are correlated with those of Figure 3.

(I) The lower part of the Urahoro group

1) Beppo formation

The Beppo formation is the basal conglomerate of the Paleogene Kushiro coal-field and covers the Cretaceous Nemuro group by an unconformity plane which has a very irregular surface, but when the latter is of conglomerate, it is not always easy to discover the boundary. Structurally they are in a relation of clino-unconformity and when the relation is broadly viewed, one finds that this formation borders with every horizon of the Nemuro group. The general lithology of this formation is conglomerate with predominant medium-coarse gravels of black slate, black sandstone, basic andesite, various kinds of cherts and schalestein ; subordinately it contains biotite-hornblende liparite and hornblende porphyry.

TABLE 4. The thickness of Paleogene formations in the Kushiro Basin (thickness in meters)

Locality \ Formation	Nb	Ch	Om	Sb	Sk	Yb	Tn	Ht	Bp	remarks
1 Koibokushokotsu	150	200	80	176	190	143	75	28	100	Saito(MS)
2 Kutcharosibetsu	275	225	80	185	175	—	—	—	—	Matsui
3 upper stream of Chikupenninai	120	120	66	—	—	—	—	—	—	Matui
4 Chikupenninai	100	200	160	155	170	140	100	35	120	Matsui
5 Koikatahorokacharo	—	120	?	110	—	100	?	0	?	Matsui
6 Takutakubeobetsu	600	30	45	55	140	125	300	0	110	Matsui
7 Shutonai river	700	70	80	80	160	130	—	—	—	Matsui
8 Honbetsu river	115	160	100	/	/	/	/	/	/	Matsui
9 Nisho river	—	170	0	/	/	/	/	/	/	Matsui
10 upper stream of Rushin	40	300	50	30	130	70	250	/	/	Mitani 1959
11 Rushin	—	—	40	45	40	50	170	/	/	Matsui
12 Satonbetsu	700	300	80	43	132	113	—	/	/	Tanai 1957
13 upper stream of Onbetsu river	450	350	80	37	142	111	350	/	/	〃
14 Isokanbetsu	—	—	—	87	147	156	—	/	/	〃
15 upper stream of Chanbetsu river	—	—	—	86	147	132	—	/	/	〃
16 Muri river	—	—	—	80	155	150	—	/	/	〃
17 Urahoro	350	300	56	53	106	81	300	/	/	Matsui
18 Akubetsu	—	190	/	—	—	—	—	—	—	Matsui
19 upper stream of Sinkushitakara		350	30	260	230	250	81	16	100	Saito(MS)
20 Okuyubetsu	—	—	12	257	168	307	45	75	50	Matsui
21 Takinoue	275	225	75	300	200	200	190	28	40	Matsui 1954
22 upper stream of Kuomanai	—	—	70	250	?	300	250	12	17	Matsui
23 upper stream of Koyama valley	—	—	—	250	200	—	—	?	?	Matsui
24 Kamicharo-Shutonai	250	430	65	—	—	—	—	/	/	Matsui
25 Teshibetsu	—	150	—	—	—	—	—	—	—	Matsui
26 Yubetsu	—	170	0	240	200	300	45	70	60	Matsui
27 lower course of Shinkushitakara	350	195	?	135	138	150	80	50	100	Matsui
28 upper stream of Kuomanai	450	170	0	145	130	—	—	—	—	Matsui
29 lower course of Kuomanai	280	85+	—	—	—	—	—	—	—	Matsui
30 Nuibetsu	150	230	0	190	140	264	—	—	—	Matsui
31 lower course of Koyama valley	280	200	0	240	140	—	—	—	—	Matsui
32 Kamicharo	250	200	20	—	—	—	—	/	/	Matsui
33 Omagari	250	250	10	260	230	—	—	/	/	Matsui
34 Kami-onbetsu	—	400	70	140	150	—	—	/	/	Matsui
35 Chanbetsu dome	—	450	80	188	—	—	—	/	/	Tanai 1957
36 Shakubetsu dome	—	350	72	140	180	—	—	/	/	Matsui
37 Kami-atsunai	250	225	70	60	100	—	—	/	/	Isii 1957
38 Kami-shoro	—	250	0	280	—	—	—	—	—	Matsui
39 Akan	—	350	0	250	180+	—	—	—	—	Matsui
40 Naka-shoro	—	250	0	250	180	—	—	—	—	Matsui
41 Shiranuka-Omagari	—	200	?	240	350	210	16	80	20	Matsui
42 Shoro	—	—	0	200	315	95	—	—	—	Shibata 1957
43 under the Kushiro plane	—	—	—	—	—	—	75	70	—	Sasa 1942
44 Harutori	—	—	—	—	125	85	103	80	26	Matsui
45 Beppo	—	—	—	—	—	—	90	70	50	Kawai 1956
46 Konbumori	—	—	—	—	125	90	100	80	50	〃
47 Kamioboro	—	—	—	—	—	—	60	30	?	〃
48 Sekineppu	—	—	—	—	—	—	100	27	0.5	〃
49 Senposi	—	—	—	—	—	—	110	30	5	Hayashi (MS)

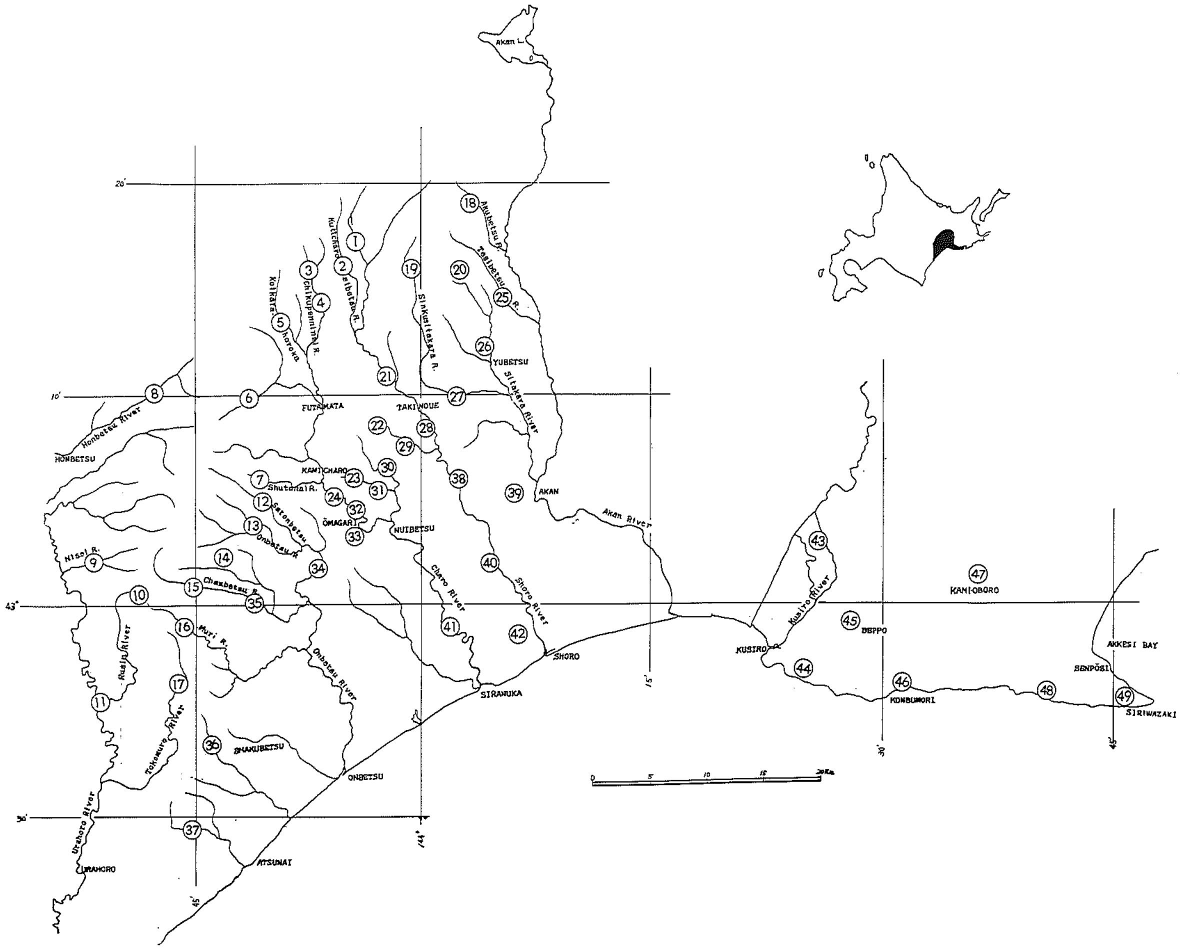


Fig. 3. Localities of the examined areas.

(The numbers of the localities are correlated with those of Table 4.)

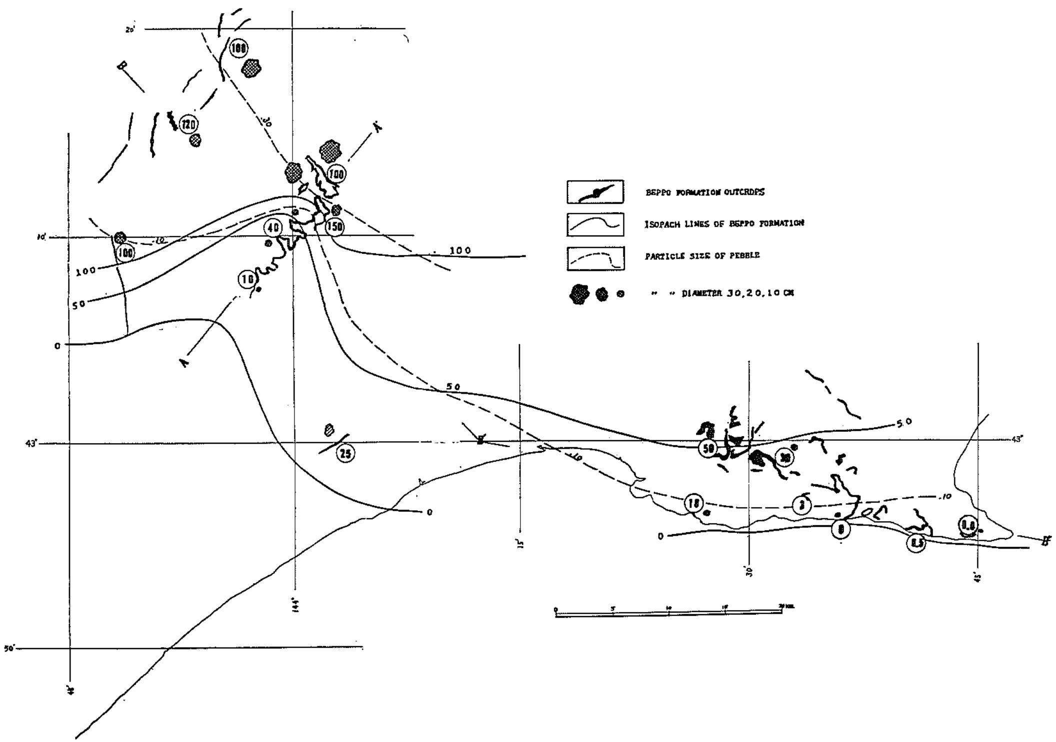


Fig. 4. Isopach map of the Beppo formation (Number in circle is thickness of the formation in each locality.)

In field observations, this conglomcrate is called popularly "Kurodama" on acount of its conspicuous numerous black pebbles and rather few white pebbles of liparite. It is generally of medium grained conglomerate with abundant sub-rounded or rounded pebbles and cobbles, which are cemented with granules of dark gray coarse sand. The whole formation is almost massive and the bedding of the conglomerate is not obvious; sometimes it bears light gray coarse sandstone of lense type; no fossils have ever been found in this formation.

The lithologic-facies of the Beppo formation, the grain size of pebbles and changes of thickness are shown in Figure 4.

—*Discussion*—

The following points are what should be noticeable as regards the changes of lithologic-facies and thickness of the Beppo formation.

A) The development of this formation is limited to the north or the east part of the Kushiro sedimentary basin, and characteristic feateres of this formation are not recognized in the Urahoro and Rushin areas.

B) The isopach lines run from NWW to SEE.

C) As for the size of pebbles, it decreases from north to south.

D) The changes of thickness in the sections from Yubetsu to Kuomanai, and from Chikupenninai to Senposhi are shown in figure 7.

These facts enable the worker to realize that the conglomerate containing black slate. gray chert, meta-sandstone, liparite and hornfels, which is a character of the Beppo formation, makes changes in its distribution and facies which make one think of the deposits in alluvial environment; further, one is led to think that the conglomerate was brought from an erosional area, situated in the north, not so distant from the present distribution area. So far, the change of thickness, grain size, and the kinds of pebbles which the writer has discussed, helps him to seek for the pebbles forming the Beppo formation in "Palaeo-Okhotsk Land", which used to be in existence to the north or north-east of this area.

2) Harutori formation

In the neighbourhood of Harutori, Kushiro city, the type locality, this formation consists of an alternation of sandstone principally and siltstone subsequently; it bears some layers of coal. Most of the sandstone is grayish arkosic, but some of it is sideritic and hard. The formation includes fine conglomerate consisting of black or red chert pebbles. The changes in facies and thickness are spectacular. The under limit of this formation is the part where the Beppo conglomerate loses its characteristic features and is transformed to sandstone. The upper limit is placed under the thick layer of red conglomerate which is the principal character of the Tenneru formation. But this division can not always be recognized throughout the whole area of the coal field nor is any development of coal seams to be found between the Beppo and Tenneru formations. Conversely in some western parts of this coal field,

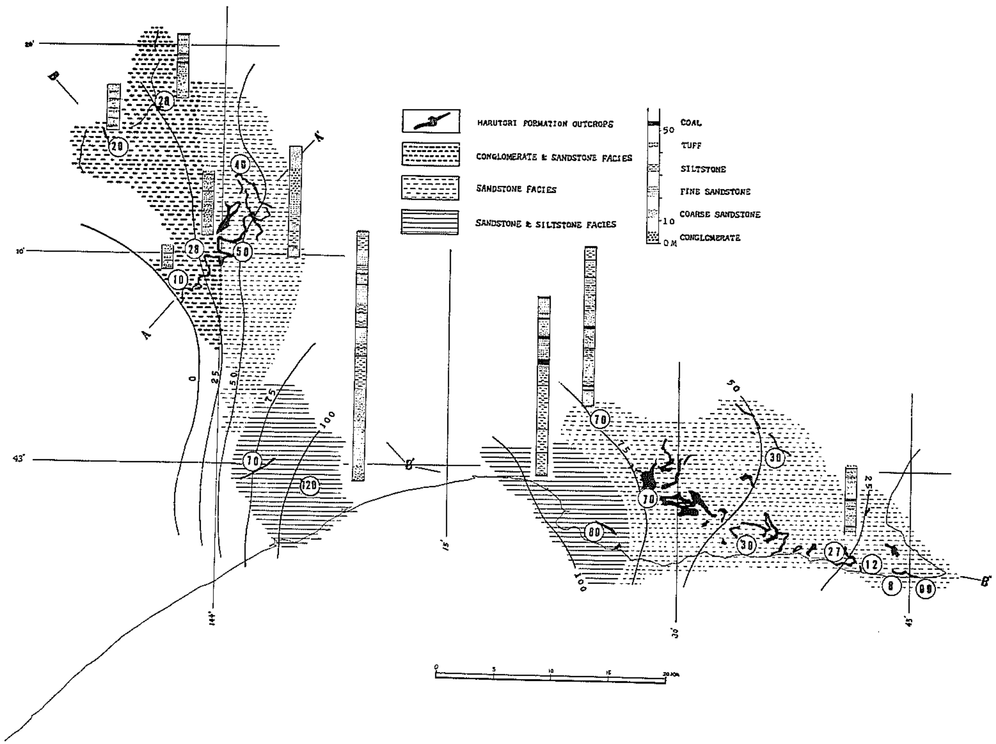


Fig. 5. Isopach and lithologic facies map of the Harutori formation (Number in circle is the thickness of the formation in each locality.)

the development of a tolerably thick coal bearing sandstone member is found in the Tenneru formation. The changes of facies and thickness of the Harutori formation in various areas are illustrated in Figure 5.

—*Discussion*—

The characters of the changes of facies and thickness of the Harutori formation can be summarized as follows.

A) In the area of Shiranuka and Harutori as the center, it is a thick formation principally composed of fine grained sediments, and at the same time seen developments of good coal layers.

B) As one goes off to the west from the above area, lithologic-facies become suddenly coarse-grained, the thickness decreases, the coal layers become worse and decrease in number, too. In the areas of Takinoue or Kuomanai, the formation is composed of considerably many pebbles and conglomerate layers, which are characteristic of the formation.

C) Likewise towards the east from the areas of Shiranuka and Harutori, there is a considerable decrease in the thickness of the formation, and the development of coal layers become worse, but this formation show no tendency of so much grain-coarseness.

D) The difference, which is characteristic of the changes in facies and thickness of the Harutori formation, from every upper formation is that there can not be recognized a clear NEN–SWS direction of extension which is seen in every formation(*) in the present area. This fact is clearly understood when companion is made between Figure 7, and Figure 12, below.

3) Tenneru formation

This formation, throughout the upper and lower parts, is composed of conglomerate, with sometimes sandstone, siltstone and alternatson parts. It sometimes includes coal seams, too. Pebbles are dominantly composed of chert, red or reddish brown in color; chert pebbles may attain some 30 to 50% of the entire number of pebbles.

This formation abounds in gray chert next to red chert, but is composed of comparatisvely less igneous rook material. It contains, as other kinds of pebbles: black slate, meta-sandstone, basalt, andesite, schlesteine, diorite, quartz porphyry, hornfels, porphyrite, dorelite and diabase.

The characters of the facies and thickness of this formation in the vasious region are shown in Figure 6.

—*Discussion*—

What is to be noted, about the changes of facies and thickness of the Tenneru formation is the following.

(*) The character of such a vagueness of direction of extension can be considered to correspond to the fact that no clear direction of extension can be seen in the changes of either the thickness or the quantity of the coal layers, main coal or lower coal in the Harutori area.

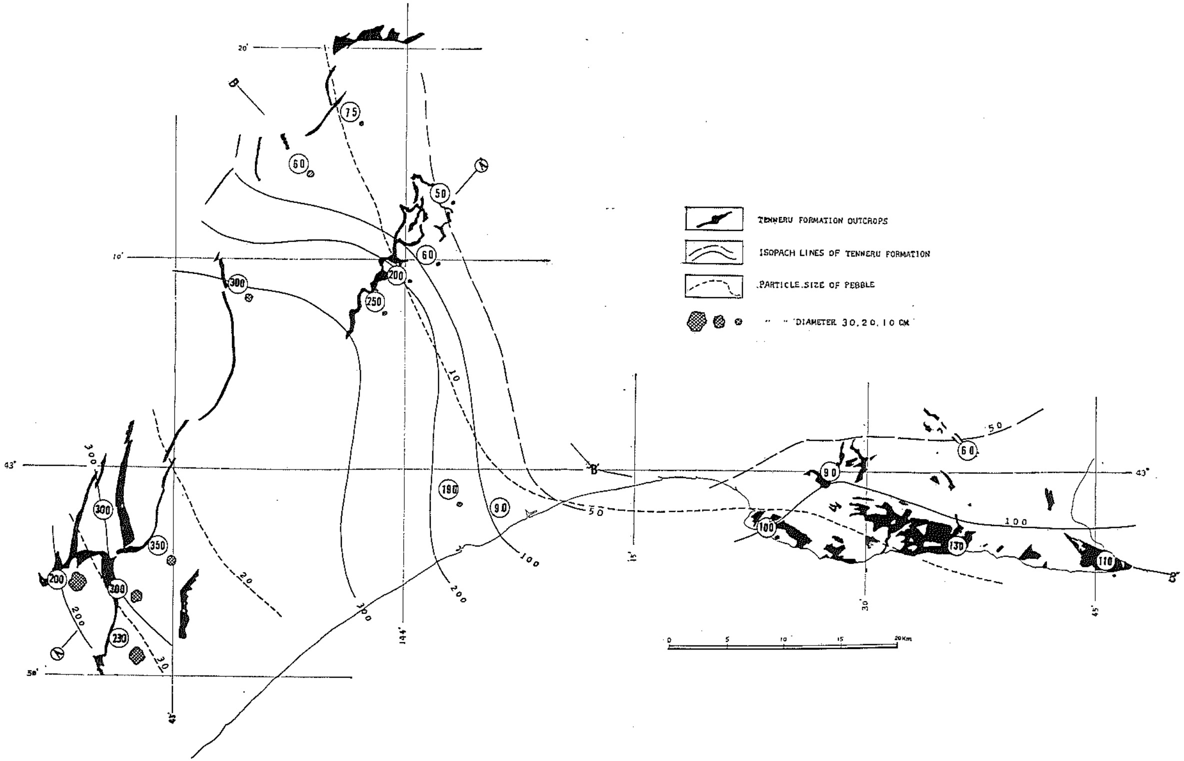


Fig. 6. Isopach map of the Tenneru formation (Number in circle is the thickness of the formation).

A) The characteristics of the facies of this formation being distinct from those of the Beppo formation, are that it is a thick formation in the southwest or in the south with decreasing thickness towards the north or northeast; the thickness suddenly decreases in the north or northeast of the areas between Chikupenninai (upper stream of the Charo river)--lower part of the Shinkushitakara river—Shoro—Beppo.

B) The change in grain size of the formation quite agrees with the changes in the thickness. In the areas of Rushin and Urahoro, the formation shows remarkable coarse lithologic-facies, and becomes gradually fine-grained towards the north and east. The grain size suddenly decreases in the parts to the east and northeast of the above mentioned Chikupenninai—Shoro—Beppo line.

C) The data from Konbumori and the Senposhi peninsula are not always numerous, but the tendency is seen that the southern portions are coarse grained and the north, fine grained.

D) Generalizing on the basis of the above mentioned points, one comes to the conclusion that the erosional area which supplied the clastic meterials, which chiefly consist of red chert pebbles, to this basin must have been located to the west and the south of this sedimentary basin.

E) It must be noted that facies of brackish or marine water fauna appear at the eastern edge of the Kushiro sedimentary basin for first time in the upper part of the Tenneru formation. And at the same time, one will be led to the thought that in almost all areas of this coal field this formation was formed as alluvial deposits in terrestrial environment.

Thus far has been a report on investigations about the changes of characteristics of the lithologic-facies and thickness of three formations of the lower part of the Urahoro group. A characteristic common to the Beppo, Harutori and Tenneru formations is seen also in the evidences that the fundamental character of the Kushiro coal field, namely the NEN–SWS direction in the change of the thickness and lithologic-facies has not yet appeared.

As already described, the two formations, Beppo and Tenneru, have been supplied with compounding materials from quite different areas to the north and west or south, and they show the opposite thickness and facies changes but the direction of extension of isopach lines is coincidentally NW–SE. It can be guessed that both formations were deposited as fan deposits or alluvial deposits constituted of the supply of coarse grain crustal material from the upheaving area which was not very far from this basin. These two formations intercalate the Harutori formation between them and they show clear difference in lithologic-facies, which indicates that when the upheaving movement in the north area was nearly ended, a more active rising started in the western and southern mountainous areas.

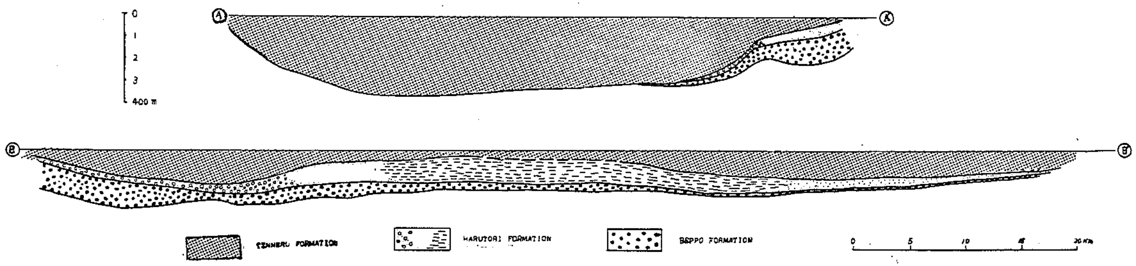


Fig. 7. Geological section of the lower Urahoro Group. (A–A′, B–B′–B″ sections in (Figs. 4, 5 & 6) illustrating the change of thickness of Beppo, Harutori & Tenneru formation).

(II) The upper part of the Urahoro group

The upper part of the Urahoro group is divided into the Yubetsu, Shitakara, and Shakubetsu formations. The characterirtics of the upper part of the Urahoro group will be grasped as the "2nd stage" of the Kushiro Paleogene sedimentary basin, which clarified its fundamental characters, and prepared for the conspicuous subsidence of this sedimentary basin in the Onbetsu stage.

4) Yubetsu formation

In the neighbourhood of the Yubetsu coal mine, which is the type locality of this formation, its main part is a fresh water facies composed chiefly of sandstone with siltstone and sometimes conglomerate subordinately. It contains 10 coal layers. The uppermost part of this formation exhibits brackish water facies. It consists of an alternation of sandstone and siltstone (thickness about 40 meters) and contains several seams of coal. Fossils are found of *Corbicula tokudai, Batissa sitakaraensis* and *Ostrea* sp. in large quantity. The lateral change of lithologic-facies and thickness is rather conspicuous, especially as one approaches the western part of the Kushiro coal field, namely in the upper course of the Charo river, Urahoro and Rushin areas, the lithologic-facies become remarkably coarse grained. In these areas it is difficult to distinguish this formation from the Tenneru formation except that the former contains coal layers.

The changes in thickness and lithologic-facies of the Yubetsu formation are indicated in Figure 8.

—*Discussion*—

Different from the lower part of the Urahoro group, in the Yubetsu stage, the clearly distinguishable features have clearly appeared. A detailed consideration of these characteristics will be presented in a later chapter. Only their main characters can be enumerated here as follows:

A) In the changes of the thickness and lithologic-facies, there appears a distinct NNE–SSW direction of extension.

B) A remarkable thick and rather coarse grained formation had been deposited in the Yubetsu-Kamicharo areas, there ascensional movement took place that expanded to the Yubetsu dome.

C) Towards the west from the thick deposited area, the thickness comparatively decreases, and in the west of Rushin to the south-west this formation thins out. Changes in the lithologic-facies are seen parallel with the changes in thickness. The changes of lithologic-facies are clearly recognized in area from east to west, namely the area which consists principally of siltstone, the area of sandstone principally, and the area containing conglomerate.

D) In the area south-east of the thick area in Yubetsu and Kamishoro is seen a remarkably thin formation having the NEN–SWS direction of extension which is parallel to the above-mentioned thick part. The changes in the thickness from the thick formation of Yubetsu-Takinoue to the thin formation area are

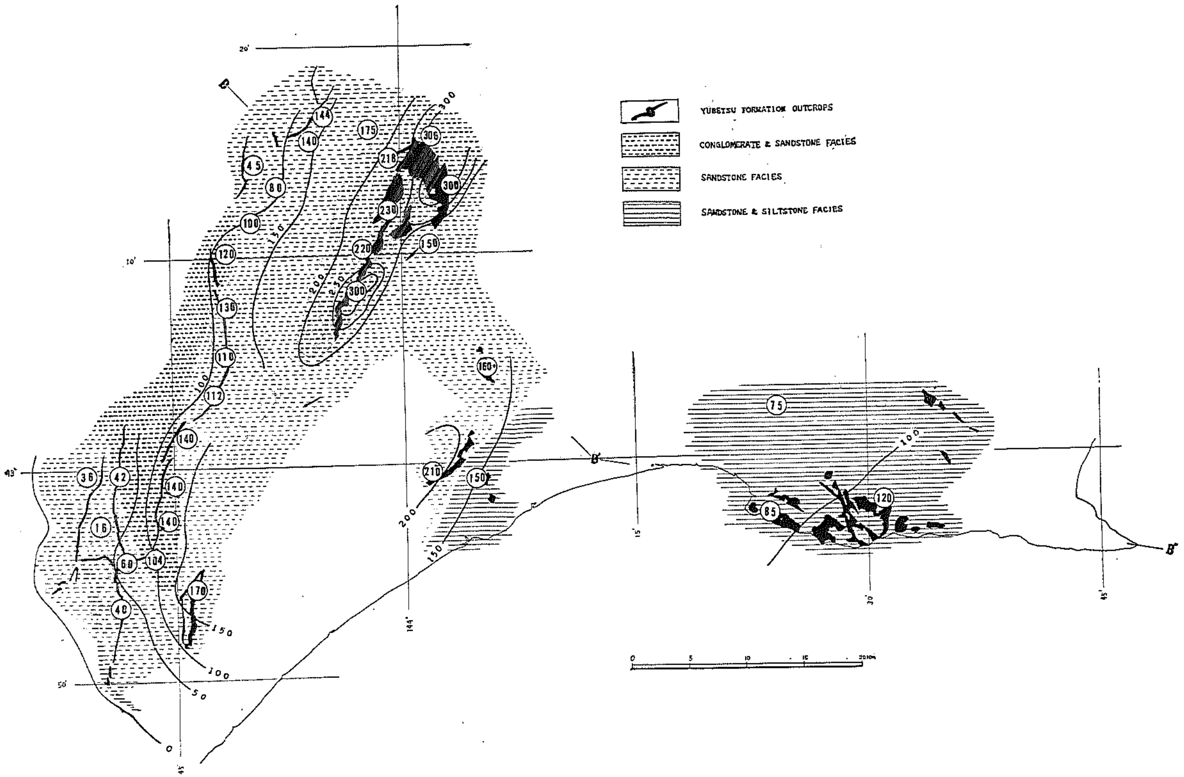


Fig. 8. Isopach and lithologic facies map of the Yubetsu formation. (Number in circle is the thickness of the formation in each locality).

rather sudden and discontinuous, whilst the changes in the lithologic-facies are very remarkable, too.

E) Towards the south-east from Kamishoro the formation becomes thin, but near the Shiranuka area there are formed thick, fine grained deposits.

F) As for the Kushiro-Konbumori areas, they consist of fine sediments, namely an alternation of siltstone and sandstone ; the lithologic-facies and thickness are stabilized, but it seems they somewhat increase in thickness towards the east.

G) Through the whole formation, Yubetsu is not remarkable in respect to chage of the lithologic-facies, but towards the east or west, especially towards the west, the coarse-grained members are numerous.

H) The development of coal layers corresponds with that of the formation. That is to say, in the thick part of this formation, coal layers comparatively thicker and in good quantity are included. But in the thin part of the formation there is a poor development of coal layers.

5) Shitakara formation

The Shitakara formation consists of deposits of brackish and marine facies; there is found also a considerably large quantity of molluscan fossils. The cliff of the Shitakara river in the neighbourhood of the Yubetsu coal mine which is the type locality of this formation (Loc. 26 in Figure 9) is divided into four members according to the lithologic facies. In descending order the formation consists of 1) a sandstone member including some layers of Ostrea beds, 2) a silty sandstone member including some marine mollscan fossils, 3) a platy sandstone member, 4) a massive coarse sandstone member. This subdivision is found rather clearly through the part to the east from the middle part of the Kushiro sedimentary basin. But this lithologic-facies subdivision becomes ambiguous as one goes to the west, and at the same time the whole formation becomes coarse-grained. But even the area which consists of coarse sandstone or conglomerate hardly includes coal layers. It is generally admitted that marine mollusca are included through the whole area, as shown in the columnar sections of various areas (Figure 9).

The changes of lithologic-facies, thickness and bio-facies of the Shitakara formation in various areas are illustrated below in Figures 10 & 11.

—Discussion—

The characteristics of the changes of lithologic-facies and thickness in the Shitakara formation show the same tendency as those of the Yubetsu formation, and the various characteristics described in the consideration of the Yubetsu formation are true of this formation.

A) On the change of the thickness and the lithologic-facies the distinct direction of NEN–SWS line of change is recognized.

B) Along the line connecting the upper course of the Shitakara river and Takinoue on the Shoro river and Kamicharo are found remarkably thick developments of this formation.

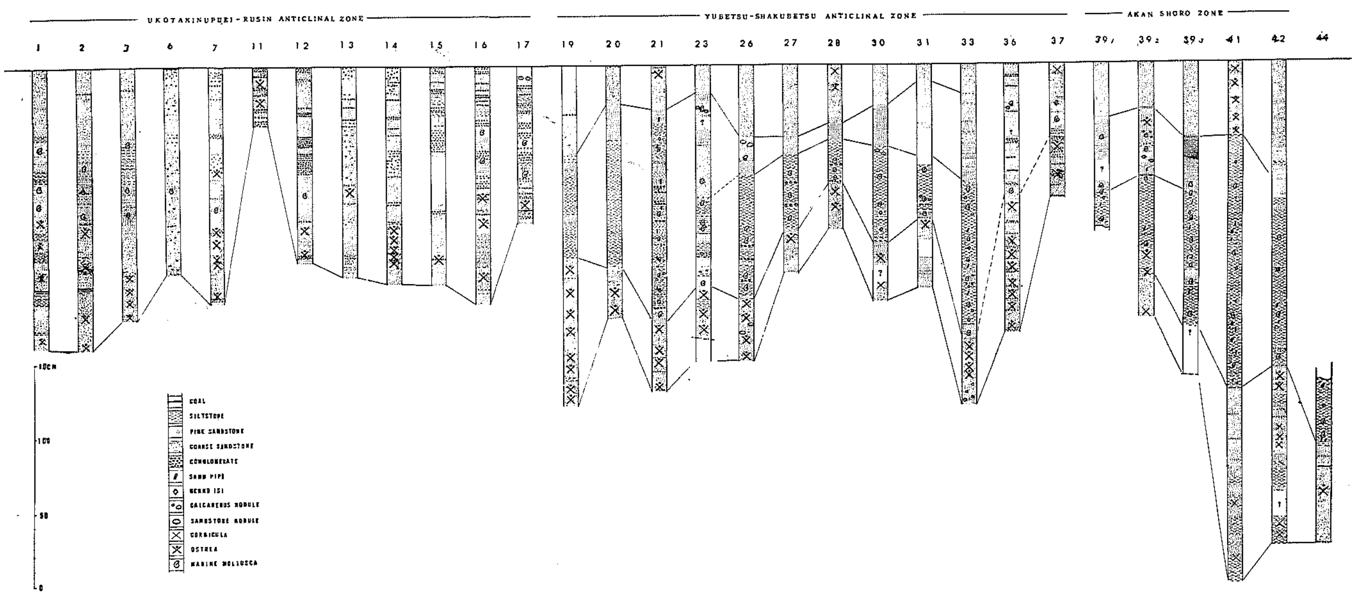


Fig. 9. Columnar sections of the Shitakara formation. (Locality numbers are correlated with those of Table 4 and Figure 3).

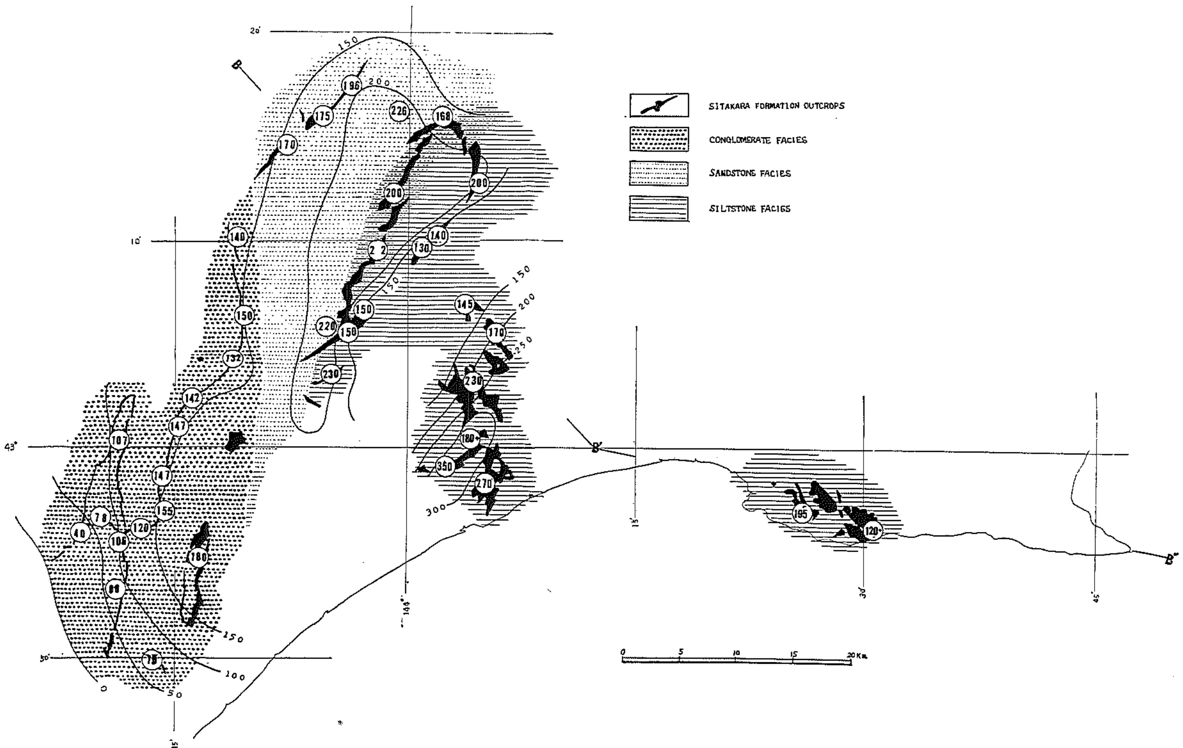


Fig. 10. Isopach and lithologic facies map of the Shitakara formation. (Number in circle is the thickness of the formation in each locality).

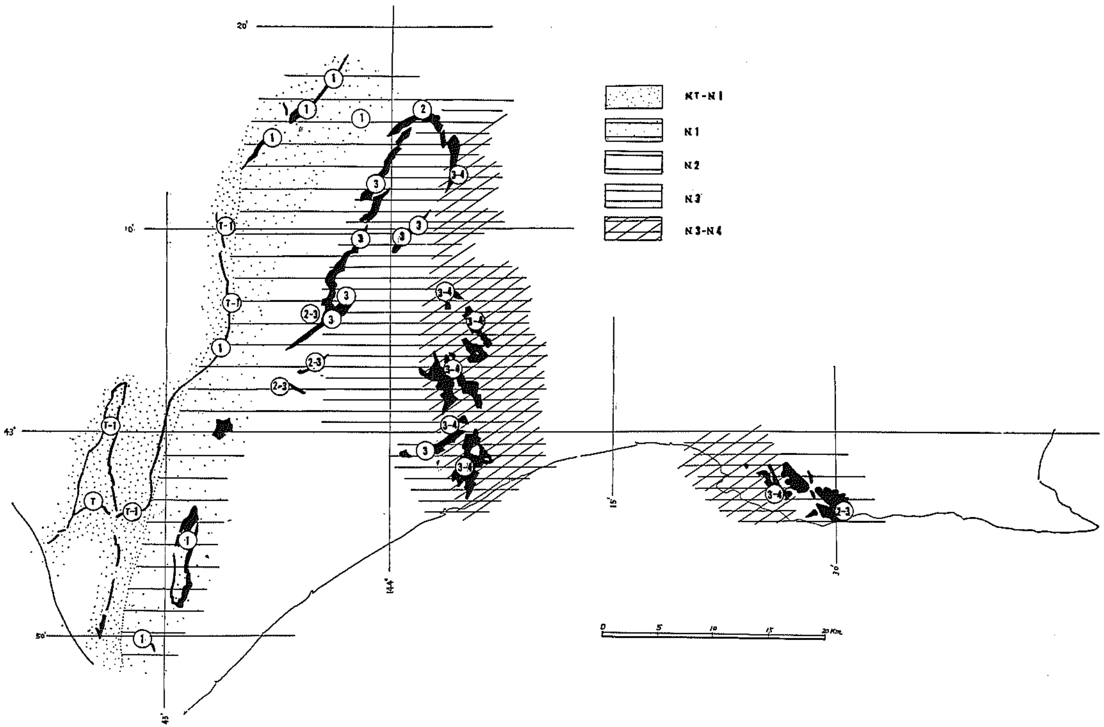


Fig. 11. Biofacies map of the middle part of the Shitakara formation.
NT: Tidal zone, N1: Euneritic zone, N2: Mesoneritic zone,
N3: Subneritic zone, N4: Bathyneritic zone.

Table. 5 The Fossil Fauna of the Shitakara Formation

Locality Numbers correspond with those of the Table 4.

Species \ Occurence	10	11	1	2	3	6	7	17	19	21	22	23	26	28	31	32	34	36	38	39	41	42	43	44
Acila (Acila) vigilia (Schenck)													R							R		R	C	
Acila sp. (osugii type)													R										R	
Nuculana sp.																		R		R		R		
Yoldia (Yoldia) laudabilis Yokoyama				C						C	C		A	C			C			C	C	C	C	C
Yoldia (Tepidoleda) sobrina Takeda										C	C	C	R				R			C		C		
Portlandia (Portlandia) watasei (Kanehara)										R	R									C	C		C	
Malletia poronaica (Yokoyama)							R			R	C		R									R	R	R
Ostrea praegravitesta Takeda	A	A	X	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Glycymeris sp.													R		R							R		
Mytilus mabuchii Oyama et Mizuno											R		A							R				
Propeamusium kusiroensis Takeda											R					R					R			
Clinocardium asagaiensis Makiyama			X	C						C											R		R	
Nemocardium ezoense Takeda	R	A	X	A		A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	A			R
Nemocardium yokoyamai Takeda			X		C		C	C		C	C	C	C	C	C	C	C	C			C			
Corbicula tokudai Yokoyama		A	X	A	A		A	A	A	A	A	A	A	A	A	A	A	A	A			A	A	
Batissa shitakaraensis (Suzuki)		A					A	C		A	C	C	C	C	C	C	C	C	C			A	A	R
Diplodonta sp.		R						R	R															
Conchocele bisecta (Conrad)				R						R			C							C			C	
Lucina sp.										R										R				
Periploma besshoensis (Yokoyama)											C		C	C	C	C				A	C	A	C	
Venericardia expansa Takeda			X	C		C				C	C	C	A	C						C	C	C		
Venericardia tokudai Takeda			X			C		A			C	C								C	C		C	
Venericardia akagii Kanehara			X										C	C		R				C	C			
Macoma sejugata (Yokoyama)				C	C				C	A			A	A		C	A		C	A		A	A	
Macoma asagaiensis Makiyama					C				C	A			C			A				C	C		A	
Pitar sorachiensis Oyama et Mizuno		R						R					C	R									R	R
Spisula sorachiensis Uozumi					R								R	R		R							R	
Chlamys kusiroensis Takeda	R	R						R					R					A	R	C			R	
Solen sp.		C		C				R		R	R								R			R	R	R
Mya grewingki Makiyama		A	X	A	A	A		C	C	A	A	A	C	C	C	C	C	C		A		A	C	R
Turritella poronaiensis Takeda									C	C			A	C	C	C	C		R	C		C	C	R
Trochocerithium wadanum (Yokoyama)				R																R	R	R		
Neptunea shitakarensis Matsui	R		X							C			C	C	C	C	C			C	C	C	C	
Neptunea shoroensis Matsui													R		R	R				R	R	R		
Neptunea huruhatai Matsui										R			C	R	R					R		C	R	
Neptunea modestoidea Takeda													R											
Neptunea ezoana Takeda																		R				R		
Ancistrolepis sp.													C								R	R		
Molopophorus kusiroensis Takeda		C						C		C			R	R					R	C		C		
Molopophorus shitakarensis Matsui										R			R	R					R	C		C		
Scaphander multistriata (Takeda)													R							C		R		
Epitonium (Cirsotrema) ezoensis Matsui				R			R						R		R							R		
Epitonium (Boreoscala) yamamotoi Matsui							R								R							R		
Epitonium sp.			X	R									R		R							R		
Turricula shitakarensis Matsui																				R		R		
Ampulina asagaiensis Makiyama		C	X	C	R	R		A					C	C							R	C	C	
Tectonatica sp.					C			R	R											R	R	C		
Dentalium nunomae Takeda				C	C				C	C	C	C	A	C					C	C		A		
Linthia yessoensis Minato										R			R											
Ophiuroidea sp.						R				R			R					R			R			
Callianassa muratai Nagao					R					R														

C) Towards the west from the area just above mentioned, the thickness decreases, and at the same time through the west from the east the whole formation becomes coarser and the subdivision by lithologic-facies becomes ambiguous.
D) In the Kamishoro and Nuibetsu area, which is adjacent to the south-east of the above mentioned area of thick formation, is seen a remarkable thin formation. This change is rather sudden and discontinuous. In the south-eastern part of this basin, namely in the Shiranuka, Kushiro and Konbumori areas, this formation principally consists of fine-grained sediments, which make a rather thick formation.

—Paleoecological summary of the Shitakara fauna—

The kinds of molluscan fossils produced in various places in this formation can be listed as in Table 5.

The molluscan fauna of the Shitakara formation exhibits a gradual change of brackish→marine→brackish from the lowest part to the top, and if an examination is made of the whole area of this sedimentary basin, one finds remarkably distinct characteristics of each area. In the area of the Yubetsu dome district, and the eastern part of this basin there is developed brackish facies represented by coarse sandstone bearing some layers of *Ostrea* beds in the lower part. This part are changes gradually to the middle part of marine facies made of fine sandstone or siltstone containing many kinds of molluscan fossills as *Neptunea*, *Mya*, *Venericardia*, *Yoldia*, *Acila* and so on. In the upper part, the formation changes to brackish facies producing a large quantity of *Ostrea*, and then this formation changes into the Shakubetsu formation composed of fresh water facies.

When the molluscan fossils are included in fine sandstone or siltstone of marine facies at the middle of this formation, it may be safely said they present strong local characteristics. Further, as shown in Figure 9 the three facies, brackish→marine→brackish, are considerably different in their development according to the areas. In the west, almost all the formation is made of coarse-grained facies, and the thickness of the marine facies is considerably restricted. On the other hand in the west or the east there exists considerable coordination between the thickness of the marine facies member and the total thickness.

In short it is known that the ratio between the marine facies in the formation and the brackish facies above and below, gradually increases from the west to east.

It is recognized that the kinds and quality ratio of the molluscan fossils in marine facies show considerable difference according to the areas and horizons. The manner of these changes is shown in Table 6. The marine facies of the Shitakara formation is subdivided into the following five types, according to the characteristic assemblages of molluscan fossils which are contained in each

TABLE 6. Bathynetrical analysis of the Shitakara and Onbetsu Faunas

Species	Bateymetrical Range						
	H.	Nt	N1	N2	N3	N4	Nb
Corbicula tokudai	—	- -					
Batissa sitakaraensis	—	- -					
Ostrea praegravitesta	—	—	- -				
Tectonatica sp.		—	—	—			
Ampulina asagaiensis		—	—	—			
Mya grewingki			—				
Linthia yessoensis		—	—				
Olivella ezoana		—	—				
Molopophorus spp.		—	—	—			
Scaphander spp.		—	—	—			
Macoma sejugata		- -	—	—	—		
Macoma asagaiensis		- -	—	—	—		
Epitonium spp.			—	—	—		
Neptunea spp.			—	—	—	—	
Nemocardium spp.			—	—	—		
Venericardia spp.			—	—	—	—	
Turritella poronaiensis				—	—		
Yoldia spp.				—	—	—	
Portlandia spp.				—	—	—	
Nuculana spp.				—	—	—	
Malletia poronaica					—	—	—
Periploma besshoensis					—	—	—
Neopsephaea antiquior					—	—	—
Acila (Acila) vigilia						—	—
Ancistrolepis japonicus						—	—
Callianassa muratai						—	—
Spirotropis (Antiplanes) rugosa						—	—
Turcicula sakhalinensis						—	—
Solemya tokunagai						—	—
Propeamusium kushiroensis						—	—

H: Brackish zone, Nt: Tidal zone, N1: Euneritic zone (0–20, 30 m), N2: Mesoneritic zone (20, 30–50, 60 m), N3: Subneritic zone (50–100, 200 m), N4: Bathyneritic zone (100–200 m), Nb: Hemibathial zone (200–300 m).

horizon and area.

1) Fossil assemblages of *Ostrea paleogravitesta* and *Corbicula sitakaraensis*: (H).

2) Fossil assemblages of *Nemocardium ezoana*, *Mya kusiroensis*, *Ostrea*

paleogravitesta: (Nt).

3) Fossil assemblages of *Chlamys kusiroensis, Macoma* spp., *Neptunea* spp., *Molopophorus kusiroensis,* and *Nemocardium ezoana*: (N1).

4) Fossil assemblages of *Epitonium* spp., *Neptunea* spp., *Nemocardium* spp., and *Venericardia* spp.: (N2).

5) Fossil assemblages of *Yoldia* spp., *Portlandia* spp., *Periploma besshoensis, Turritella poronaica* and *Scaphader* spp.: (N3).

6) Fossil assemblages of *Acila* sp., *Malletia poronaica, Conchocele bisecta,* and *Nuculana* sp.: (N3–N4).

A careful consideration of the assemblages will be included in the discussion below of molluscan fossils in the Onbetsu group. Here are given obvious conclusions.

The change of these fossil assemblages 1) to 6) can be regarded as indicating the increasing of the depth of the esea, uneritic zone—mesoneritic zone—subneritic zone. The extension of each zone in the middle part of the Shitakara formation in various areas can be depicted as in Figure 11. The extent of the distribution of every zone is in close accordance with the characteristics of the lithologic-facies map. At the same time it should be considered that the characteristics of these assemblages not only reflect changes in depth but also the effect of the differences in the sea bottom sediments.

As has been noticed above, the characteristics of the subsiding movements of this basin when the Shitakara formation was formed, and the changes in depth to the bottom of the sea do not always coincide. That is, that the depth of water in the sedimentary basin in respect to time and space make rather remarkable changes, can be seen as characteristics of the basin. At the same time, it must be noticed that the subsiding movements of this area had no relations with the change of the sea depth, which evidences itself as the facies changes, and the subsiding was a higher dimensional and longer continued movement than the later.

6) Shakubetsu formation

The area of the Shakubetsu coal mine, which is the type locality of this coal bearing formation, is composed of alternations of gray medium arkose sandstone chiefly and dark gray siltstone subordinately; several thin conglomerate layers are seen in the lower and uppermost part. Observed in this formation are 20+cyclothems of sedimentation. In the western part of the field, the "Hatokuso conglomerate." which is characterized by white pebbles of liparite or liparitic tuff, is developed broadly.

The lower part of the formation consists of sandstone of brackish facies containing crowded *Ostrea paleogravitesta, Corbicula tokudai,* and *Batissa sitakaraensis*; the middle main part, sandstone, siltstone and numerous coal layers, is fresh water facies; in the upper part is again developed the brackish facies. Further, marine facies are seen in some parts of the eastern ares.

The number of coal layers exceeds 10+ in each area, but their number, thickness and quality changes follow the distinct variation of the facies and thickness of this formation in each area. The changes of facies and thickness of the Shakubetsu formation in various areas are illustrated in Figure 12.

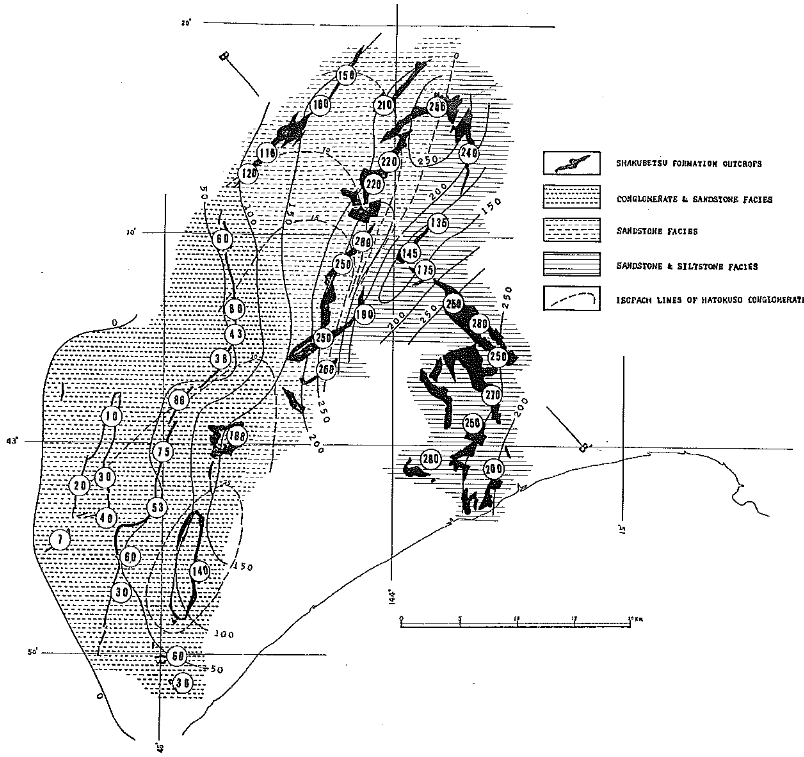


Fig. 12. Isopach and lithologic facies map of the Shakubetsu formation. (Number in circle is the thickness of the formation in each locality).

—Discussion—

The characters of the changes of facies and thickness of the Shakubetsu formation show the same tendency as those of the Yubetsu and Shitakara formations.

A) The changes of the thickness and facies are recognized to take the distinct direction of NEN–SWS.

B) Along the line connecting Okuyubetsu–Takinoue–Kamicharo area found remarkable thick developments of the Shakubetsu formation.

C) Towards the west from the area just mentioned, the thickness decreases and there seems to be a thinning out at the western areas such as at Rushin, Nisho river and the uppermost course of the Charo river areas, but as the base of the Onbetsu group covers this farmation unconformably in these areas, the usual obvious characteristics of thinning out can not be observed.

D) In the areas of the lower course of Shinku-shitakara, Kamishoro and Nuibetsu, which are connected with the south-east of the above mentioned area of thick formation, the thickness of this formation decreases rather suddenly and discontinuously. In the south-east of this area, the thickness is gradually increased. It attains to about 270–280 meters in Shoro–Nakashoro. The direction of the thick part is also NEN–SWS.

E) The changes of lithologic-facies are remarkable in this formation, too. The subdivision of lithologic-facies—conglomerate facies, sandstone-siltstone facies—can be made as illustrated in Figure 12.

F) The good development of "Hatokuso conglomerate" is seen in Tokomuro and Urahoro areas; decreases in thickness and grain size are seen to the north or east. The conglomerate is traceable in the area of the upper course of the Charo and Shoro rivers, with branchings off of several thin layers in these areas, but in the eastern wing of the Yubetsu dome, the Hatokuso conglomerate suddenly decreases, and gradually thins out.

G) Towards the east from the line connecting the Yubetsu dome area and the Shakubetsu–Kamiatsunai districts, the uppermost part of the Shakubetsu formation bears beds crowded with *Ostrea* and *Corbicula* remains, 10+ meters thick. Towards the west from the above mentioned line, on the contrary, these facies are not seen; the base of the Onbetsu group unconformably covers the Shakubetsu formation. In these areas, the eroded surface of the latter is observed. In the more western area—the upper course of the Chikupenninai—the Omagari member covers the Shitakara formation and Yubetsu formation, and at the uppermost course of this river, it unconformably covers the Tenneru formation. The same relation of the Onbetsu and Urahoro groups is seen in Tokomuro area, too.

H) In Yubetsu, Kamicharo and Shoro areas the uppermost part of this formation contains numerous remains of *Ostrea* sp., *Corbicula* spp., *Mytilus* sp., and a few *Macoma* sp. This fact affords evidence that the marine water influenced this horizon near this area. This tendency is supported by the discovery of *Ostrea* sp, from almost all horizons of these formations in the area of the course of the Kamishoro.

I) From the above evidences, it can be conjectured that the gradual change of facies, from the lower to the upper part of the Shakubetsu formation, brackish→fresh→brackish (a part marine), increases from the eastern to the western part of this coal field.

—Summary discussion of the characteristics of facies and thickness of the upper part of the Urahoro group—

The writer considers the Yubetsu, Shitakara and Shakubetsu formations as the upper part of the Urahoro group. As already described, the gradual facies change of this part is as follows: fresh water→brackish water→marine water→brackish water→fresh water→brackish water (a part marine) in decending order.

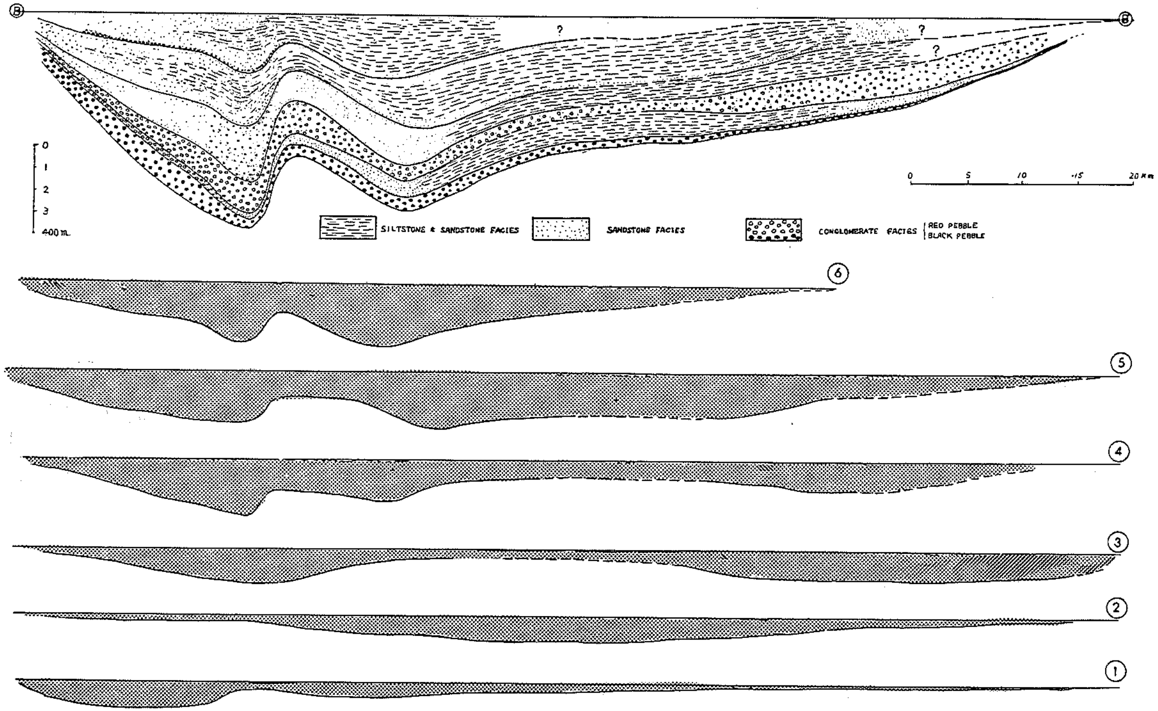


Fig. 13. Geological section of Urahoro group (B–B′ section in Fig. 4, 5, 6, 8, 10 & 12).

① Beppo formation	② Harutori formation
③ Tenneru formation	④ Yubetsu formation
⑤ Shitakara formation	⑥ Shakubetsu formation

Each formation or member is composed of coarse grained crastic facies in the western area, and changes gradually to finer grained facies to the east. On the other hand, characteristics of areal changes in thickness of these formations are almost imutable as shown by isopach lines of the above mentioned Figures.

The characters which attact attention are that, in spite of the fact of repeated facies changes—marine facies→brackish facies→fresh water facies, the subsiding shown in the horizontal continuity of the facies and the changes of thickness of each formation, did not disrupt these same characteristics. This continuity is shown in Figures 8, 9 and 11.

The writer wishes to characterize this 2nd stage as having the fundamental characteristics of elongated directions of the subsiding movement and sedimentation. This stage continued into a general subsidence as shown in the Onbetsu group.

The geological section of the Urahoro group is illustrated as in Figure 13.

§ 6. Changing of lithologic-facies, bio-facies and thickness of the Onbetsu group through the ages.

The Onbetsu group is composed of marine deposits, consisting almost entirely of siltstone and sandstone; it overlies the Urahoro group, with a slight unconformity in the western part of this basin, or almost conformably in central part of it. The group is well developed in the central and western parts of the Kushiro sedimentary basin, but in the eastern part of the basin it is eroded out unconformably with the Neogene Tertiary or Quaternary deposits.

On the other hand, in the western margin of this coal field, as may be observed in the middle or upper tributaries of the Honbetsu river, the Onbetsu group is developing farther to the west than the occurrence of the Urahoro group.

The group is divided into two formations as follows:

Onbetsu group	Nuibetsu formation:	Alternation of dark gray tuffaceous sandstone and light gray siltstone, containing pyroclastic grains, and sometimes intercalated with thin and thick tuff-breccia or agglomerate in the middle and upper parts.
	Charo formation:	
	Charo member:	Dark gray siltstone, intercalated with marly layers and nodules, calcareous bands, thin tuff layers.
	Omagari member:	Greenish gray sandstone, intercalated with thin conglomerates at the basal part, upper part gradually becomes fine grained and transforms to the Charo member.

The leading characteristic of the Onbetsu group will be grasped as an indication of the conspicuous subsidence of the Kushiro coal field: that is to say, this group represents a developmental stage of the sedimentary basin.

I) Charo formation

A) Omagari member:

This member is the basal part of the Charo formation, composed chiefly of greenish gray fine to medium sandstone and includes partially interbedded thin, fine conglomerate.

The upper part of the member is made up of fine sandstone, silty sandstone or platy alternation of them. The conglomerate of this member has commonly "Hatokuso" character, but its liparitic pebbles are remarkably fewer and smaller than those of the Shakubetsu formation. In the central part of this coal field, the Omagari member consists commonly of greenish gray platy sandstone containing numerous marine molluscan fossils, many marly nodules in which marine molluscs are included, sand pipes, "Genno-ishi", coal patches, fine pebbles and glauconite grains.

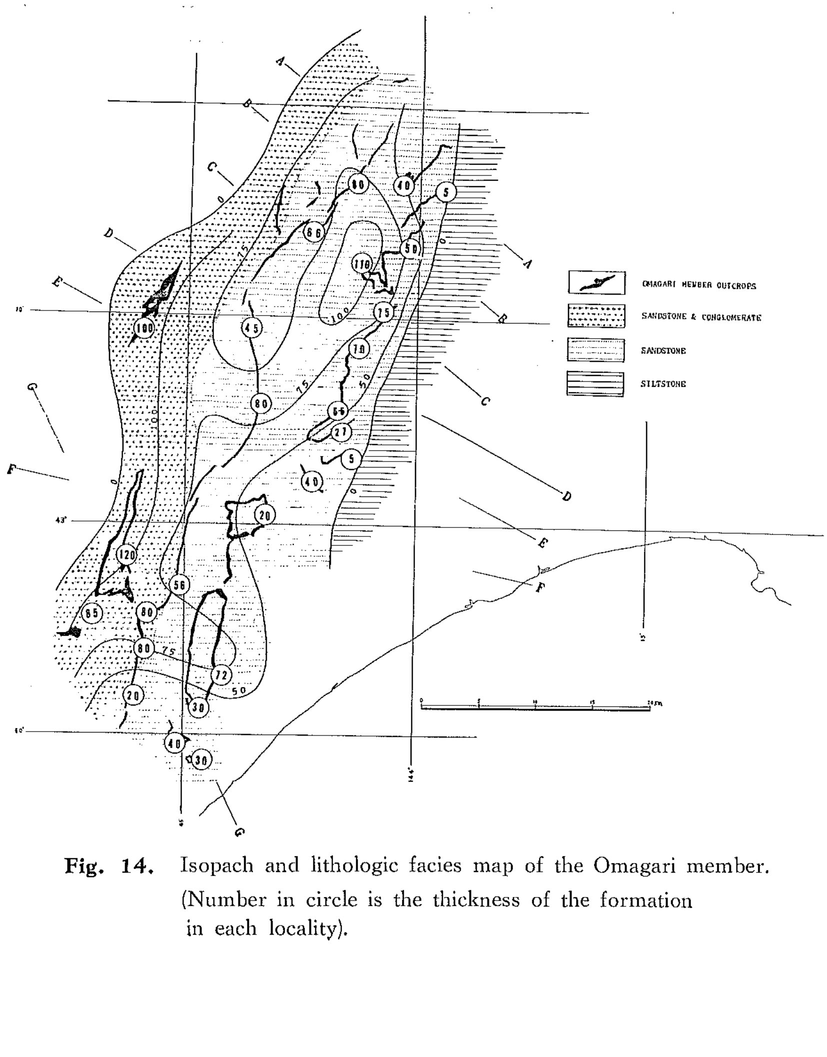


Fig. 14. Isopach and lithologic facies map of the Omagari member. (Number in circle is the thickness of the formation in each locality).

The lateral changes in the lithologic-facies and thickness are rather conspicuous in the western part of the field where the whole member becomes coarse grained, but it is generally known that marine mollusca are included through the whole area.

The changes of facies and thickness of the Omagari member in various area can be illustrated as in Figure 14.

B) Charo member:

The main part of the Charo formation consists of dark gray siltstone of marine facies in which are found a considerably large quantity of calcareous nodules, "Genno-ishi", sand-pipes, sandstone dykes, marine molluscs and foraminiferal fossils. It contains in certain parts fine-grained sandstone and thin tuff layers. In the lower part of the Yubetsu and Kamishoro area, is developed a grayish white tuff layer several meters thick.

In the western marginal districts of this sedimentary basin—the Tokomuro & Honbetsu river areas—, this formation consists of sandy facies and is very much akin to the Omagari member. But, they can be distinguished from one

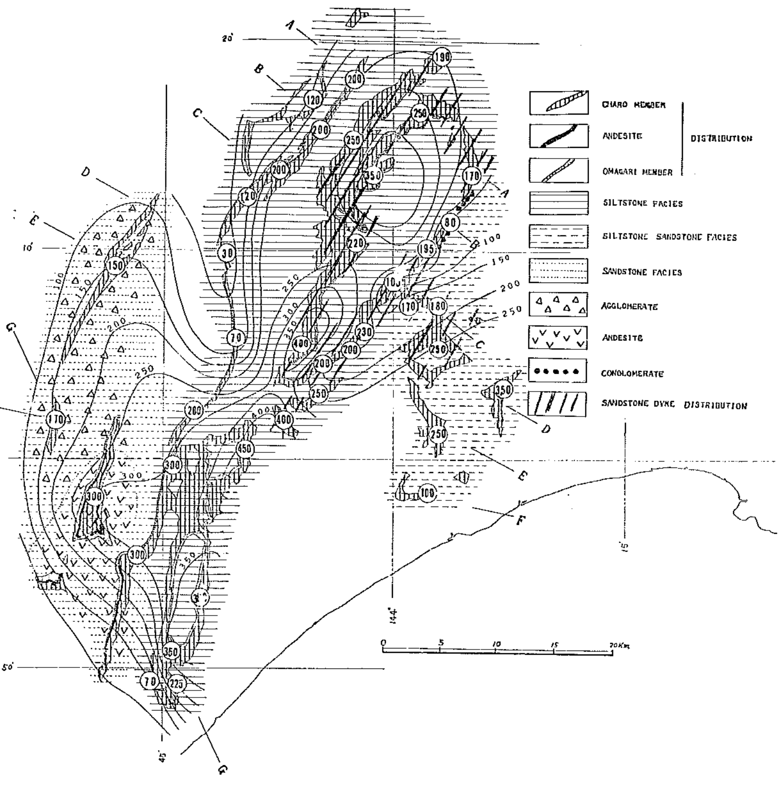


Fig. 15. Isopach and lithologic map of the Charo formation. (Number in circle is the thickness of the formation in each locality).

another by the following characters: andesitic lava layer, tuff breccia beds and agglomeratic conglomerate several tens of meters thick, developed at the basal part of the Charo member; the conglomerates under these pyroclastic layers, contain liparite pebbles, that is they have "Hatokuso" character, whilst on the other hand, the upper part has no such character.

In the eastern districts—Akan and Shoro zones—the formation consists of sandy siltstone and intercalates many light gray fine to medium sandstone layers, thin and thick; at the same time the formation contains only rather few molluscan fossils. Such fossils obtained from various area in this formation are listed in Table 7. The changes of the thickness and lithologic-facies of the Charo formation are illustrated in Figures 15 & 16.

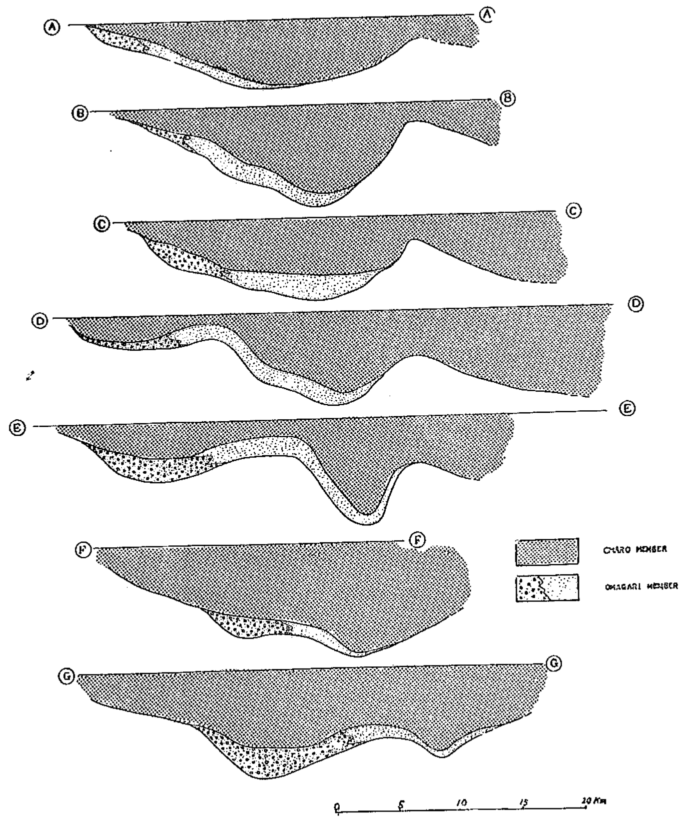


Fig. 16. Geological sections of the Charo formation, illustrating the changes in thickness.
(Each section corresponds with sections indicated in Figure 15).

II) Nuibetsu formation:

This formation is the most widely distributed among the Paleogene sediments of the Kushiro coal field. It consists of an alternation of black tuffaceous sandstone and light gray rather hard tuffaceous siltstone. The siltstone contains partially siliceous hard shale, marly nodules, marly lenses or layers. The sandstone consists of quartz, feldspars and idiomorphic mafic minerals such as augite, hornblende and others of volcanic origin. This pyroclastic sandstone layer gradually or discordantly changes to tuff-breccia horizontally and perpendicularly. The distinguishable development of tuff-breccia can be traced from the upper tributary area of the Akubetsu river, at the northeast edge of this field, to the Omagari area of the middle course of the Charo river via Yubetsu, Kamishoro, Nuibetsu areas, forming an arcute zone. The regional characteristics of the alternation of siltstone, sandstone and tuff breccia are conspicuous in the area developing the tuff breccia. The sandstone/siltstone ratio is very high and from the northwest or south-east refinds that the siltstone facies becomes more predominant as illustrated in Figure 17.

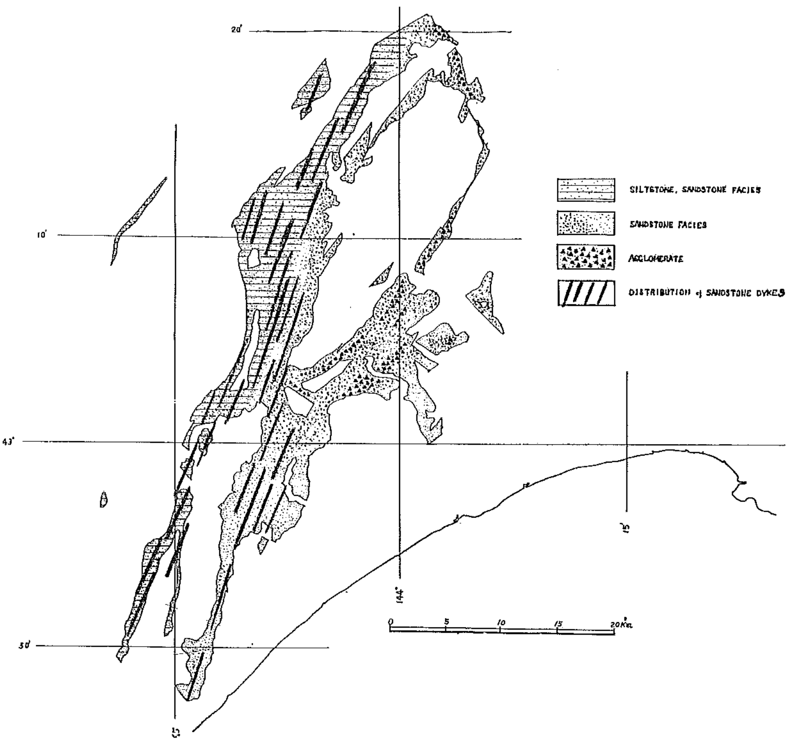


Fig. 17. Lithologic facies map of the Nuibetsu formation.

In the part of alternated siltstone and sandstone, intraformational foldings, large or small in scale, are developed. In the western districts of the Kamicharo–Tokomuro synclinal zone, numerous sandstone dykes frequently are intruded into both the Charo and Nuibetsu formations. The sandstone making up these dykes is quite similar to the black pyroclastic sandstone composing the Nuibetsu formation itself. The molluscan fossil contents of the formation, as shown in Table 7, vary with locality within the formation.

III) Paleoecological analysis of the Onbetsu fauna:

In the Onbetsu group, molluscan fossils are found scattered throughout almost every horizon. The majority of the species, as *Yoldia*, *Portlandia*, *Venericardia*, *Turritella*, *Trochocerithium*, *Periploma*, and so on are not restricted to any one locality or particular horizon; however, some species such as *Neptunea*, *Macoma*, *Tectonatica*, *Ampulina*, *Nemocardium*, *Acila*, *Ancistrolepis*, *Turcicula*, *Neopsephaea*, *Propeamusium*, *Solemya* and so on are found only in restricted localities and positions within the formation.

So far as the collected materials as concerned, it is evident that the Onbetsu fauna has no typical brackish water genera, that is, no genera which lived in the supertidal zone, except the lower part of the Omagari member. Also it should be stated that specimens are always with intact valves in upright position, and in thier natural living position; those occurring as isolated examples and those occurring only as fragments are restricted to the basal coarse sandstone and conglomerate part of this group. The nature of the sediments entombing the fossils is in harmony with the state of fossil-occurrences.

From the above mentioned facts, it is inferrible that physical phenomena such as currents sufficiently strong for long distance transportation of the shells did not exist.

The paleoecological distribution of the molluscan fossils is particularly obscure, and consequently the data available for deducing for ecology of Oligocene species are almost non-existent. However, it is fortunate that knowledge concerning the geographical distribution, bathymetrical range, thermal gradient and local ecological features is gradually accumulating.

The principal contributions to such problems have been made mainly by OYAMA (1952), TAKEDA (1953), MINATO (1953), KANNO (1960), HIRAYAMA (1955), OMORI (1955), MINATO & UOZUMI (1957) GEKKEL, P. H. (1957) and others. Although knowledge is not complete, according to data presented in these previous works the main species of the Onbetsu fauna may be analysed on the basis of their bathymetrical range as above shown in Table 6. However this analysis is very tentative because the depth of habitate of various widely living species with water temperature, salinity and other ecological conditions. On the basis of quantitative consideration of the Onbetsu molluscan fanna, the assemblages of molluscan fossils found at each point vary with locality and position within the formation; they can be subdivided into 5 types from their indicated bathymetrical ranges as follows:

(I) Fossil assemblage of *Ostrea*, *Corbicula*, *Batissa*, *Tectonatica*, *Ampulina*, *Mya*, *Linthia*, *Olivella*, *Molopophorus*, *Scaphander* and *Macoma*. (Nt–N 1).

(II) Fossil assemblage of *Epitonium*, *Neptunea*, *Nemocardium* and *Venericardia*. (N1–N 2).

(III) Fossil assemblage of *Venericardia*, *Turritella*, *Yoldia*, *Portlandia*, *Nuculana*, *Malletia*, *Neopsephaea* and *Acila*. (N2–N3).

Table.7 The Fossil Fauna of the Onbetsu Group

Locality Numbers correspond with those of the Table 4.

formation	OMAGARI																	
Species / Occurence	8	11	1	2	3	4	5	6	7	17	21	22	23	24	33	34	36	37
Solemya tokunagai Yokoyama				R														
Acila (Acila) vigilia (Schench)				R														
Acila sp (osugii type)		R								R		R			C			
Nuculana sp (pseudoscissurata type)	R				R													
Nuculana sp	R										R	R					R	
Yoldia (Yoldia) laudabilis Yokoyama		A	C	C	C	C	C		A	A	C	C	C	C	C	C	R	C
Yoldia (Tepidoleda) sobrina Takeda		C								C								
Portlandia (Portlandia) watasei (Kanehara)	C	C		C	R					A								
Portlandia (Megayoldia) ovata (Takeda)	C																	
Malletia poronaica (Yokoyama)																		
Lima sp																		
Ostrea praegravitesta Takeda							C							R				
Mytilus sp											R							
Propeamusium kusiroense Takeda																		
Clinocardium asagaiensis Makiyama	C	R	C	C						R	C			C		R	C	
Nemocardium ezoense Takeda	C		C	C	C						R		C					
Nemocardium yokoyamai Takeda	A		C		R			C			R		C					C
Corbicula tokudai Yokoyama				R		C					A	C			A	A		
Batissa shitakaraensis (Suzuki)						R					R							
Conchocele bisecta (Conrad)		C		R						C	C	A			R		R	C
Lucina sp.																		
Periploma besshoensis (Yokoyama)	C	R			R					R	C							
Venericardia ezoense Takeda																		
Venericardia expansa Takeda		R		C	R					A	C				R	R		
Venericardia elliptica Takeda	C	C						C	C		C	C			R	C	R	
Venericardia tokudai Takeda	C	R						C							R		R	
Venericardia akagii Kanehara							C											
Macoma sejugata (Yokoyama)	R	C		C	A	A	A	C		C	A			C		C		
Macoma asagaiensis Makiyama		C			A	A	A	C		C	A			C		C		
Hubertschenckia ezoensis Takeda																		
Spisula sp	R										R			R	R			
Solen sp	R																	
Mya kusiroensis Makiyama	C			C	A						A	C			A	R	R	
Turritella poronaiensis Takeda	R	R								C								
Trochocerithium wadanum (Yokoyama)	R																	
Neptunea shitakarensis Matsui								C			R							
Neptunea modestoidea Takeda		C									C							
Neptunea ezoana Takeda		C									C							
Neptunea subcarinata Matsui																		
Neptunea onbetsuensis Matsui	R				R		C									C		R
Neptunea dispar Takeda																		
Buccinum sp.																		
Ancistrolepis japonicus Takeda																		
Molopophorus kusiroensis Takeda																		
Molopophorus shitakarensis Matsui																		
Scaphander multistriata (Takeda)																	R	
Scaphander ezoana Matsui																		
Epitonium (Gyroscala) poronaiensis Matsui	R																	
Olivella ezoana Matsui																		
Neopsephaea antiquior Takeda																		
Turcicula sakhalinensis Takeda																		
Turricula shitakarensis Matsui								R										
Tudicula japonica Takeda																		
Tudicula ishii Matsui																		
Spirotropis (Antiplanes) yubetsuensis Matsui																		
Spirotropis (Antiplanes) rugosa Takeda				C														
Ampulina asagaiensis Makiyama																		
Tectonatica sp.	R	R			R	R	C	R			R					R	R	
Dentalium nunomae Takeda				C							C							
Simple coral																		
Linthia yessoensis Minato																	R	R
Ophiuroidea sp.											C						R	
Callianassa muratai Nagao					C													

formation	CHARO																										
Species / Occurence	8	9	11	1	2	3	5	17	18	19	20	21	24	25	25	25	26	27	28	30	33	34	36	37	38	39	41
Solemya tokunagai Yokoyama					R														R					R			
Acila (Acila) vigilia (Schench)				R	C	R	R	C			A	A			A				C	R					R		
Acila sp (osugii type)	C															R											
Nuculana sp (pseudoscissurata type)						R																					
Nuculana sp	R	C				R			R			C				R								R			
Yoldia (Yoldia) laudabilis Yokoyama		C	C	C	C	R		C	C	C		C	C	C	C	C	R	C	C	C	C	A	R	C	C		C
Yoldia (Tepidoleda) sobrina Takeda	C	C	C		C	R							C	C	C	C	R	C	R	R							
Portlandia (Portlandia) watasei (Kanehara)	C			C	C			C		C		C		C	C	C			C	C	C			C	C		
Portlandia (Megayoldia) ovata (Takeda)					C						R		C	C	C	C	C	C	R								
Malletia poronaica (Yokoyama)	C		R	R	R			C	R		A	C		C	C		C	C	C	C	A						
Lima sp																											
Ostrea praegravitesta Takeda						R						R		C		R											
Mytilus sp																											
Propeamusium kusiroense Takeda			R					R	R		C	A		C	R	R	R	C	R						R		
Clinocardium asagaiensis Makiyama	C	C							R			A						R			R						
Nemocardium ezoense Takeda															C												
Nemocardium yokoyamai Takeda		C												C	R				R								
Corbicula tokudai Yokoyama																										R	
Batissa shitakaraensis (Suzuki)												R															
Conchocele bisecta (Conrad)	R		R		R												C	C			R			A	R		
Lucina sp.									R																		
Periploma besshoensis (Yokoyama)	C	R	C					C				A	C	C	C	C	R	C	C	C				C	C		
Venericardia ezoense Takeda		C	C		C	C	R	A	C	C	C	C	C	C	C	C	R	C	C		R						
Venericardia expansa Takeda		C	C		R	C	R	C		C	C	C	C				R		C		R	A	R	C	C		C
Venericardia elliptica Takeda			R		C				C	C		C	C						C			C				R	
Venericardia tokudai Takeda				C					R			C	R						C							R	
Venericardia akagii Kanehara	C	A			R	R		R	R	C		C		C	C	R			C	C	R				R		R
Macoma sejugata (Yokoyama)		A				R			R	C	C	C		C	C	R				R						R	
Macoma asagaiensis Makiyama														R			R										
Hubertschenckia ezoensis Takeda		R																						C			
Spisula sp																											
Solen sp																											
Mya kusiroensis Makiyama																						R	R				C
Turritella poronaiensis Takeda	C	C	C					C	R	R	C	C	C	C	C	C	A	C	C	C	C	C	R	C			
Trochocerithium wadanum (Yokoyama)	R	R		R	C	C	R	R	R		C	A				C			C	R		C	C	C	R	R	
Neptunea shitakarensis Matsui		C				R									R												
Neptunea modestoidea Takeda				R	C					C		C		R	C	R			C								
Neptunea ezoana Takeda				C								R		C	C	C		C	C		C	R	R	C			
Neptunea subcarinata Matsui												R							R		C	R	R				
Neptunea onbetsuensis Matsui		R					R				C	C		C	R	R	A	C	R	C	C	C		R	R		
Neptunea dispar Takeda																R											
Buccinum sp.								R																			
Ancistrolepis japonicus Takeda			R					C	R			R	R				R	R	R					C	R		
Molopophorus kusiroensis Takeda								C	R				R														
Molopophorus shitakarensis Matsui								R					R														
Scaphander multistriata (Takeda)	C		R					R			C	R	R						R	R	R			R			
Scaphander ezoana Matsui											R	R								R	R			R	R		
Epitonium (Gyroscala) poronaiensis Matsui										R		R							R	R	R						
Olivella ezoana Matsui	R							C			C		R					C									
Neopsephaea antiquior Takeda							R	C	R		R		R					R	R	R	R	R	R	R	R		
Turcicula sakhalinensis Takeda													R						R								
Turricula shitakarensis Matsui																											
Tudicula japonica Takeda																			R								
Tudicula ishii Matsui																											
Spirotropis (Antiplanes) yubetsuensis Matsui													R												R		
Spirotropis (Antiplanes) rugosa Takeda																R	R								R		
Ampulina asagaiensis Makiyama					R					C						R	R		C	R	C			C			
Tectonatica sp.			R	R			R		R				R				R					R	R			R	R
Dentalium nunomae Takeda	C				C	C			R	C	C	C	C				A		C	R	R						
Simple coral											R																
Linthia yessoensis Minato																											
Ophiuroidea sp.															R												
Callianassa muratai Nagao			C			C		C			C	R				R	R	C			C	R	A				

formation	NUIBETSU																		
Species / Occurence	11	2	5	6	7	17	18	2	6	24	26	27	28	30	33	34	36	37	38
Solemya tokunagai Yokoyama		R	C					R										R	
Acila (Acila) vigilia (Schench)		C	C	C	C			C	A	A	R		C			C			
Acila sp (osugii type)			R	R			R						C				R		
Nuculana sp (pseudoscissurata type)																			
Nuculana sp									C		R	R			R		R		
Yoldia (Yoldia) laudabilis Yokoyama			C	C	C	C			R	R	R								
Yoldia (Tepidoleda) sobrina Takeda		C	C		C	C		R	R	C			C			R	R		R
Portlandia (Portlandia) watasei (Kanehara)			C	C	C	C		C	C	A			C			C	R		
Portlandia (Megayoldia) ovata (Takeda)									C	C			C		C	R	R		
Malletia poronaica (Yokoyama)		R	C	C	C	C		C	C	C		C	C			C	A		R
Lima sp					R							R							
Ostrea praegravitesta Takeda												R	R						
Mytilus sp																R			
Propeamusium kusiroense Takeda				R					C		R		C	R				R	
Clinocardium asagaiensis Makiyama															R		R		
Nemocardium ezoense Takeda																			
Nemocardium yokoyamai Takeda																			
Corbicula tokudai Yokoyama																			
Batissa shitakaraensis (Suzuki)																			
Conchocele bisecta (Conrad)	C		C			C					R	C	C		R				
Lucina sp.									R						R			R	
Periploma besshoensis (Yokoyama)			R	C				C	C	C		R	C		R		R		
Venericardia ezoense Takeda				C	A	C		C		C		C	C						
Venericardia expansa Takeda		R		C	A			C	C	C	C	C	C	R		C	C		
Venericardia elliptica Takeda		C						C				C	C	R	C		R		
Venericardia tokudai Takeda			C		C								R		C	C	R		
Venericardia akagii Kanehara																			
Macoma sejugata (Yokoyama)					R						R		R	R					
Macoma asagaiensis Makiyama																			
Hubertschenckia ezoensis Takeda	A					R													
Spisula sp																			
Solen sp																			
Mya kusiroensis Makiyama																R	R		
Turritella poronaiensis Takeda	C	R	C	C		C		C	C	R	A	C	C	C	R	C	C		
Trochocerithium wadanum (Yokoyama)					R	C			R		R		C				C	R	
Neptunea shitakarensis Matsui																R			
Neptunea modestoidea Takeda		R									R		R				R		
Neptunea ezoana Takeda									R				C		C	R	R		
Neptunea subcarinata Matsui										R			R		C				
Neptunea onbetsuensis Matsui									R		C		R						
Neptunea dispar Takeda									R	R			R		R		R		R
Buccinum sp.						R													
Ancistrolepis japonicus Takeda						C	R	C	R	C			R		R		R		
Molopophorus kusiroensis Takeda																			
Molopophorus shitakarensis Matsui																			
Scaphander multistriata (Takeda)		R	R	R			R		R			R					R		
Scaphander ezoana Matsui		R		C					R	R		C	R						
Epitonium (Gyroscala) poronaiensis Matsui																	C		
Olivella ezoana Matsui		R									R		R						
Neopsephaea antiquior Takeda																	R		
Turcicula sakhalinensis Takeda																	R		
Turricula shitakarensis Matsui		R											R						
Tudicula japonica Takeda									R								R	R	
Tudicula ishii Matsui		R						R			R								
Spirotropis (Antiplanes) yubetsuensis Matsui											R								
Spirotropis (Antiplanes) rugosa Takeda											R								
Ampulina asagaiensis Makiyama	R	R														R	R		R
Tectonatica sp.		R		C	C			C			R				R	C	R		R
Dentalium nunomae Takeda																			
Simple coral																			
Linthia yessoensis Minato												R							
Ophiuroidea sp.																			
Callianassa muratai Nagao						C					C	C							R

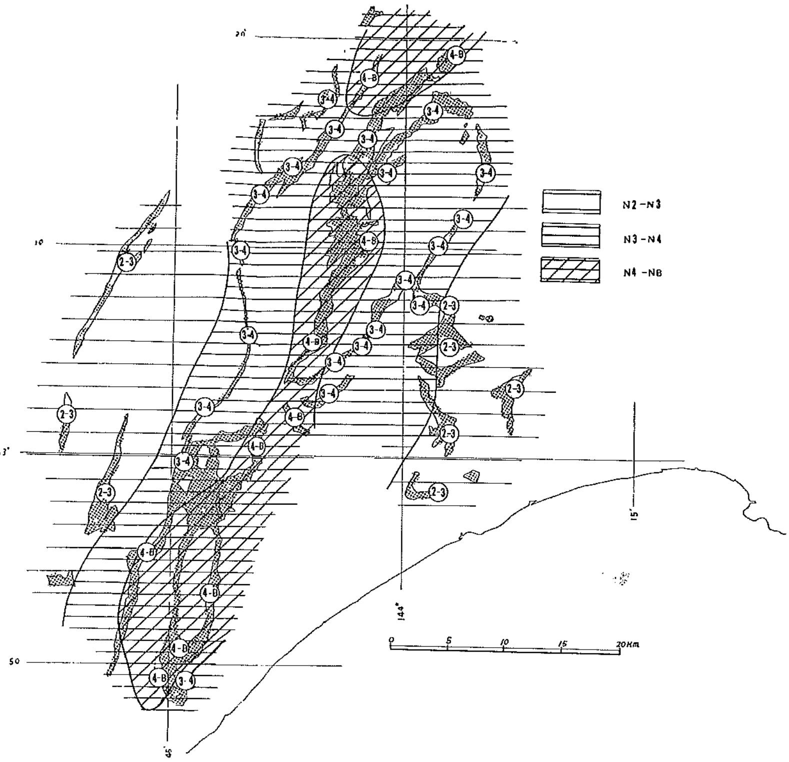


Fig. 18. Biofacies map of the Charo formation.
N2: Mesoneritic zone. N3: Subneritic zone.
N4: Bathyneritic zone. Nb: Hemibathial zone.

(IV) Fossil assemblage of *Acila, Ancistrolepis, Callianassa, Spirotropis,* and *Turcicula.* (N3–N4).

(V) Fossil assemblage of *Spirotropis, Turcicula, Solemya* and *Propeamusium.* (N4–N5).

On the basis of the above given bathymetrical analysis, the Onbetsu fauna presents a mixture of both rather cool (shallow and inland sea type), and cold (deep and open sea type) water habitants.* That is to say the Onbetsu sea was probably not very deep; its depth changed regionally and periodically, and the sedimentary environments changed gradually from conditions favorable for inner bay to those for open sea habitants, for the duration of the deposition of the Onbetsu group, as illustrated in Figures 18, 19, 20a, 20b, 20c and 20d.

The characteristics of the lithologic-facies, bio-facies and thickness of the Onbetsu group may be summarized as follows:

A) This group spreads to the western pre-Cretaceous area in an overlapping way. At the same time the deepest part of the Onbetsu sea and the thickest deposited area moved to northwest from southeast.

* In the Onbetsu sea, the warm thermal condition, which prevailed at the time of the middle and lower Shitakara stage, did not exert influence.

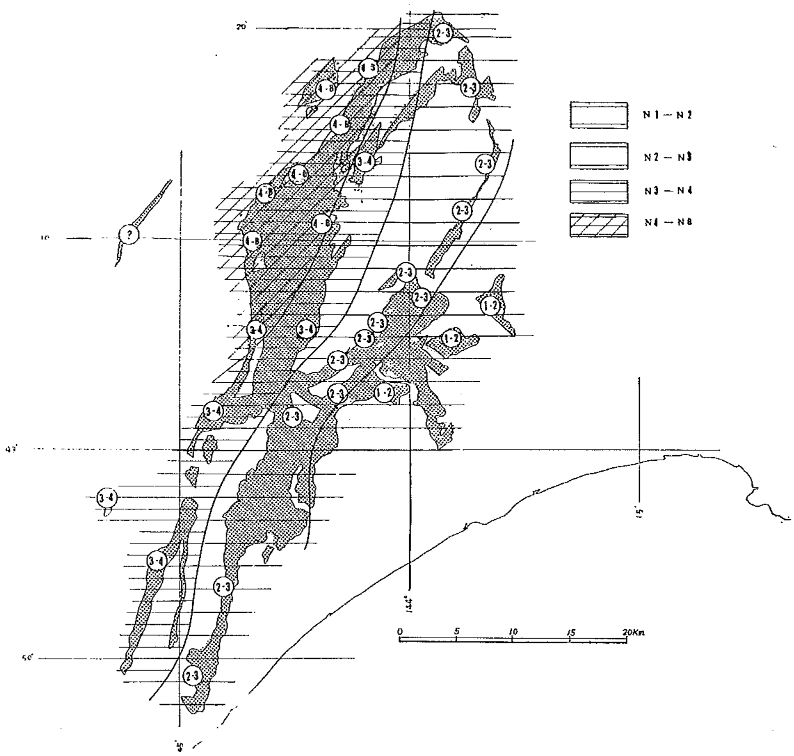


Fig. 19. Biofacies map of the Nuibetsu formation.
N1: Euneritic zone. N2: Mesoneritic zone.
N3: Subneritic qone. N4: Bathyneritic zone.
Nb: Hemibathial zone.

B) Just to the west of the line connecting Okuyubetsu with Omagari on the Charo river (axis of the Yubetsu–Shakubetsu anticlinal zone) is the Omagari member developed. The change in thickness and lithologic-facies takes the direction of NEN–SWS.

C) The Omagari member contains "Hatokuso" conglomerate and by this feature is distinguished from the lower part of the Charo member in the western marginal area. The lower half of the Charo formation consists of andesitic tuff breccia or agglomerate in the southwestern part of the basin.

D) The main part of the Charo formation (Charo member) consists chiefly of dark gray siltstone in the whole area, but is intercalated with rather numerous sandstone layers in the eastern area (Akan-Shoro zone), pyroclastic sandstone or conglomerate facies in western, Honbetsu and Rushin areas. The regional changes of lithologic facies are in harmony with bio-facies analysis as illustrated in Figures 13 and 15.

E) The Charo formation has the same distinct direction as that of the upper part of the Urahoro group. Along the Okuyubetsu–Omagari line are found remarkable thick developments. Towards the west from this area, the

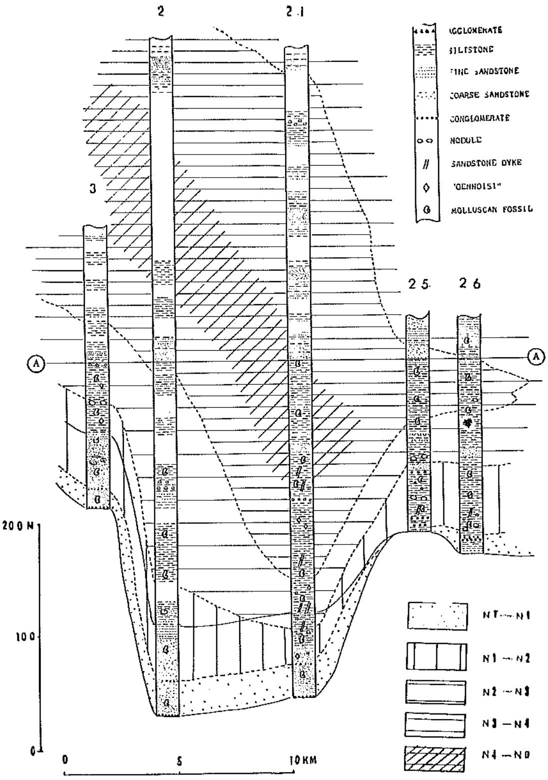


Fig. 20 a~d. Colmnar sections of the Onbetsu group, showing vertical succession of biotopes.

1) Locality numbers are correlated with those of Table 4 and Figure 3.

2) Each section coresponds with section in figure 15. These A–A′BB′C–C′D–D′ lines mean the base of Nuibetsu formation.

thickness decreases; on the other hand in the area Kamishoro–Nuibetsu which is connected with the part to the south-east of the above mentioned line, is seen a remarkable thin formation; this change of thickness is rather sudden. In the south-eastern part of this basin, namaly in the Akan–Shoro area, this formation consists of sandy siltstone alternating with sandstone layers.

F) The characteristics of regional and periodical changes of lithologic-facies and bio-facies show that the most deep area (N4–Nb) occurs in the west wing of the Yubetsu–Shakubetsu anticlinal zone, and to the north-west or south-east from this area, the bathymetrical depth reaches only N2–N3. This is illustrated in Figures 18 & 20 a–d.

G) In the Yubetsu–Omagari anticlinal zone, namely the area where the thickest formation was deposited, or where the most rapid sinking occurred, there develop sandstone dykes, intraformational foldings, minor and planeless faults. The evidence afforded by lithologic and bio-facies and thickness of the

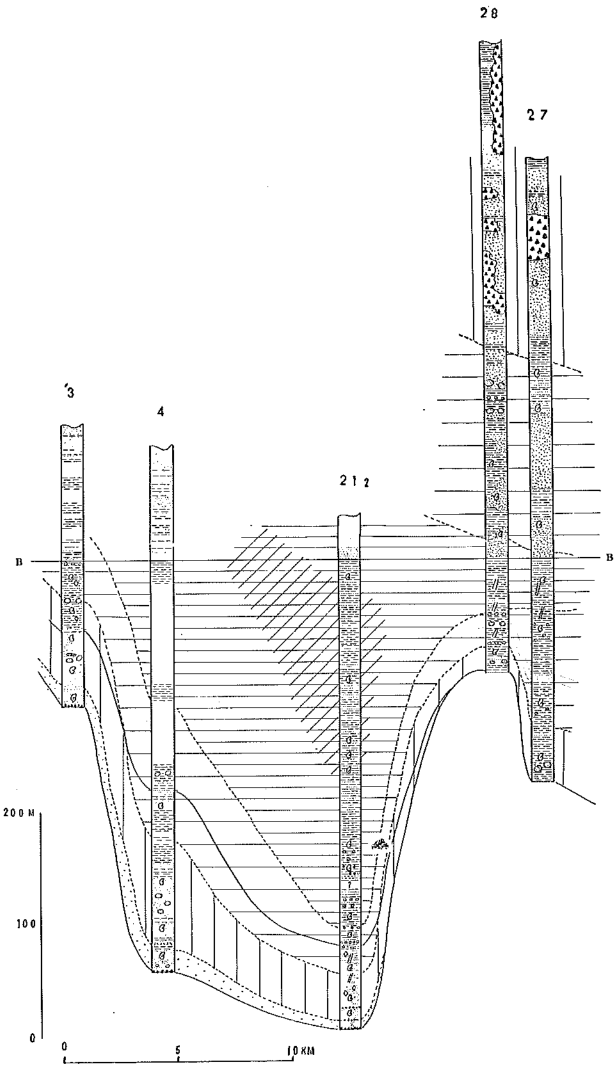


Fig. 20 b.

lower part of the Onbetsu group (Charo formation) shows that the actualities which are indicated in the areal difference of basemental sinking and deposition, were continued in this stage, too. Further, such items of evidence as sandstone dykes, intraformational foldings and faultings indicate that this basin was subjected to stages of rapid subsidence in the whole area, partial small scaled rising and sinking, irregular deposition, folding and faulting during the sedimentation, after the quiet subsiding upper Urahoro stage.

H) The lithologic-facies of the upper part of the Onbetsu group—Nuibetsu formation—has the characteristic, as illustrated in Figure 17, of the tuff breccia facies which develops in the Akubetsu–Kamishoro–Nuibetsu–Omagari arcuate

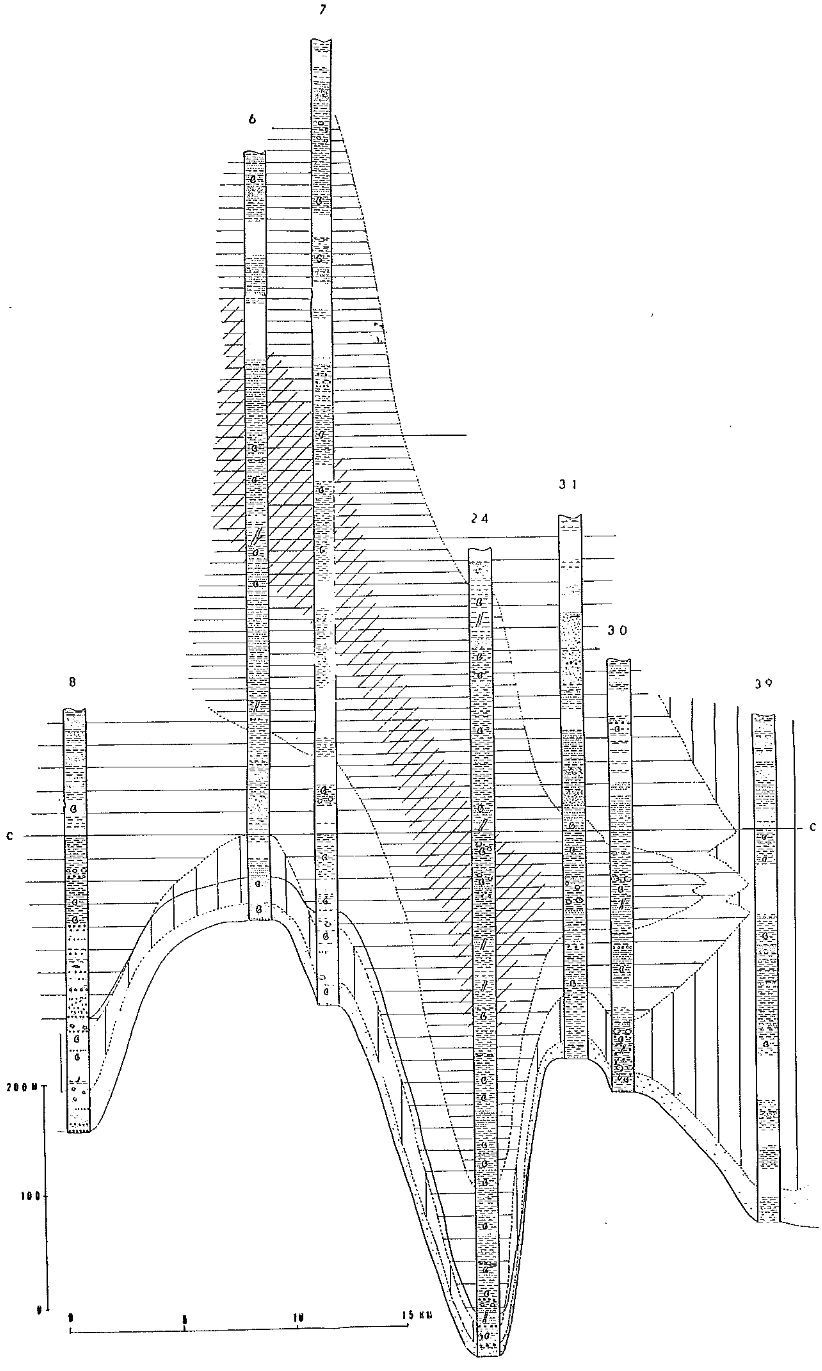


Fig. 20 c.

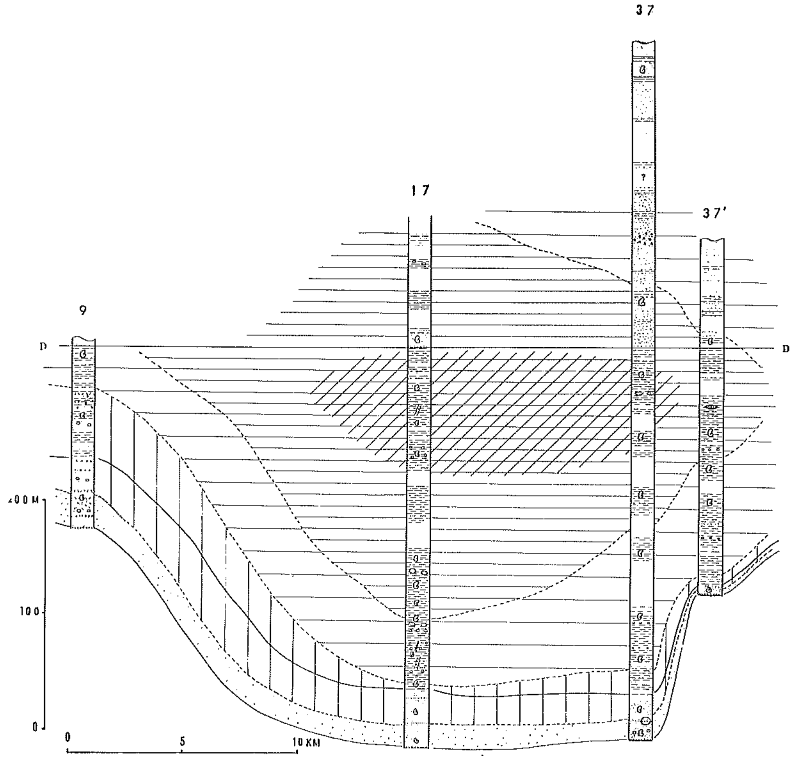


Fig. 20 d.

zone. To the north-west or south-east from this zone, the sandstone/siltstone ratio decreases gradually.

I) The bio-facies section of the Charo Nuibetsu formations show the deepest area was transported gradually to the Ukotakinupuri–Rushin zone from the Yubetsu–Shakubetsu zone, namaly from east to west. This change of facies of the Nuibetsu formation is illustrated in Figures 18, 19 and 20 a–d. The position and direction of this tuff breccia erupted zone coincides with the main direction in which the most thick formation was deposited, during the deposition of the Yubetsu–Charo formations as already discussed and illustrated.

J) Aa for the occurrence of sandstone dykes, intraformational foldings and faultings, transport to the west wing of the Kamicharo–Tokomuro synclinal zone from the Yubetsu–Shakubetsu anticlinal zone during the Charo and Nuibetsu ages, these diastrophic movements were accompanied with rapid sinking movements.

K) In the age of the Nuibetsu formation, the basin spreaded widely to the north-west and the deepest sinking area shifted to the west; this Paleogene sedimentary basin attained to the maximum of sinking-developmental stage, and was about to upheave and undergo orogenic movements.

§ 7. Relation between tectonic and sedimentary facies, and the thickness of formations in the Kushiro sedimentary basin

As stated above, the development of intraformational folding, planeless faulting and sandstone dykes in various horizons and areas of this sedimentary basin are closely connected with the sedimentational features of the basin. The relation of the structural movements during the process of sedimentation to the facies and thickness of the formations which make up the Kushiro sedimentary basin, may be summarized as follows:

A) The intraformational foldings are observed a) in the uppermost part of the Tenneru formation in the Senposhi peninsula, b) in the upper Charo- lower Nuibetsu formation in the Ukotakinupuri-Rushin and Kamicharo-Tokomuro zones.

B) The planeless faults develop at the heterogeneous facies of the uppermost Charo and Nuibetsu formations in the Yubetsu-Kamicharo dome area.

C) The sandstone dykes intrude in rather crowded manner a) in the Yubetsu-Beppo formations in the Konbumori-Kushiro areas in the Shitakara stage; b) in the Yubetsu-Shiranuka districts in the Charo stage; c) in the Ukotakinupuri-Rushin and Kamicharo-Tokomuro areas in the Nuibetsu stage. The petorographical features of these sandstone dykes are quite like the sandstose layers of Shitakara, Charo and Nuibetsu formations. The dykes contain foraminiferal and molluscan fossil fragments which indicate their ages, too.

These structural movements during the process of sedimention, occurred in some areas where the most sudden disturbance in sedimentation evidently took place. They were moving to the west from the east as already mentioned. Then the present writer propeses to call these structural movements in the sedimentational stage "the structural movements in embryonal stage".

The geological structures of this sedimentary basin, which was formed in the stage of upheaving or during its existence as a sedimentary basin, as already mentioned in § 4, have been controlled by these features of sedimentation— that is to say NNE-SSW direction and the position of the folding structures and large scale faultings are in coincidence with the sedimentational features of this basin.

D) The NNE-SSW direction of extension in the geological structure which becomes rather decreasingly obvious from NW to SE, coincides with the characteristics of sedimentary facies and thickness in those areas as above mentioned.

E) Remarkable dome zones are situated at the positions where remarkable thick formations have been deposited, namely;

(A) Akan-Shoro anticlinal zone: the area in which the thick formations of the Yubetsu-Shitakara formations were deposited extending in NNE-SSW direction.

(B) Yubetsu-Shakubetsu anticlinal zone: the area in which the thick formations of the Yubetsu, Shitakara, Shakubetsu and Charo formations were deposited with same direction.

(C) Ukotakinupuri–Rushin anticlinal zone: the area in which the thick formation of the Nuibetsu formation was deposited.

The evidence indicates that "the thick deposited area in the sedimentary stage, upheaves remarkably in the later stages".

F) The boundaries of the thick deposited and thin deposited areas are rather discontinuous, and at such places the large scale faults occur, taking direction parallel with the isopach lines. As the remarkable instance one can see the Yubetsu and Osappe faults, as illustrated in Figure 2. It is obvious that those faults occurred in subordination to the dome-forming movements at the discontinuous positions of changes in thickness and lithologic-facies of formations.

About the details of the relation between sedimentation and the structural movements, the writer hopes to avail himself of an opportunity to make a report sometime in the future.

§ 8. Conclusion

In this paper, there have been described the changing of lithologic-facies, bio-facies and thickness of the Paleogene groups in the Kushiro sedimentary basin, and also the relation between tectonic and sedimentary features of these groups.

At the beginning of the movements of the sedimentary basin, it can be safely said that there were contradictions causing self-movements of the sedimentary basin, as the internal cause which means lithologic-facies and thickness of the formation, and the horizontal change in them.

Next, the process of formation of strata is governed by the upheaving movement of the area; this movement is reflected by the distribution of facies and thickness of formations. Accordingly, the study of the process of the development of strata, the formation of the geological structures, can only be conducted in conjunction with a study of the continuity and discontinuity of facies and their thickness.

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