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Upper Cretaceous fore-arc basin sequences in Northeast Japan: large-scale controlling factors as eustasy, volcanism and relative plate motion

Hisao Ando

Department of Environmental Sciences, Faculty of Science, Ibaraki University, Bunkyo 2-1-1, Mito 310-8512, Japan

ABSTRACT

Cretaceous to early Paleogene Yezo forearc sediments are widely distributed across a 200km-wide and 1400km-long belt in Northeast Japan to south Sakhalin including off the Pacific. Two second-order upward-shallowing cycles (megasequences) for the Cretaceous are recognized through the temporal and spatial distributions of facies successions and sequences by using a total of 26 sections of underground- and undersea-drilling data in addition to the surface sections. Each of two cycles also includes a few third-order and several fourth-order depositional sequences. Since the stacking patterns of the sequences and the timing of their boundaries and key surfaces are broadly concordant with the oscillation of the global esustasy curves, the third- and fourth-order sequences seem to have been formed under the control of global eustasy. Shallow-marine to paralic facies in the late stage of the first cycle is represented by the Mikasa Formation (late Albian to Turonian) in Hokkaido, while the eustasy curves reach the highstand maximum at late Cenomanian. This discrepancy in addition to the southward shift of the depocenter of delta systems may suggest local tectonic movement in the western margin of central Hokkaido. The Campanian to Maastrichtian paralic facies of the second cycle represented by the Hakobuchi Group in Hokkaido and its correlatives in north Honshu, represent a large-scale shallowing trend. This trend and its contemporary igneous activities in the arc and rapid growth of accretionary complexes in the subduction zone, appear to have reflected the directional change of the Kula plate motion near 85 Ma. The uppermost Maastrichtian to Upper Paleocene including the K/T boundary are missing everywhere in the Yezo basin. Two sedimentary cycles characterized by marine to non-marine facies of the late Paleocene and the uppermost Paleocene to lower Eocene, are developed unconformably each other in a few areas. These are possibly related with the slow down of plate motion after 65 Ma and its associated subaerial erosion and igneous activity by uplifting of the arc.

INTRODUCTION

Forearc basin sedimentation is controlled by several factors such as plate tectonic movements, arc volcanisms, forearc accretionary processes and global eustasy on a large scale. Besides them, sediment supply, local tectonics such as basin subsidence and uplift are also important on a middle scale. Their effects are often difficult to be discriminated each other. Their total effects occur as local relative sea-level changes (e.g., Jervey, 1988 and others).

The major objective of this paper is to discuss how these factors controlled the Cretaceous to Paleogene fore-arc basin sedimentation along Northeast Japan to south Sakhalin on the basis of the temporal and spatial distributions of facies successions and depositional sequences. Furthermore, their sedimentary patterns are discussed for reconstructing the sedimentary history and basin evolution of the Yezo forearc.

GEOLOGIC FRAMEWORK IN NORTHEAST JAPAN AND SOUTH SAKHALIN

The pre-Neogene geologic framework of Northeast Japan and south Sakhalin are characterized by the Cretaceous to Paleogene two arc-trench systems, namely, the Paleo-Japan and Paleo-Kuril arc-trench systems, as reviewed in Nanayama et al. (1993), Kimura (1997) and Ando (1997 and submitted) (Fig.1) The north-south trending Paleo-Japan arc-trench system has three components of magmatic arc, fore-arc basin and fore-arc accretionary complexes from west to east.

The magamatic arc is represented by early Cretaceous plutonic rock batholiths J sporadically exposed in the Abukuma, South Kitakami, North Kitakami and Oshima Belts.

Volcanic rocks are also narrowly distributed along the Pacific coast of the South and North Kitakami Belts, and in the Rebun-Kabato Belt. The adakitic granite zone inferred through the prominent positive magnetic anomaly belt from off central Honshu to central Hokkaido, is broadly bounded on the east by the fore-arc basin (Finn, 1994; Tsuchiya and Kanisawa, 1994; Tsuchiya et al., 1999). These geologic elements are thought to belong to the buried Cretaceous magmatic arc.

The Upper Cretaceous to Paleocene sediments filling the easterly fore-arc basin are distributed over 1,400 km long from the Pacific coast of central Honshu to south Sakhalin through central Hokkaido. It has been known that they extend widely beneath into shelf and continental slope off the Pacific in terms of seismic survey and underground and ocean drilling for oil exploration during a few decades. This basin is called the Yezo fore-arc basin in the eastern margin of the paleo- Asian continent (e.g., Kimura, 1994;

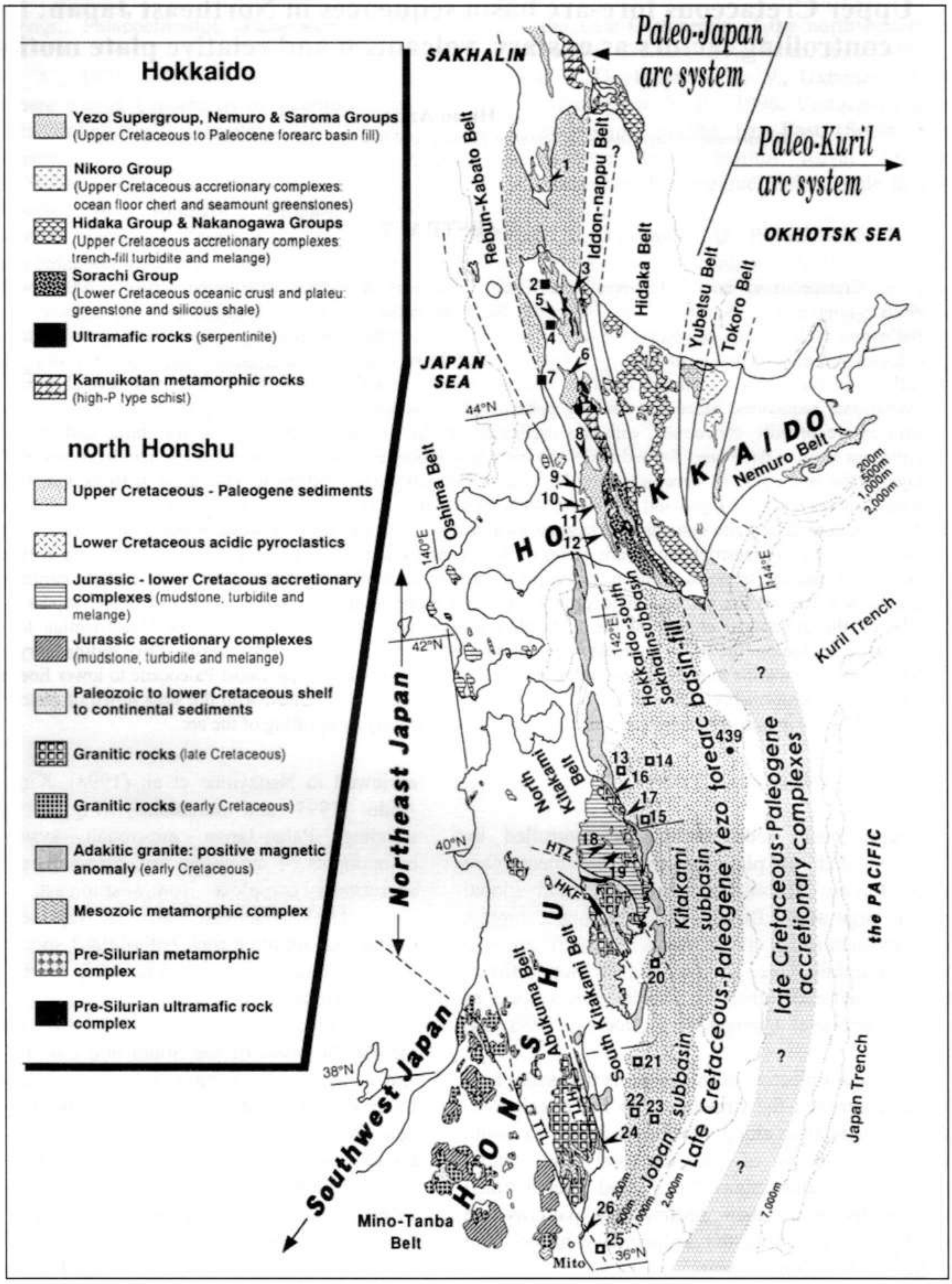

Fig.1 Pre-Neogene geological map and tectonic framework of Northeast Japan. White and black squares and arrows indicate the locations of surface and under-sea drilling sites, and surface sections respectively. 1: Kril'on Peninsula, south Sakhalin, 2: Tenpoku, 3: Nakatonbetsu, 4: Enbetsu, 5: Nakagawa-Enbetsu, 6: Chikubetsu-Haboro, 7: Rumoi, 8: Ashibetsu, 9: Mikasa, 10: Yubari, 11: Oyubari, 12: Hobetsu, 13: off Hachinohe, 14: off Sanriku, 15: off Kuji, 16: Taneichi , 17: Kuji, 18: Kogawa, 19: Iwaizumi, 20: Kesennuma, 21: Soma, 22: off Iwaki, 23: off Joban, 24: Iwaki, 25: Kashima, 26: Nakaminato. 439: DSDP site (von Huene et al., 1982). TfL: Tanakura Tectonic Line; HTL: Hatakawa Tectonic Line; HKF: Hizume Kesennuma Fault; HTZ: Hayachine Tectonic Zone.

Ando, 1997 and submitted), and is subdivided into the Hokkaido-south Sakhalin, Kitakami and Joban subbasins in terms of its geometry, surface tectonic features and stratigraphic setting (Fig. 2). Distribution and geologic structure of the fore-arc strata are considerably different between the Hokkaido-south Sakhalin subbasin and the Kitakami and Joban subbasins, partly because of post-Paleocene tectonic deformation is characterized by intra-arc left-lateral strike-slip faults movements in north Honshu and arc-arc collision in Hokkaido. Compared with contemporaneous accretionary complexes mentioned below, the Yezo fore-arc strata preserve a good geohistorical record such as depositional facies and their successions, micro- and mega-fossils, and others, due to a lack of intense tectonic deformation.

Early Cretaceous to Paleogene accretionary complexes had been formed in the eastern oceanic side of the forearc. They are now exposed as the Idon-nappu and Hidaka Belts in central Hokkaido and the southeastern end of Sakhalin, because of tectonic uplift by the Miocene collision processes of the paleo-Japan and paleo-Kuril arcs. These two belts were presumed to extend southward beneath the modern fore-arc offshore of north Honshu, especially beneath the deep-sea terrace to upper trench slope (Kimura, 1994, 1997, etc.).

STRATIGRAPHIC PATTERNS OF THE YEZO FORE-ARC SEDIMENTS

The Upper Cretaceous to Paleocene siliciclastic sediments filling the Yezo fore-arc basin provided many kinds of stratigraphic data for reconstructing the sedimentary history of the basin. A total of 26 sedimentary successions including 15 surface sections, three underground and eight under-sea drilling holes for oil exploration, from the southernmost part of Sakhalin to Nakaminato in central Honshu, are correlated with a high-resolution in Ando (submitted). The stratal patterns of depositional facies, upward-coarsening/-fining facies successions, depositional sequences, sequence boundaries and related key surfaces, and index fossils, are compiled there on the basis of several previous stratigraphical researches of land outcrop sections in addition to my field survey. Age control is based mainly on megafossils as ammonites and inoceramids for the surface sections and microfossils as foraminifers, calcareous nannoplankton, pollen and dinoflagelata for the drilling holes. The spatial and temporal distributions of fore-arc strata are somewhat very complicated, and time control by index fossils and radiometric ages is often scarce, but show some general patterns during Albian to Paleocene. Therefore, remarkable stratigraphic patterns are briefly described here.

In general, shallow-marine to fluvial deposits are exposed narrowly and fragmentarily along the Pacific coast in the Kitakami and Joban subbasins and in the western part of the Hokkaido-south Sakhalin subbasin (Sorachi-Yezo Belt of Hokkaido). Offshore marine muddy sediments are widely distributed in the middle to eastern part of the latter, reflecting the paleogeographic setting. This distributional difference between subbasins depends on mainly tectonic structures and partly exposure conditions. Fore-arc strata in Hokkaido were widely distributed along the meridian mountainous zone formed by the Miocene collision of the paleo-Japan and paleo-Kuril arc systems. They were folded and steeply or vertically inclined and are exposed a few times across fold axes. But in the former two subbasins of north Honshu, they are short ranging in stratigraphic interval because of episodic paralic sedimentation, and are limited to be exposed because of the simple seaward-dipping homocline or open folding. Some drilling holes beneath the Pacific shelf provide continuous geological columns.

Hokkaido-south Sakhalin subbasin

The Cretaceous fore arc sediments in the Hokkaido-south Sakhalin subbasin is represented by the Yezo Supergroup (Okada, 1983) which has been conventionally divided into the Lower, Middle and Upper Yezo Groups and Hakobuchi Group since Matsumoto (1951), as reviewed in Hirano et al. (1992). The group has been known to contain well-preserved ammonite and inoceramid fauna enabling biostratigraphic zonation since very extensive and pioneering biostratigraphical studies by Matsumoto (1942, 1943). It overlies the Sorachi Group of an ophiolite or ocean floor sequence mostly conformably with some local discordance (Kito et al., 1986; Kito, 1987; Takashima et al., 1997a, b; Takashima and Nishi, 1999; Ueda et al., 2000). The supergroup is generally dominated by muddy siliciclastics, but shows two second-order upward-shallowing cycles represented by the Lower to Middle Yezo Groups (late Hauterivian to Turonian) and the Upper Yezo and Hakobuchi Groups (Coniacian to Maastrichtian), respectively (Okada and Matsumoto, 1971; Ando, 1997). These two cycles are thought to be equivalent to megasequences in sequence stratigraphy, judging from their duration and thickness.

The Lower Yezo Group (late Hauterivian to lower Albian: Takashima et al., 1997a) is mainly composed of offshore mudstone and turbidites with few megafossils. The lower half of the Middle Yezo Group is characterized by offshore dark grey mudstone commonly bearing ammonites and inoceramids within calcareous concretions. The upper half contains sandy shallow-marine strata associated with fluvial conglomerate and flood plain to lagoonal mudstone only in the western central part of the Sorachi-Yezo Belt, though offshore sandy mudstone with turbidite are dominant in the eastern part of the belt. The first shallow-marine sediments are called the Mikasa Formation representing the western marginal facies of the Yezo basin. The formation constitutes of three third-order depositional sequences and a few fourth-order sequences or parasequences

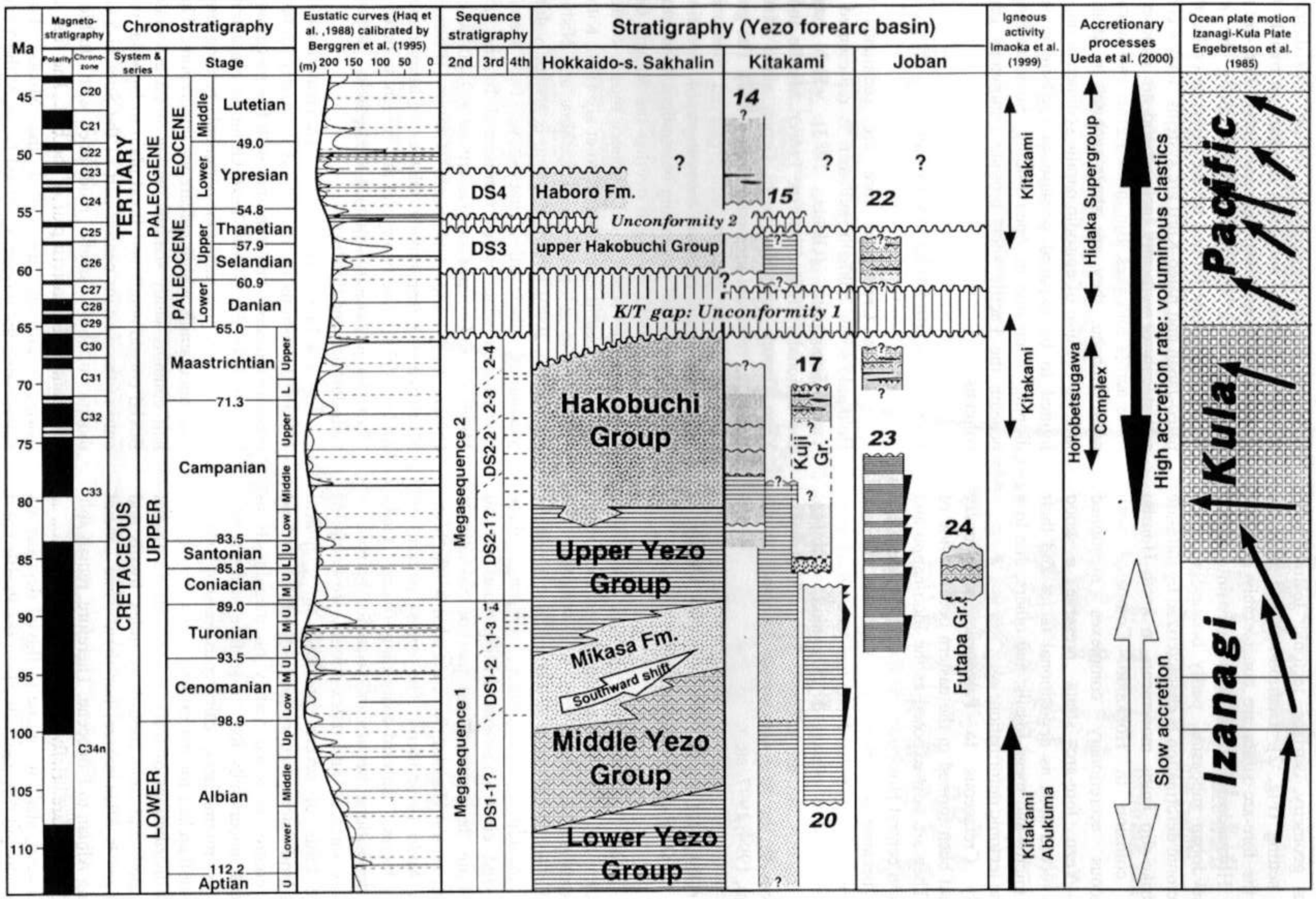

Fig. 2 General stratigraphy and controlling factors on the Yezo forearc basin sedimentation during Cretaceous to middle Eocene. Sequence stratigraphy is based on Ando (1990b, 1997 and submitted) concerned with paralic sediments in the Hokkaido-south Sakhalin subbasin.

(Ando, 1990a, b, 1997), though it shows some local and lateral facies changes. The age of the Mikasa Formation ranges from late Albian to late Turonian in terms of ammonites and inoceramids biostratigraphy.

The Upper Yezo Group (late Turonian to early Campanian) equivalent to the lower part of the second cycle is characterized by monotonous and homogeneous offshore mudstone, and locally intercalated with volcanic sandstone, conglomerate and turbidite. The uppermost unit of the Yezo Supergroup is the Hakobuchi Group overlying the Upper Yezo Group mostly conformably and locally unconformably. In many areas, it is clinounconformably covered by Paleogene deposits such as the upper Eocene Ishikari Group bearing characteristic coal measures or the uppermost Eocene to lower Oligocene Poronai Group of relatively offshore marine origin (Ando, 1993; Shigeta et al., 1999; Kodama et al., 2000). Compared with the underlying strata, shallow-marine to fluvial sandstone predominates in the Hokobuchi Group except the Nakatonbetsu area of north Hokkaido situated in the eastern offshore part of the basin. The group shows the complicated stacking patterns of third- to fourth-order depositional sequences and parasequences. It shows several repetitive upward-coarsening facies successions of offshore sandy siltstone to shoreface sandstone, associated with fluvial sandstone, mudstone and sometimes coaly beds as lowstand elements. The author's recent study revealed the presence of over ten fourth-order sequences in the Hobetsu area of south Hokkaido. Taking the temporal and spatial distribution of facies successions and sequences for 9 surface and drilling sections in Hokkaido into account, the group is characterized by two or three third-order sequences and over ten fourth-order sequences, reflecting local and relative sea-level changes.

The uppermost Maastrichtian and Paleocene strata had not been biostratigraphically documented anywhere in the Yezo basin, until Yasuda (1986) found Paleocene planktonic foraminifers from the uppermost part of the Hakobuchi Group in the Nakatonbetsu area. Recently, late Paleocene dinoflagellata and nannofossils were discovered from the Oyubari and Nakatonbetsu areas, respectively (Suzuki et al., 1997; Okada et al., 1998). More recently, Ando et al. (2001) found a remarkable unconformity in the Nakatonbetsu area, which seems to have eroded the KIf boundary, its nearby horizon and the Lower Paleocene, judging from biostratigraphy of ammonite, inoceramids, foraminifers and calcareous nannofossils. It is confirmed that a different sedimentary cycle of the upper Paleocene beneath the post-early Eocene overlying beds, exists in the uppermost part of the Hakobuchi Group of a few areas. Furthermore, there is the Haboro Formation unconformably overlying the Hakobuchi Group, though its distribution is limited to the Haboro areas in north Hokkaido. Kurita and Obuse (1994, 1997) and Kurita et al. (1992) reported the late Paleocene to early Eocene dinoflagelata and pollen flora from the surface section in the Haboro area and drilling cuttings at the Tenpoku drilling hole (JNOC, 1995). It seems to have been deposited under nearshore and coastal marsh environments at the last stage of the Yezo basin, judging from the lithological similarity with the uppermost part Hakobuchi Group.

Kitakami and Joban subbasins

Shallow-and non-marine facies predominate in every horizon of surface sections of the Futaba Group, the Kuji Group and its correlatives, in comparison with the Hokkaido-south Sakhalin subbasin (Ando, 1997). Their stratigraphic ranges are limited to the Coniacian to Santonian and the upper Campanian to Maastrichtian, though the latter is umeliable to some extent because of limited biostratigraphic time control. However, under-sea drilling data show the presence of thick offshore marine mudstone facies associated with shallow- and non-marine facies. This facies differentiation is due to the geographic position of the surface sections and the drilling sites within the basin. The surface sections mentioned above were situated in the western margin of the basin at that time. According to seismic surveys on the Pacific shelf, the Cretaceous to Paleocene sediments within the Yezo forearc basin unconformably underlie the Eo-Miocene as acoustic basements (e.g., Nakamura, 1990).

Though it is difficult to recognize the two upward-shallowing cycles clearly from our stratigraphic data within the two subbasins, the predominance of non-marine or fluvial-plain facies in the Campanian and Maastrichtian is roughly consistent with the Hakobuchi Group in Hokkaido. For the Cenomanian to Turonian, sites 13 (off Hachinohe) and 15 (off Kuji) of the Kitakami subbasin indicate fluvial and shallow-marine facies correlative to the Mikasa Formation in western central Hokkaido (Sasaki, K. and Iwasaki., 1992). Site 20 (Kesennuma) also shows an upward-coarsening succession of shallow-marine facies in the Cenomanian (JNOC, 1985). In this site, the second shallow-marine facies appear at the upper Turonian to Coniacian above the Upper Cenomanian to Turonian offshore facies. This facies succession is similar to the east Ikushunbetsu section described in Ando (1990a, fig. 3, column G). On the other hand, the under-sea drilling data of the Joban subbasin (site 21: Soma and 23: off Joban; JNOC, 1991, 1992) show repetitive upward-coarsening (shallowing) facies successions for the upper Cenomanian to Campanian, even though this differentiation is not well explained.

The uppermost Maastrichtian and lower Paleocene strata as well as the K/T boundary have not been found and seem to have been eroded away as same as in Hokkaido, though time control is scarce except for a very recently drilled hole (14: off Sanriku, JNOC, 2000). Logging data from this hole shows the presence of the fluvial facies of the uppermost Paleocene to lower Middle Eocene correlated with the Haboro Formation in north Hokkaido.

The stratigraphic interval between upper the Campanian and Paleocene is broadly correlative for general facies successions and their distribution within the three subbasins.

Controlling factors on Yezo fore-arc sedimentation

Global eustasy

In terms of the correlation of four surface paralic strata as the Futaba, Kuji and Hakobuchi Groups and the Mikasa Formation, Ando (1997) pointed out that the stacking patterns depositional sequences and the timing of sequence boundaries and key surfaces bounding systems tracts, appear broadly concordant with the oscillation patterns of the Haq curves (global cycle chart: Haq et al., 1988) in frequency, phase and somewhat amplitude, despite some local discordance. Each group or formation constitutes a few to several third-order depositional sequences less than a few l00m thick. Some of the sequences also consist of fourth-order sequences or parasequences usually less than 100m thick. At least, cycle duration or their length is well correlated. Especially timing of lowstands may be correlated with major sequence boundaries. This conclusion was confirmed by the high-resolution stratigraphic correlation (Ando, submitted), additionally using drilling data. However, the author thinks that two second-order sequences of the Yezo basin would have been controlled by plate motion mentioned below, while the third-order ones were extensively controlled by global eustasy.

Basin subsidence and local tectonics

Total thickness of the fore-arc strata of the Cretaceous to Paleocene varies from area by area, but sections in the Hokkaido-south Sakhalin subbasin are generally a few times thicker than those in the Kitakami and Joban subbasins. All continuous sections in Hokkaido exceed a few thousands metres in maximum thickness, for instance, more than 5,000m for section 11(Oyubari). On the other hand, the thickness is about 2,700m for sites 22 (off Iwaki) and 23 (Joban) of the Joban subbasin even in maximum, though it is a composite value because of no good continuous sections (JNOC, 1991, 1992). This is partly because of the geographic position of the stratigraphic sections within the basin, but much thicker sections of the Hokkaido-south Sakhalin subbasin suggest that the subbasin also subsided a few times faster than in the Kitakami and Joban. Very thick and long-ranging sedimentary successions including paralic strata such as the Mikasa Formation and the Hakobuchi Group, clearly indicate that the basin evolution was tectonically controlled by such a large-scale effect as plate motion.

The Mikasa Formation as the western marginal shallow-marine to paralic facies during late Albian to Turonian, forms three third-order depositional sequences, some of which further include three or more fourth-order sequences (Ando, 1997). Many of them showing upward-coarsening facies successions probably reflect the repetitive delta progradation. Their stratigraphic distribution suggests the southward shift of the delta system or paralic depositional systems (Ando, 1990a, b, 1997). Taking the highstand maximum at late Cenomanian in the eustatic (Haq) curves into account, the abundant paralic facies and the southward shift of the depositional center, are possibly related to local tectonics in the western central margin of the subbasin.

Besides them, over ten fourth-order sequences are also recognized in the upper Campanian to Maastrichtian Hakobuchi Group. Because the global eustasy curves show until the third-order oscillations, controlling factors on fourth-order sequences should be sought from like local tectonics other than eustasy. During Coniacian to Santonian, the Hokkaido-south Sakhalin subbasin was dominated by offshore muddy sedimentary environments for the Upper Yezo Group. This transgressive and highstand stage has been domestically called the Urakawan transgression. This means that the basin was stable and starved of terrigeneous clastics, taking limited distribution of turbidites and debris- flow deposits into account. However, there is no evidence for the Coniacian to Santonian transgressive and highstand trend in the Kitakami and Joban subbasins. Some differentiation within the Yezo basin may have taken place.

Plate motion and accretionary processes

Very thick and long-ranging sedimentary successions of the Yezo Supergroup including paralic strata such as the Mikasa Formation and the Hakobuchi Group, clearly suggest that the basin evolution was tectonically controlled by such large-scale effects as plate motion. Ito and Masuda (1992) briefly pointed out the spatial and temporal sediment distribution in many Japanese Mesozoic-Cenozoic basins are characterized by distinct synchronism. They thought that basin evolution and major episodes are attributed to the relative motion of ocean plates along the Japanese convergent margin: in case of the Upper Cretaceous, Kula and Pacific plates (Engebretson et al., 1985).

According to Engebretson et al. (1985), the azimuth change occurred from NNE to W or WNW for the Kula Plate motion at about 85Ma. This timing appears to be related with much coarse terrigeneous sediment supply during Campanian and Maastrichtian throughout the Yezo basin, represented by the Hokobuchi and Kuji Groups and their correlatives. Shallow-marine to fluvial sediments associated with acidic tuff and coaly or carbonaceous beds almost filled the basin up until late Maastrichtian. As the plate motion became to slow down to some extent after 65Ma, rates of basin subsidence and sedimentation might have gone down. Missing of the uppermost Maastrichtian to lower Paleocene including the K/T boundary throughout the basin seem to be related to this episode and associated subaerial erosion by uplifting of the arc, though no evidence for heavy tectonic disturbance. Reflecting this tectonic setting, marine to non-marine through paralic Late Paleocene sediments were developed sporadically in a few areas of the basin. Because no remarkable lithological changes at the gap can be detected at least, the same basin framework would have been kept to some extent. Furthermore, the lithological similarity between the uppermost Hakobuchi and the Haboro Formation suggests that the latter is an element of the Yezo basin. These strata represent the final filling phase of the basin. After late Eocene, basin and tectonic settings as well as sedimentary facies in Hokkaido have changed, as pointed out by Iijima (1996) and Kurita and Yokoi (2000).

Recently, Ueda et al. (2000, 2001) documented the spatial relation of the late Jurasssic to Paleogene accretionary complexes in the Idon-nappu and Hidaka Belts and the overlying fore-arc basin-fill, Hokkaido. Rapid growth of the accretionary complexes along the subduction zone might have been related with high rate of sedimentation and subsidence of the fore-arc basin. The upper Campanian to Maastichtian Horobetsugawa Complex is thought to have been formed under the control of relative motion of Kula Plate as same as the fore-arc shallow-marine sedimentation (e.g., Kimura, 1997; Ueda et al., 2000, 2001). Because contemporaneous accretionary sediments in north Honshu have still not been found beneath the continental slope off the Pacific, a large amount of the accretionary prisms appear to have been tectonically eroded through subduction processes along the Japan Trench (von Huene et al., 1982; von Huene, 1994; Kimura, 1997).

Igneous activity

In terms of Rb-Sr whole rock isochron ages, Imaoka et al. (1999) presumed three igneous activities during Cretaceous to middle Paleogene along the magmatic Honshu Arc. The early Cretaceous activity of 135 to 100Ma was the most active in north Honshu, represented by widely-distributed granite and narrowly-associated andesitic volcanics in the five belts as the Abukuma, South Kitakami, North Kitakami, Oshima and Rebun-Kabato Belts. In the North Kitakami and Oshima Belts, granitic rocks (130-115 Ma) intruded into Jurassic to early Cretaceous accretionary complexes (Tsuchiya and Kanisawa, 1994, etc.). Acid tuff beds are not so common in the fore-arc sediments, though somehow frequent in some horizons such as the lower Turonian of the Middle Yezo Group, and possibly Coniacian to lower Santonian in the middle part of the Upper Yezo Group. The uppermost Albian to Turonian Mikasa Formation has a moderate amount of sand and gravel derived from intermediate to basic igneous rocks, reflecting the lower Cretaceous andesitic to basaltic volcanics distributed in the westerly Rebun-Kabato Belt (Okada, 1965; Okada and Matsumoto, 1971; Nagata et al., 1986). Especially the lower Turonian fluvial conglomerates of the Mikasa Formation commonly contain green andesite pebbles (Ando, 1990a,b). The predominance of arkosic sandstone throughout the Futaba Group means that the Lower Cretaceous granite batholith was already exposed on the hinterland at the stratal formation (Ando et al., 1995; Ando, 1997). Because of no radiometric age data for 89 to 76 Ma in the former four belts mentioned above, the igneous activity seems to have been ceased in north Honshu, though very active in Southwest Japan. It took place again in north Honshu during 75 to 71Ma, and intermittently continued until Paleogene though not as extensive as Early Cretaceous. Acidic tuff layers suddenly increase from the Campanian to Maastrichtian strata throughout the basin exemplified by the Kuji Group in Honshu and the Hakobuchi Group in Hokkaido. The large-scale shallowing for upper Campanian and Maastrichtian appears to have been caused by combination of active accretionally processes and uplift of the continental magmatic arc probably relating with plate motion.

CONCLUSIONS

1. The temporal and spatial distributions of facies successions and sequences in the Cretaceous to Paleocene Yezo forearc basin sediments indicate two second-order upward-shallowing cycles (megasequences) for the Cretaceous, though not so conspicuous in the Kitakami and Joban subbasins. Each of two cycles also includes a few third-order and several fourth-order depositional sequences.

2. The third- to fourth-order sequences is thought to have been formed under the control of global eustasy as a major cause, since the stacking patterns of depositional sequences and the timing of sequence boundaries and key surfaces appear broadly concordant with the oscillation patterns of the Haq curves.

3. Shallow-marine to paralic facies in the late stage of the first cycle is represented by the Mikasa Formation (late Albian to Turonian) in Hokkaido, while the eustatic (Haq) curves reach the highstand maximum at late Cenomanian. This discrepancy in addition to the southward shift of the depocenter of delta systems may suggest local tectonic movement in the western margin of central.Hokkaido.

4. The Campanian to Maastrichtian paralic facies of the second cycle represented by the Hakobuchi Group in Hokkaido and its correlatives in north Honshu, represent a large-scale shallowing trend. Igneous activities and rapid growth of accretionary complexes respectively occurred in the arc and the subduction zone also during late Campanian to Maastrichtian. These three geologic events appear to have reflected the directional change of the Kula plate motion near 85 Ma.

5. The uppermost Maastrichtian to Upper Paleocene including the K/f boundary are missing everywhere in the Yezo basin. Two sedimentary cycles characterized by marine to non-marine facies of the late Paleocene and the uppermost Paleocene to lower Eocene are developed unconformably in a few areas. These are possibly related with the slow down of plate motion after 65Ma and its associated subaerial erosion and igneous activity by uplifting of the arc

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