18. DIATOM CORRELATION OF LEGS 56 AND 57 WITH ONSHORE SEQUENCES IN JAPAN

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INTRODUCTION

The Japan Trench transect undertaken on Legs 56 and 57 of the Deep Sea Drilling Project provided an excellent opportunity for the correlation of a series of deep sea drilling sites with land-based sections along the Pacific side of Japan. In order to reconstruct the Pleistocene-Neogene geologic history of the Japanese Islands and adjacent seas, emphasis is placed on planktonic correlation of the Pleistocene-Neogene of Japan with the Pacific Pleistocene-Neogene. However, the general low diversity of calcareous microfossils, including planktonic foraminifers and calcareous nannofossils within higher latitude North Pacific sequences, has hampered correlations in this area. Alternately, a reliable diatom biostratigraphy has been developed in the North Pacific region including the higher latitude areas. Absolute age assignments for important diatom datums have been made by correlation with the paleomagnetic stratigraphy (Burckle and Opdyke, 1977) and various radiometric dates (Koizumi, 1977). The diatom zonal sequences for the Pleistocene-Neogene strata in the North Pacific region were calibrated to a geochronologic framework (Koizumi, 1977).

CORRELATION OF ONSHORE SEQUENCES WITH LEGS 56 AND 57 SITES

Among the Pleistocene-Neogene sections in the Japanese Islands studied by Koizumi, 12 sections from 6 regions along the Pacific side—Choshi, Jōban Coalfield, Fukushima, Miyagi, Sannohe-Kadonosawa and eastern Hokkaido—are correlated with the Pleistocene-Neogene deposits recovered in Sites 438, 440, and 436 based upon diatom datum levels (Figure 1). These sites were chosen from landward side in the fore-arc basin (Site 438), trench inner slope (Site 440), and seaward side on oceanic crust (Site 436), based on the results of onshore studies by Barron (this volume) and Harper (this volume). A number of correlation charts (Figures 2, 3, 4, and 5) are largely self-explanatory. Some supplementary data from published and unpublished sources on age, lithology, and paleontological aspects are given in the following text.

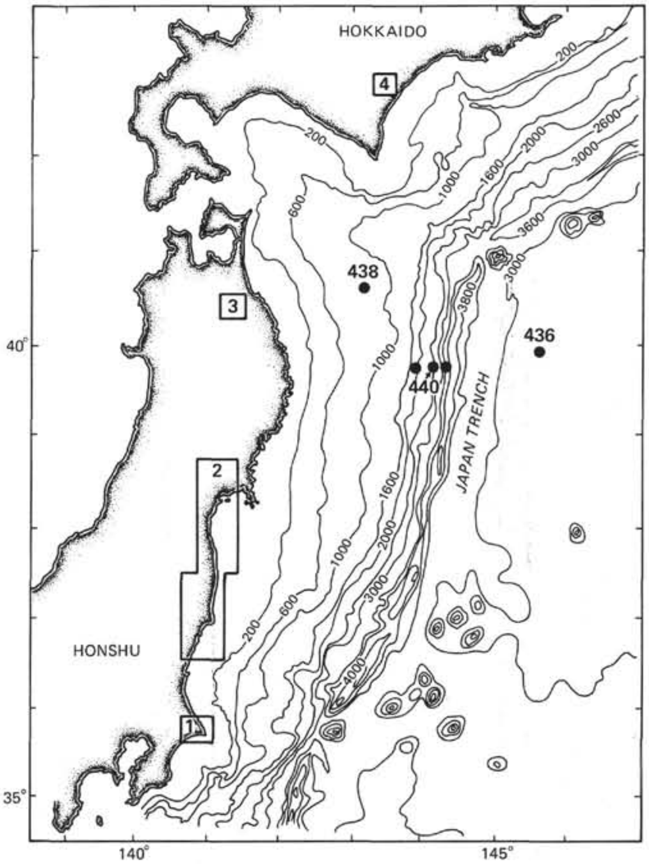

Figure 1. *Location of Pleistocene-Neogene sections in Japan and DSDP sites mentioned in text. 1, Choshi; 2, Jōban Coal-field and Fukushima-Miyagi Prefectures; 3, Sannohe-Kadonosawa; 4, eastern Hokkaido. (Contour depths are in fathoms [from map "Topography of North Pacific" by Chase, Menard, and Mammerickx, Institute of Marine Resources, Geological Data Center, Scripps Institution of Oceanography, 1971].)*

Choshi Sequence (Figure 2)

The Choshi region is about 100 km northeast of Tokyo. The Metogahana Formation, the oldest Neogene unit in this region, rests unconformably upon Cretaceous basement rocks. This formation is composed mainly of bluish gray tuffaceous siltstone intercalated with thin layers of tuff and pumiceous sandstone and conglomerate in the lower part (Matoba, 1967). Although diatoms are present in this unit, all other groups are very scarce. Results of a preliminary study of these diatom floras were presented by Koizumi (1977). The Plio-Pleistocene series of fine-grained clastic marine sediments are developed continuously upward from the basal conglomerate of the Na-arai Formation. A composite microfossil scheme was erected for this region (Koizumi and Kanaya, 1976) on the basis of various mi-

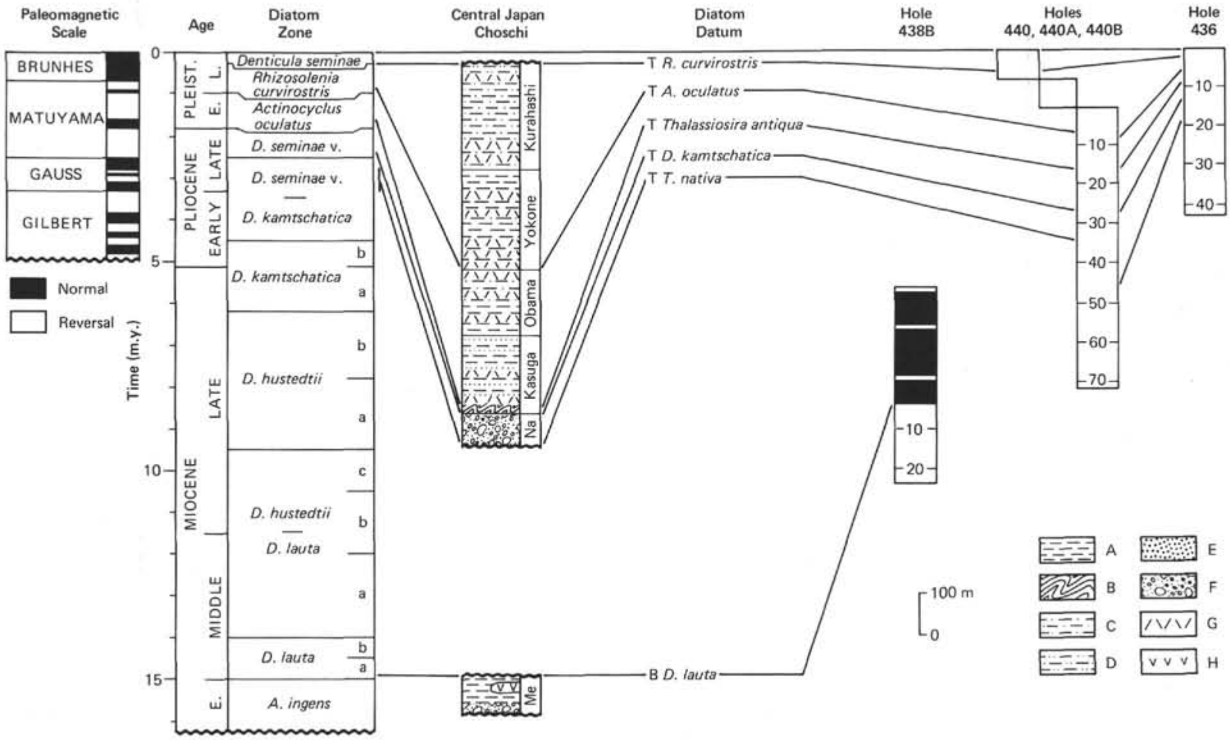

Figure 2. *Correlation of Choshi section with DSDP Sites 438, 440, and 436 on diatom datum levels. (In drill section column, black areas show unrecovered interval, and figures show core number. B and T indicate the level of the first and last occurrences of diatom species. Me, Metogahana; Na, Na-arai. Symbols for lithology are interpreted as follows: A, siltstone; B, intraformational deformation; C, sandy siltstone; D, silty sandstone; E, sandstone; F, conglomerate; G, tuff; H, andesite.)*

cropaleontological events (Matoba, 1967; Takayama, 1973; Sakai, in Mitsunashi et al., 1976) as well as paleomagnetic data (Niitsuma, 1970). Specifically, the *Denticula seminae* var. *fossilis* Zone assemblage in the lower part of the Kasuga Formation is followed by the *D. seminae* var. *fossilis–D. kamtschatica* Zone assemblage in the Na-arai Formation.

The *Actinocyclus ingens* Zone (Barron, this volume) assemblage in the lower part of the section at Site 438 is correlated with the assemblage of the Metogahana Formation. The Plio–Pleistocene diatom zone assemblages of the Na-arai, Kasuga, Obama, Yokone, and Kurahashi Formations are compared with those of Sites 440 and 436 (Figure 2)

Jōban Coal-field Sequence (Figure 3)

The Jōban Coal-field is about 180 km northeast of Tokyo, along the Pacific coast side of Ibaragi and Fukushima Prefectures, Japan. The Jōban Coal-field represents one of the best-studied Cenozoic sequences in Japan both in terms of stratigraphy (e.g., Hanzawa, 1957; Sugai et al., 1957; Mitsui, 1971) and paleontology (e.g., Fukuta, 1955; Kamada, 1962). The subdivisions established for the Tertiary sections in this field have been widely used as a classic standard for the time-stratigraphic subdivisions of those in the Pacific side of the central and eastern Honshu, Japan. However, new age interpretations for the Neogene sections in this field have been suggested by the recent studies of diatoms and other planktonic microfossils (Figure 3).

According to Sugai et al. (1957), the Tertiary sediments of the Jōban Coal-field are divided into five groups and are in an unconformable relation to each other as follows:

Quaternary	Quaternary Deposits	
	unconformity	
Pliocene?	Taga Group (600 m)	Tomioka Formation Hirono Formation
	clino-unconformity	
Late Miocene	Takaku Group (220 m)	Shimotakaku Formation Numanouchi Formation Kamitakaku Formation
	para-unconformity	
Middle Early Miocene	Shirado Group—Nakayama Formation (100 m)	
	para-unconformity	
	Yunagaya Group—five formations (omit) (500 m)	
	clino-unconformity	
Oligocene	Shiramizu Group—three formations (omit) (450 m)	
	clino-unconformity	
Late Cretaceous	Basement Rocks (Futaba Group)	

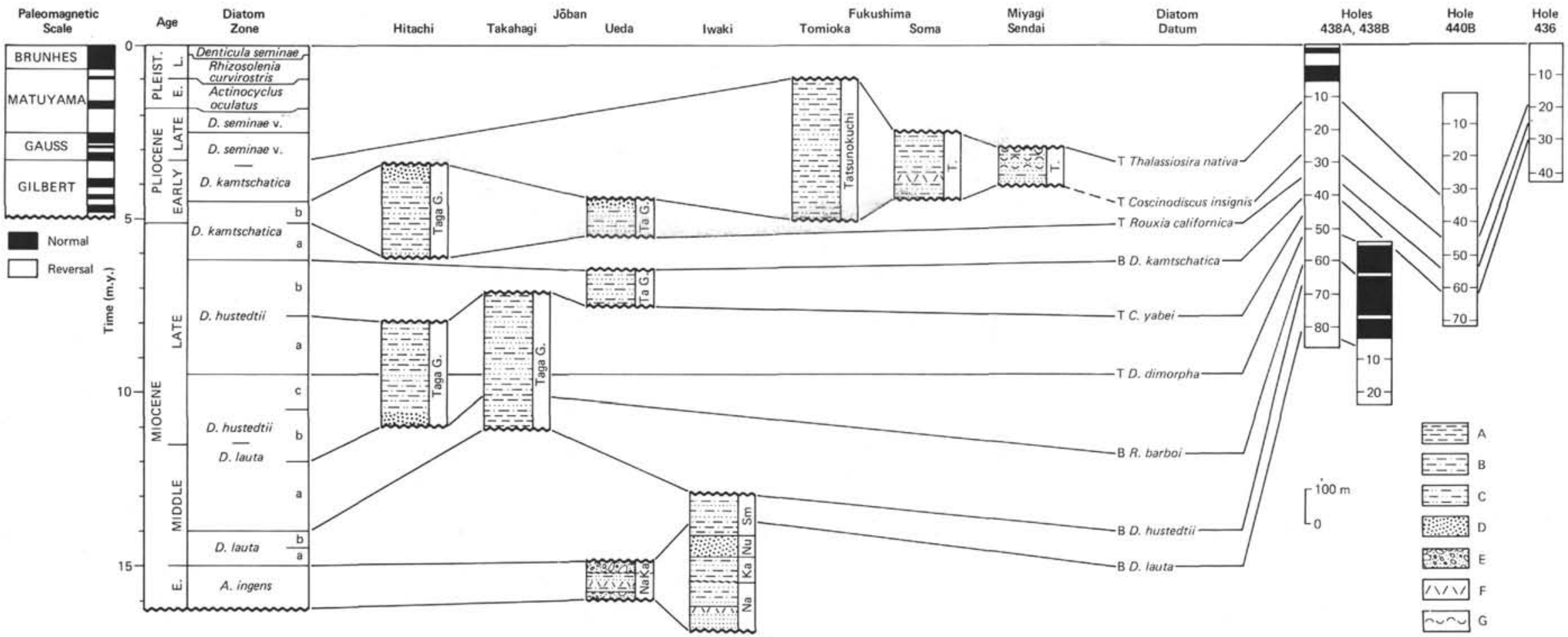

Figure 3. *Correlation of Jōban and Fukushima-Miyagi sections with DSDP Sites 438, 440, and 436 based on diatom datum levels. (In drill section column, black areas show unrecovered interval, and figures show core number. B and T indicate the level of the first and last occurrences of diatom species. Na, Nakayama; Ka, Kamitakaku; Nu, Numanouchi; Sm, Shimotakaku; T, Tatsunokuchi. Symbols for lithology are interpreted as follows: A, siltstone; B, sandy siltstone; C, silty sandstone; D, sandstone; E, conglomerate; F, tuff; G, molluscan fossils.)*

The Nakayama Formation represents one cycle of sedimentation: namely, the lower part of this formation consists of conglomerate and conglomerate-bearing sandstone which grades into an overlying fine-grained facies of pumice tuff and tuffaceous sandstone. Sandstones in the formation yield abundant molluscan and plant fossils. The Takaku Group is exposed only in the northern and southern Iwaki districts, whereas the Taga Group is distributed throughout the whole area and unconformably overlies the pre-Taga groups. The Takaku Group shows cyclic sedimentation consisting of coarse-grained conglomerate-bearing sandstone (the Kamitakaku Formation), fine-grained sandstone (the Numanouchi Formation), and tuffaceous siltstone (the Shimotakaku Formation) (Mitsui, 1971). Among these formations, the Numanouchi Formation contains abundant molluscan fossils of the Kadonosawa Fauna type. Recently, the Taga Group was subdivided into two formations (Mitsui et al., 1973). Because detailed stratigraphic classification of these formations is not yet established, the Taga Group of Sugai et al. (1957) is followed here. Although the Taga Group in the Tomioka area of the Fukushima Prefecture is subdivided into the Hirono and Tomioka Formations by Sugai et al. (1957), we consider these units correlative with the Tatsunokuchi Formation. The basal part of the Taga Group consists mainly of fine- to medium-grained sandstone intercalated with layers of mudstone. The major part is composed mainly of gray, massive siltstone intercalated with thin layers of sandstone. Mollusca, foraminifers, and diatoms occur in the middle part of the Group. The foraminiferal assemblages from this portion of the unit represent the *Sphaeroidinella seminulina* Zone to the *Globorotalia menardii–Globigerina nepenthes* Zone, indicating the Tortonian to Sarmatian age (Saito, 1963).

Diatom assemblages from the Nakayama Formation to the lower part of the Shimotakaku Formation represent the *Actinocyclus ingens* Zone, but the upper part of the Shimotakaku Formation contains the *Denticula lauta* Zone assemblage. The Taga Group can be subdivided into two parts by means of diatom biostratigraphy, as described by Mitsui et al. (1973). The lower part of the Group is within the *D. lauta–D. hustedtii* Zone, and the *D. hustedtii* Zone and the upper part of the Group correlate to the upper part of the *D. kamtschatica* Zone.

The diatom sequences in the Jōban Coal-field correlate well with Sites 438, 440 and 436.

Fukushima–Miyagi Sequence (Figure 3)

The Tatsunokuchi Formation is distributed along the Pacific coast of Fukushima Prefecture and in the lowland terrain between the Kitakami Massif and the Ou Range of Miyagi Prefecture. This formation consists mainly of micaceous and pumiceous siltstone intercalated with thin layers of medium- to coarse-grained sandstone and contains abundant molluscan fossils named Tatsunokuchi Fauna (Nomura, 1938), characterized by the occurrence of *Fortipecten takahashii*.

The marine diatoms from the Tatsunokuchi Formation were previously described and analyzed by Koizumi (1972, 1973). Diatom assemblages from this formation correlate with the *Denticula seminae* var. *fossilis–D. kamtschatica* Zone assemblage of Sites 438, 440, and 436.

Sannohe–Kadonosawa Sequence (Figure 4)

The Mabuchi River region from Sannohe to Kadonosawa is located in the approximately same latitude with that of a series of the drilling sites occupied by Legs 56 and 57. The Neogene deposits developed in this region are situated between the Kitakami Massif and the Ou Range.

According to Chinzei (1966), the Neogene deposits are divided into two groups, the lower Shiratorigawa and the upper Sannohe Groups.

Pliocene		Togawa Formation
	Sannohe Group	Kubo Formation
Latest	(1000 m)	Shitazaki Formation
Miocene		Tomesaki Formation
		Suenomatsuyama Formation
Late	Shiratorigawa	
Early	Group	Kadonosawa Formation
Miocene	(450 m)	
		Yotsuyaku Formation

The Shiratorigawa Group is distributed in the southeastern part of the region. This group represents one cycle of sedimentation. The Kadonosawa Formation consists mainly of gray siltstone frequently intercalated with layers of pumice tuff. This formation contains abundant molluscan fossils named Kadonosawa Fauna (Otuka, 1934). The Suenomatsuyama Formation is composed of tuffaceous sandstone accompanied by two masses of pyroxine andesite; the sandstone contains some molluscan fossils.

The Sannohe Group is distributed in the northwestern part of the region. The Tomesaki Formation is predominated by muddy facies. The basal part of this formation is a thick shell limestone (coquina). The molluscan fauna of this limestone is similar to that of the Suenomatsuyama Formation (Chinzei, 1966). The Shitazaki Formation consists mainly of thick homogeneous siltstone. The upper part of the formation consists of tuffaceous sandstone and, in places, alternation of sandstone and siltstone containing abundant molluscan and other fossils.

The *Actinocyclus ingens* Zone assemblage in the lower part of the Kadonosawa Formation is followed by the *Denticula lauta* Zone assemblage and the lower part of the *D. lauta–D. hustedtii* Zone assemblage between the upper part of the Kadonosawa Formation and the Suenomatsuyama Formation. Although the uppermost part of the *D. lauta–D. hustedtii* Zone assemblage is observed in the lower part of the Tomesaki Formation, the major part of that zone is missing. The *D. hustedtii* Zone assemblage is found in the overlying Shitazaki Formation. This hiatus is marked by a presence of the thick shell limestone at the base of the Sannohe Group as previously suggested by Chinzei (1966), but he judged it not critical. The *D. kamtschatica* Zone assemblage

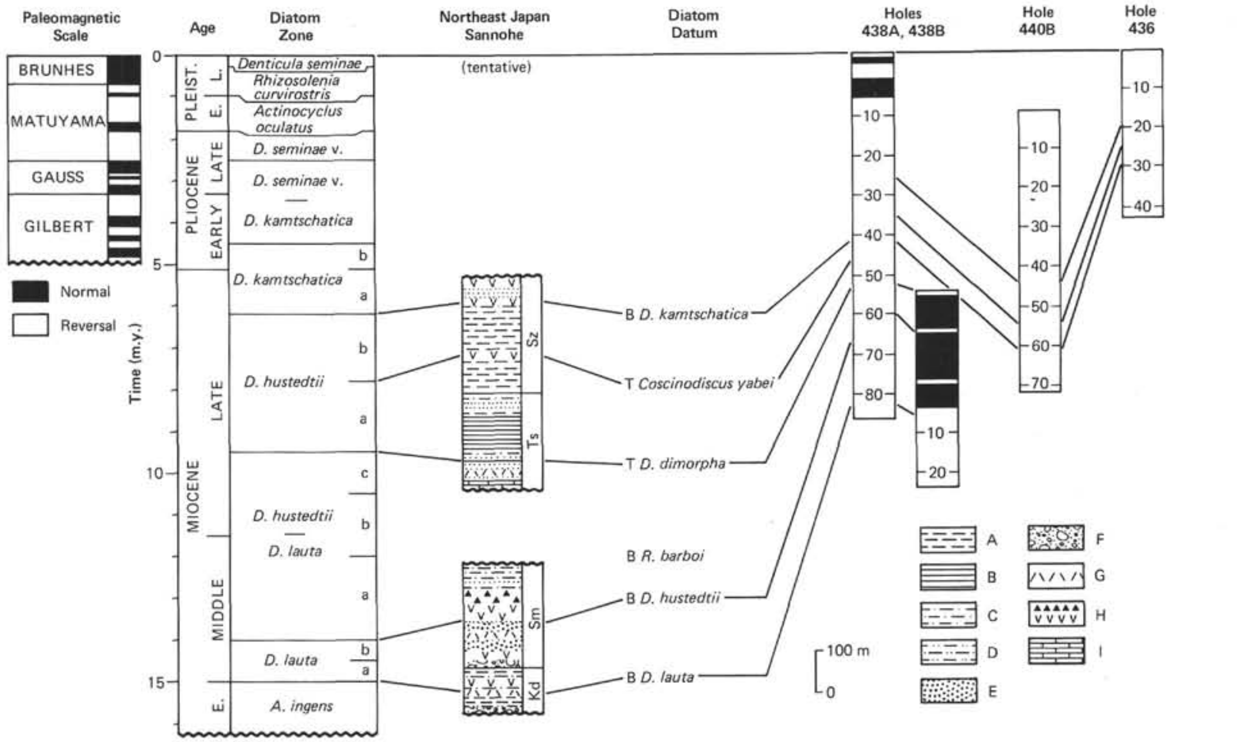

Figure 4. *Correlation of Sannohe–Kadonosawa section with DSDP Sites 438, 440, 436 based on diatom datum levels. (In drill section column, black areas show unrecovered interval, and figures show core number. B and T indicate the level of the first and last occurrences of diatom species. Kd, Kadonosawa; Sm, Suenomatsuyama; Ts, Tomesaki; Sz, Sitazakai. Symbols for lithology are intepreted as follows; A, siltstone; B, hard shale; C, sandy siltstone; D, silty sandstone; E, sandstone; F, conglomerate; G, tuff; H, tuff breccia; I, shell limestone.)*

has not yet been found in any samples from the Shitazaki Formation. The same diatom sequences have also been found in the study by Akiba (1977).

The diatom assemblages in the Shiratorigawa Group are correlated with those in the lower part of the section at Site 438. Alternately, the *D. hustedtii* Zone assemblage in the Sannohe Group is correlated with those in the middle part of the section at Site 438 and the lower part of the section at Sites 440 and 436.

Tokachi Sequence (Figure 5)

Neogene deposits are widely developed in the Tokachi Plain, situated in the coastal region of eastern Hokkaido. The geology of this plain was described in detail by Onitsuka (1962) and Yamaguchi (1970). Diatom-rich sediments of the Toyokoro hill terrain of the central part in the Tokachi Plain belong to the Taiki and Nukanai Formations (Yamaguchi, 1970).

The Taiki Formation is predominated by pale gray massive diatomaceous to tuffaceous siltstone. The upper part of the formation is interbedded with thin layers of fine-grained sandstone and in places alternates with sandstone and siltstone; diatoms are present in this unit, and other fossils are scarce. The Nukanai Formation consists mainly of fine-grained sandstone and contains abundant molluscan fossils named the Takikawa-Honbetsu Fauna (Uozumi and Fujie, 1958) and is characterized by the occurrence of *Fortipecten takahashii*. The basal part of the formation is an alternation of sandy siltstone and fine-grained sandstone and overlies the Taiki Formation in places by a slight unconformity.

The diatom assemblages from the Taiki Formation represent the *Denticula hustedtii* Zone assemblage and the lower part of the *D. kamtschatica* Zone assemblage. The Nukanai Formation is within the upper part of the *D. kamtschatica* Zone assemblage.

The diatom sequences in the Toyokoro terrain are correlated with those of the middle part of the section at Sites 438 and 436 and the lower part of the section at Site 440.

CONCLUSIONS

The diatom sequences at Legs 56 and 57 drill sites are similar to those of many land-based sections in northern Japan. Burckle and Opdyke (1977) pointed out that Koizumi's diatom zonal scheme (1975, 1977) can be traced over the whole North Pacific region and is thus useful for the North Pacific. However, the continuously cored sections recovered by DSDP are much more useful for the studies on diatom distributions than land-based sections in view of the continuous and relatively undisturbed sedimentary sequences and the abundance of well-preserved microfossils.

In order to establish better time relationships among paleontological events in the North Pacific region, a composite scheme should be erected using the stratigraphic positions of various groups of microfossils, including planktonic foraminifers, calcareous nanno-

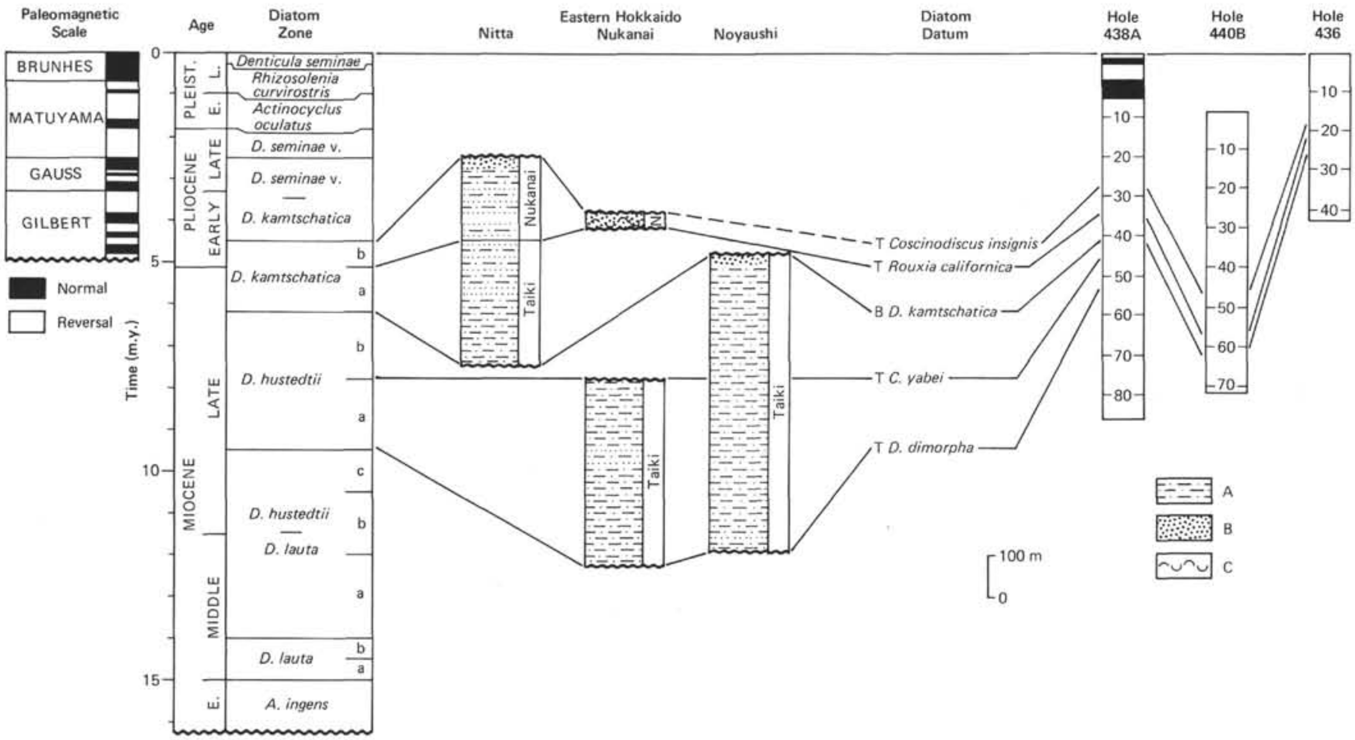

Figure 5. *Correlation of Toyokoro sections with DSDP Sites 438, 440, and 436 based on diatom datum levels. (In drill section column, black areas show unrecovered interval and figures show core number. B and T indicate the level of the first and last occurrences of diatom species. Symbols for lithology are interpreted as follows: A, sandy siltstone; B, sandstone; C, molluscan fossils.)*

plankton, and radiolarians plotted against the diatom zones and events. Such a composite scheme will assist in correlating both deep sea and land-based sequences and interpret biological events in the North Pacific region.

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REFERENCES

Akiba, F., 1977. Neogene diatom biostratigraphy in the Ninohe district, Iwate Prefecture. *J. Jpn. Assoc. Petl. Technol.*, 42, 275.

Burckle, L. H., and Opdyke, N. D., 1977. Late Neogene diatom correlation in the circum-Pacific. *In* Saito, T., and Ujiie, H. (Eds.), *Proceedings of the First International Congress on Pacific Neogene Stratigraphy:* Tokyo (Kaiyo Shuppan).

Chinzei, K., 1966. Younger Tertiary geology of the Mab chi River valley, northeast Honshu, Japan. *J. Fac. Sci. Univ. Tokyo [2]*, 16, 161.

Fukuta, O., 1955. On the Takaku Group in view of micropaleontological standpoint. *Bull. Geol. Surv. Jpn.*, 6, 649.

Hanzawa, S., 1957. *Tohoku Region.* Tokyo (Asakura).

Kamada, Y., 1962. Tertiary marine mollusca from Jōban Coal-field, Japan. *Paleont. Soc. Jpn., Spec. Pap.*, 8.

Koizumi, I., 1972. Marine diatom flora of the Pliocene Tatsunokuchi Formation in Fukushima Prefecture. *Trans. Proc. Palaeont. Soc. Jpn.,* N. S., No. 86, 340.

________, 1973. Marine diatom flora of the Pliocene Tatsunokuchi Formation in Miyagi Prefecture. *Trans. Proc. Palaeont. Soc. Jpn.*, N. S. , No. 79, 126.

________, 1975. Late Cenozoic diatom biostratigraphy in the circum-Pacific region. *J. Geol. Soc. Jpn.*, 81, 611.

________, 1977. Diatom biostratigraphy in the North Pacific region. *In* Saito, T., and Ujiie, H. (Eds.), *Proceedings of the First International Congress on Pacific Neogene Stratigraphy:* Tokyo (Kaiyo Shuppan), p. 235.

Koizumi, I., and Kanaya, T., 1976. Late Cenozoic marine diatom sequence from the Choshi District, Pacific Coast, Central Japan. *In* Takayanagi, Y., and Saito, T. (Eds.), *Progress in Micropaleontology:* New York (Micropaleontology Press), p. 144.

Matoba, Y., 1967. Younger Cenozoic foraminiferal assemblages from the Choshi District, Chiba Prefecture. *Science Reports of the Tohoku University, Sendai, Japan, Second Series (Geol.)*, 38, 221.

Mitsui, S., 1971. Studies on the mechanism of deformation of sedimentary rocks in the Iwaki area of the Jōban Coal-field, Fukushima Prefecture. *Science Reports of the Toho-*

ku University, Sendai, Japan, Second Series (Geol.), 42, 199.

Mitsui, S., Ouchi, K., Endo, S., and Hasegawa, Y., 1973. Stratigraphy and geological age of the Taga Group in the Jōban Coal-field of Fukushima and Ibaraki Prefectures. *Res. Rep. Kochi Univ.*, 22 (No. 9), 1.

Mitsunashi, T., Nakagawa, H., and Suzuki, Y. (Eds.), 1976. Boso Peninsula. Guidebook for Excursion 2. *Proceedings of the First International Congress on Pacific Neogene Stratigraphy:* Tokyo (Kaiyo Shuppan).

Niitsuma, N., 1970. Some geomagnetic stratigraphical problems in Japan and Italy. *J. Mar. Geol.*, 6, 99.

Nomura, S., 1938. Molluscan fossils from the Tatsunokuchi shell bed exposed at Goroku cliff in the western border of Sendai. *Science Reports of the Tohoku University, Sendai, Japan, Second Series (Geol.)*, 19, 235.

Onitsuka, T., 1962. Studies on the petroleum geology of the Tokachi region in Hokkaido. *J. Jpn. Assoc. Pet. Technol.*, 27, 173.

Otuka, Y., 1934. Tertiary structures of the northeastern end of the Kitakami mountainland, Iwate Prefecture. *Bull. Earthq. Res. Inst.*, 12, 155.

Saito, T., 1963. Miocene planktonic foraminifera from Honshu, Japan. *Science Reports of the Tohoku University, Sendai, Japan, Second Series (Geol.)*, 35, 123.

Sugai, K., Matsui, H., Sato, S., Kitagawa, Y., Sasaki, M., Miyashita, M., and Kawachi, H., 1957. Geological Maps of the Coal Fields of Japan (I), Geological Map and Explanatory Text of the Jōban Coal Field, Scale 1:50,000. *Geol. Surv. Jpn.*

Takayama, T., 1973. On the distribution of calcareous nannoplankton in the youngest Cenozoic of Japan. *Geol. Soc. Jpn. Mem.*, 8, 45.

Uozumi, S., and Fujie, M., 1958. Tentative correlation chart of the Neogene formations, Hokkaido. *Cenozoic Res.*, 26, p. 24.

Yamaguchi, S., 1970. On the stratigraphy of the northern part in the Toyokoro hill terrain. *Mem. Hokkaido Branch, Geol. Surv. Jpn.*, 21, 47.