Magnetostratigraphy of the Yamato Group and the Sendai Group, Northeast Honshu, Japan (II)*

Ken-ichi MANABE

Department of Earth Science, Faculty of Education, Fukushima University, Fukushima 960-12

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Magnetostratigraphy of the Late Cenozoic sedimentary sections in the inland areas of the southern part of Northeast Honshu was studied. In the previous paper, the Late Cenozoic stratigraphy of the studied area and the methods of paleomagnetic studies were described (Manabe, 1979). In this paper, the results of the paleomagnetic studies and the magnetostratigraphic correlations are presented.

PALEOMAGNETIC STRATIGRAPHY

1. AIZU BASIN

The intensity of remanent magnetization of the samples partially demagnetized in the alternating field of 200 Oe mostly ranges from $10^{-7}$ to $10^{-5}$ emu/cm$^3$ (Tables 1-4).

a. Magnetization of each formation

Shiotsubo Formation: The Shiotsubo Formation is characterized by the mixed normal and reversed polarities in the Shiotsubo section (Fig. 9), the normal polarity being comparatively predominant. The stratigraphic interval of normal polarity about 36m in thickness was recognized in the middle part of the formation. The site SH-05 corresponds to the lower part of this interval, which yielded so-called "Yama Fauna".

* Continued from this Bulletin No. 29, p. 65.
Fig. 9. Magnetostratigraphy of the Shiotsubo Formation in the Shiotsubo section. Site numbers correspond to those in Table 1. Magnetic polarity in the section was interpreted from the latitude of VGP. Black represents normal, white reversed polarity. Magnetic intensity is plotted on a logarithmic scale.

Fujitoge Formation: The Fujitoge Formation has mostly reversed polarity magnetization in the measured sections, but three short normally magnetized intervals were recognized in it.

In the Kamifujisawa section two short normally magnetized intervals were recognized in the section (Fig. 10). One of them is recognized in the lower half of the middle part and the other is slightly below the boundary between the lower and middle parts. The lower normal polarity interval has a split feature. The intensity of remanent magnetization is generally weak throughout the section, but the biotite-bearing tuff (B.T.) at the top of the middle part of the Fujitoge Formation, which can be traced to the other sections as a key-bed, has comparatively high intensity and concentrated direction, so that it seems quite reliable as a paleomagnetic marker horizon.

The magnetic polarity sequences of the Miyako-gawa, Ohbayashi and Fujitoge sections are nearly consistent with that of the Kamifujisawa section (Fig. 11).

Fig. 10. Magnetostratigraphy of the Fujitoge Formation in the Kamifujisawa section. (See Fig. 9 for further explanation.)
Two short normally magnetized intervals are also recognized, and the reversed polarity interval between them persists across the boundary between the lower and middle parts of the formation. The magnetic intensity of this paired parts is generally weak, but it seems quite reliable paleomagnetically because of its lateral continuity.

**Izumi Formation**: In the Yasakano section the lower and middle parts of the Izumi Formation is characterized by mostly normal polarity, while the upper part has dominant reversed polarity (Fig. 12). A short normally magnetized interval in the upper part and reversed polarity interval at the base of the lower part of the formation were recognized.

In the Hara-gawa section, a short interval of reversed polarity occurs between \( I_2 \) and \( I_3 \) tuff layers (Fig. 13), but equivalent to this reversed polarity horizon is uncertain in the Yasakano section. This inconsistency is considered to be caused by the secondary magnetization created in the later

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**Table 1. Results of paleomagnetic measurement for the Shiotsubo Formation.**

<table>
<thead>
<tr>
<th>Site</th>
<th>( N )</th>
<th>( D )</th>
<th>( I )</th>
<th>( R )</th>
<th>( \varphi )</th>
<th>( \lambda )</th>
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<tbody>
<tr>
<td>Fujitoge</td>
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<td>1.881</td>
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<td>14.7</td>
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<td>-57.8</td>
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</tbody>
</table>

Note: \( N \) = number of separately oriented samples; \( D \) and \( I \) = mean declination and inclination of remanent magnetism, in degrees east and below horizontal; \( J \) = mean intensity of magnetization in \( \text{emu/cm}^3 \times 10^5 \); \( R \) = resultant vector, assigning unit vector per sample; \( k \) = precision parameter; \( \varphi \) and \( \lambda \) = latitude and longitude of VGP, in degrees north and in degrees east of Greenwich, respectively.
geomagnetic field, probably of during the Brunhes normal epoch. Therefore, it is interpreted that the reversed interval recognized in the Hara-gawa section reflects the past geomagnetic polarity.

The upper part of the formation in the Sakamato section has mostly reversed polarity, but normally magnetized short interval was also detected.

**Nanaorizaka Formation**: The magnetic polarity sequence of the Nanaorizaka Formation was observed in four sections. The formation is characterized by the reversed polarity, but normally magnetized intervals were recognized in the upper and lower parts of the formation.

In the Hara-gawa section the lower part of the Nanaorizaka Formation is well exposed along the river. The upper half and the lower half of the sequence are characterized by the reversed and normal polarities, respectively (Fig. 13). At the top of the lower part, just below the T1 tuff, a normally magnetized horizon was recognized. The normal polarity interval of the lower half of the sequence is of a split feature.

In the Todera section the polarity sequence of the upper part of the formation was obtained. The lower half and the upper half of the section are characterized by reversed and normal polarities, respectively (Fig. 14). In this section and the Nishimura section the T4 tuff layer is normally magnetized, while in the southern Iritazawa and Suzumebayashi sections the same tuff layer showed reversed magnetization. This inconsistency is presumed to relate with some differences in the environment of deposition, though the exact reason remains uncertain. The T4 tuff exposed in the Iritazawa and Suzumebayashi sections has a lithologic feature of pumice flow tuff deposited on dry land, while the lithofacies in the Todera and Nishimura sections indicates the fluvial or lacustrine condition. Furthermore, the T4 tuff in the Todera and Nishimura sections has been weathered as compared
with that of the southern sections. It is considered that the original magnetization of the T4 tuff was reversed polarity, and the removal of secondary magnetization might be not sufficient on the samples from the Todera and Nishimura sections.

**Todera Formation**: In the Todera section, all horizons examined are characterized by the normal polarity (Fig. 14). The same feature was recognized in the Iritazawa and Suzumebayashi sections. The intensity of remanent magnetization is comparatively high in these sections.

### b. Classification of magnetozones

The correlation of fifteen magnetostratigraphic columns on the basis of pyroclastic key-bed is shown in Figure 15. Magnetozones were classified on the polarity sequence which has been compiled from the local correlation as shown in the figure. Letters and numbers were adopted to designate the classified magnetozones.

**AZ-A normal polarity zone**: This zone occupies the uppermost part of the studied

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<table>
<thead>
<tr>
<th>Formation</th>
<th>Site number</th>
<th>Latitude of VGP (degrees)</th>
<th>Intensity (emu/cc)</th>
<th>Polarity</th>
</tr>
</thead>
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<td>NANAORIZAKA</td>
<td>90 60 30 0 30 60 90</td>
<td>South</td>
<td>North</td>
<td>South</td>
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</tbody>
</table>

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**Fig. 13.** Magnetostratigraphy of the Izumi and Nanaorizaka Formations in the Hara-gawa section.

**Fig. 14.** Magnetostratigraphy of the Nanaorizaka and Todera Formations in the Todera section.
section and is characterized by stable normal polarity magnetization. The lower transition coincides with the boundary between the Todera and Nanaorizaka Formations.

**AZ-B reversed polarity zone**: AZ-B zone coincides with the whole Nanaorizaka Formation and the upper half of the Izumi Formation. This zone is characterized by the dominant reversed polarity magnetization. The horizon of lower transition is situated about 20 m below the base of the T5 tuff layer in the Hara-gawa section.

In this magnetozone, two subzones, AZ-B-1 and AZ-B-2 normal polarity subzones, are discriminated. The upper transition of AZ-B-1 subzone is just below the T3 tuff layer and the lower transition is about 50 m above the T2 tuff layer of the Nanaorizaka Formation in the Todera section. AZ-B-2 subzone is discriminated in the lower part of the Nanaorizaka Formation in the Hara-gawa section. The upper transition of this subzone is about 80 m below the T1 tuff layer and the lower transition is coincident with the boundary of the Nanaorizaka and Izumi Formations.
AZ-C normal polarity zone: This zone is characterized by normal polarity and almost coincident with the middle part of the Izumi Formation. The horizon of lower transition is at the base of I3 tuff layer of the Izumi Formation in the Hara-gawa section.

AZ-D reversed polarity zone: This magnetozone coincides with the lower part of the Izumi Formation and the whole Fujitoge Formation, and it is characterized by the dominant reversed polarity. The lower transition is about 10 m below the base of the Fujitoge Formation in the Shiotsubosection. In this zone four normal polarity subzones, AZ-D-1, AZ-D-2, AZ-D-3 and AZ-D-4, are discriminated. AZ-D-1 subzone is situated in the lower part of the Izumi Formation with its upper transition at the top of the I2 tuff layer in the Hara-gawa section and the lower transition about 20 m above the base of the Izumi Formation in the Miyako-gawa section. The welded tuff in this subzone at Futamata, about 3 km south of the Iritazawa section was dated to 3.8 m.y. in K-Ar age (Suzuki et al., 1976).

The upper transition of AZ-D-2 subzone is at the boundary between the Izumi and
Fig. 15. Magnetostratigraphic correlation of fifteen sections in the Aizu Basin and classification of magnetozones. Broken line shows the horizon of pyroclastic key-bed. Solid line shows the boundary between the stratigraphic subdivisions of the Yamato Group.

the Fujitoge Formations, and the lower one is about 10 m below the boundary in the Miyako-gawa section. AZ-D-3 and AZ-D-4 subzones are discriminated in the middle and lower parts of the Fujitoge Formation, respectively. In the Kamifujisawa section, the upper transition of AZ-D-3 subzone is about 57 m below the biotite bearing tuff layer and the lower one is about 20 m above the boundary between the middle and lower parts of the formation. The upper and the lower transitions of AZ-D-4 subzone are situated about 6 m and 24 m below the boundary between the middle and upper parts, respectively, in this section.

AZ-E normal polarity zone: This magnetozone coincides with the upper half of the
Fig. 16. Comparison of established magnetozone with floral assemblage zone in the Aizn Basin. Floral assemblage zone, pollen flora and climatic change are according to Suzuki (1976).

Pollen Flora:
- APTB = Abies, Picea, Tsuga, and Betula
- TCTF = Taxaceae, Cupressaceae, Taxodiaceae, and Fagus
- CTFU = Cupressaceae, Taxodiaceae, Fagus, and Ulmus
- TFL = Taxodiaceae, Fagus, and Liquidambar
- TFU = Taxodiaceae, Fagus, and Ulmus

Characteristics:
- Juglans sachalinensis
- Quercus serrata
- Buxus japonicus
- Picea jezoensis
- P. maximowiczii
- Betula platyphylla var. japonica
- Menyanthes trifoliata
- Alnus japonica - Styrrax japonicus
- Trapa bispinata - Fagus crenata
- Pinus koraiensis - Abies veitchii
- Corylus heterophylla var.
- Carpinus tschonoskii - F. maximowiczii
- Juglans megacinarre - Metasequoia japonica
- Juglans sachalinensis
- Metasequoia japonica
- Glyptostrobus europaeus
- Fagus microcarpa - Styrrax japonicus
- P. nipponica
- Buxus japonicus
- Fagus palaeocrenata - Liquidambar formosana - P. nipponica
- Fagus palaeocrenata - Liquidambar formosana - Populus alczana
- Fagus palaeocrenata - Acer deblilum
- Neolitsea protoaciculara - P. proponiciponics
- Fagus palaeocrenata - Cinnamonum sp.
- Cyclobalanopsis sp.
The comparison between magnetozone and fossil zone

The comparison of magnetozone with floral assemblage zone in the Aizu Basin is shown in Figure 16. Some noticeable paleobotanical evidence in the comparison between the magnetozones and the floral assemblage zones are as follows.

1) The Natsui Floral Assemblage Zone, which is characterized by the extinction of the warm-temperate deciduous tree elements such as *Liquidambar* and the appearance of new species such as *Populus kitamiama* and *Paliurus nipponicus*, corresponds to the normal polarity subzone AZ-D-2.

2) The first appearance of *Menyanthes* and the extinction of *Glyptostrobus* recognized at the horizons close to the boundary between the Koyanaizu and the Fukurohara Floral Assemblage Zones are in the upper half of the magnetozone AZ-C.

3) The Osawa Floral Assemblage Zone which is characterized by the replacement of older elements by many living subalpine elements corresponds to the normal polarity subzone AZ-B-1.

2. SHIRAKAWA AREA

The result of paleomagnetic measurements of the Shirakawa Formation in the Shirakawa area is summarized in Table 5 together with that of the Seaburiyama Formation in the vicinity of Mt. Seaburi.

The intensity of magnetization of the samples from each welded tuff after demagnetization treatment averages $10^{-4}$ emu/cm$^3$, and NRM directions concentrate rather well. All welded tuff of the Shirakawa Formation have reversed polarity which is considered to represent a single reversed polarity magnetozone in the Shirakawa area. The NRM directions of these welded tuff are slightly different each other. The D1 tuff has a westward declination, while the D2 and the D3 tuff have eastward declinations. Moreover, the latitude of VGP of the D3 tuff is higher than that of the D2 tuff.

Any fossils have not been found from the Shirakawa Formation, but the D1 tuff has been dated to 1.4 - 1.6 m.y. in K-Ar age, as described previously. The NRM intensity is also high in the Seaburiyama Formation, ranging from $10^{-4}$ to $10^{-3}$ emu/cm$^3$. The lower part (KU-SY01) and the middle part (IS-SY02, SE-SY03) of the formation have a reversed polarity, while the upper part (SE-SY04) has a inter-
mediate polarity.

The correlation of the results of NRM measurement between the dacitic tuff of the Shirakawa, Seaburiyama and Nanaorizaka Formations have been attempted by the author (Manabe, 1977). These tuff layers are mostly characterized by reversed polarity, therefore, the result of measurement is not in conflict with the stratigraphic evidence. Although individual correlations of the welded tuff of the Shirakawa and Seaburiyama Formations with the pumiceous tuff in the Nanaorizaka Formation have not been succeeded, the reversed polarity magnetozone established from the Shirakawa Formation is considered to be correlative with AZ-B reversed polarity zone in the Aizu Basin.

3. SENDAI AREA

The results of paleomagnetic measurement and the lithology of the Sendai Group are schematically shown in Figure 17. Prior to measurement all specimens were partially demagnetized by an alternating magnetic field, and subsequently thermal demagnetization was performed by heating up to 200°C. The NRM intensity of the samples after these treatments ranges from $10^{-7}$ to $10^{-5}$ emu/cm$^3$.

a. Magnetization of each formation

**Kameoka Formation**: The Kameoka Formation is mostly characterized by the normal polarity. At the top of the formation, a short interval of intermediate polarity was recognized. The intensity of the remanent magnetization is generally high, and the NRM directions are well concentrated (Table 6).

<table>
<thead>
<tr>
<th>Fossil plant</th>
<th>Kameoka F.</th>
<th>Tatsurokuchi F.</th>
<th>Mukaiyama F.</th>
<th>Dainenji F.</th>
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<tbody>
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<td><em>Picea</em> sp.</td>
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<tr>
<td><em>Sequoia</em> sp.</td>
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<td><em>Metasequoia</em> sp.</td>
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<tr>
<td>A. sp.</td>
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<td>*</td>
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<tr>
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(LOCALITY NUMBERS CORRESPOND TO THOSE IN FIGURE 8.)
Fig. 17. Magnetostatigraphy of the Sendai Group. Site numbers correspond to those in Figure 8 and Table 6.

Table 6. Results of paleomagnetic measurement for the Sendai Group.

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<th>Site</th>
<th>n</th>
<th>b</th>
<th>i</th>
<th>h</th>
<th>j</th>
<th>x</th>
<th>y</th>
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</table>
Tatsunokuchi Formation: The main part of the Tatsunokuchi Formation has mostly reversed polarity in the Tatsunokuchi Gorge. Two short normally magnetized intervals occupy the basal part and the top of the formation, respectively. The thickness of the normal polarity interval in the basal part is about 10 m or less, and that at the top of the formation is about 15 m or more. The average NRM intensity is about $1.0 \times 10^{-6}$ emu/cm$^3$, and the NRM directions are comparatively concentrated.

Mukaiyama Formation: All samples collected from the Mukaiyama Formation have reversed polarity. The NRM intensity is rather weak, and the concentration of NRM directions at a site is not good. But it is considered that the remanent magnetization is stable, because there are no polarity changes during both alternating magnetic field and thermal demagnetization treatments.

Dainenji Formation: The lower half of the Dainenji Formation is characterized by the normal polarity, and the upper half by reversed polarity. The thickness of the lower normal polarity interval is about 26 m, and that of the upper reversed polarity interval is about 30 m. The intensity of magnetization is comparatively high in this normal polarity interval.

b. Magnetozone and plant fossil

Magnetozones were classified on the polarity sequence of the remanent magnetization, and letters and numbers were adopted as designations of the classified magnetozones.

SE-B reversed polarity zone: This magnetozone coincides with the whole Dainenji and Mukaiyama Formations. The zone is characterized by the dominant reversed polarity. The upper and lower transitions are restricted by unconformity. In this magnetozone, a normal polarity subzone, SE-B-1 subzone, is discriminated in the middle part. The lower transition of the subzone is coincident with the boundary between the Dainenji Formation and the underlying Mukaiyama Formation. The upper transition is about 30 m above the base of the Dainenji Formation in the Sozenji section.

At Kanearai-zawa about 3 km southwest of the Sozenji section, Liquidambar has been found (Okutsu, 1955) which is correlated with SE-B-1 subzone. At the locality SD-1, the Iwanuma section is correlated with SE-B-1 subzone and yielded abundant plant fossils including such species as Nyssa sylvatica and Fagus microcarpa (Table 7). In the Yoshinari section, Palmetus nipponicus occurred in the lowermost part of the Dainenji Formation which is also correlative with this subzone.

SD-C normal polarity zone: This zone is characterized by normal polarity and nearly coincident with the upper one-third of the Tatsunokuchi Formation. The interval of normal polarity is comparatively short, and the upper transition coincides with unconformity. The lower transition is about 35 m above the base of the Tatsunokuchi Formation.

From the floor of the Hirose River at Hyojo-gawara nuts of Juglans cinerea have been found (Okutsu, 1955). This horizon is in the lower half of SD-C magnetozone.
**SD-D reversed polarity zone:** This magnetozone coincides with most of the Tatsunokuchi Formation and the whole Kameoka Formation. The zone is characterized by the dominant reversed polarity. The lower transition is represented by unconformity. In this magnetozone a normal polarity subzone, SD-D-1 subzone, is discriminated in the lower part. SD-D-1 subzone is nearly coincident with the Kameoka Formation, and the upper transition is about 10 m above the boundary between the Tatsunokuchi and Kameoka Formations in the Sakuragaoka section. The lower transition is restricted by the unconformity mentioned above.

Abundant plant fossils including *Fagus palaeocrenata* have been yielded from the Kameoka Formation, which is coincident with SD-D-1 subzone, in the Sakuragaoka section (Table 7).

4. MAGNETOSTRATIGRAPHIC CORRELATION

a. Correlation between Aizu Basin and Sendai Area

The correlation of the magnetozones between the Yamato and Sendai Groups was estimated first by the characteristics of plant fossil assemblages. Further detailed correlation was made on the reversal sequence in remanent magnetization (Fig. 18). The plant fossil assemblage from the Dainenji Formation is here designated as the Dainenji flora. In the same way the terms of Mukaiyama, Tatsunokuchi and Kameoka floras are used here for descriptive convenience.

Although an unconformity exists between the Tatsunokuchi and Mukaiyama Formations, the composition of the Tatsunokuchi flora is similar to that of the Mukaiyama and the Dainenji floras. These three floras are characterized by *Glyptostrobus*, *Metasequoia* and *Fagus microcarpa*, and they are also characterized by lack of boreal species. In this character these are different from the Otezawa Flora in the Aizu Basin, which is characterized by the temperate broad-leaved elements associated with extinct elements and the boreal species such as *Menyanthes trifoliata* and *Picea maximowiczii*. The Dainenji flora contains *Liquidambar*, *Nyssa sylvatica* and *Paliurus nipponicus*. The last is one of the characteristic species of the Koyanaizu Flora in the Aizu Basin, though *Liquidambar* has not been found in the Koyanaizu Flora. The Tatsunokuchi flora contains *Juglans cinerea* which is one of the characteristic species of the Fukurohara Flora.

On the other hand, the Kameoka flora is characterized by *Glyptostrobus* and *Fagus palaeocrenata*. In the Aizu Basin, *Fagus palaeocrenata*, an element of the temperate deciduous broad-leaved trees, is one of the characteristic species in the flora of the Fujitoge Formation. But this species disappears at the top of the Natsui Floral Assemblage Zone, and the overlying Koyanaizu Floral Assemblage Zone is characterized by *F. microcarpa*. This floral change is similar to that recognized between the Kameoka and Tatsunokuchi floras. On this evidence, the Kameoka Formation was correlated with the upper part of the Fujitoge Formation, and the remaining part of the Sendai Group was correlated with the Izumi Formation.

In the next step, magnetozones were correlated with each other. SD-D reversed polarity zone of the Sendai Group was correlated with the upper part of AZ-D reversed polarity zone of the Yamato Group.

SD-D-1 subzone was correlated with the both of AZ-D-1 and AZ-D-2 subzones, because SD-D-1 subzone seems to be subdivided into two parts by the intermediate po-
L arity horizon at the top of the Kameoka Formation (Fig. 17). Then, SD-C magnetozone was correlated with AZ-C normal polarity zone. SE-B reversed polarity zone was correlated with the lower portion of AZ-B zone occupying below AZ-B-2 subzone, referring to the character of floral composition mentioned above.
The comparison of magnetozones between the Sendai and Yamato Groups indicates that a considerable difference in thickness between SD-C normal polarity zone and AZ-C zone is due to the unconformity between the Tatsunokuchi and Mukaiyama Formations. In the Aizu Basin, the first appearance of the boreal element such as Menyanthes trifoliata var. minusculus and the extinction of Glyptostrobus europaeus occur in the upper part of AZ-C zone, which can be attributed to climatic deterioration. Therefore, the unconformity within the Sendai Group may have been regulated from the lowering of sea level related to climatic change.

b. Correlation between Aizu Basin and Uonuma Area

In the Oguni and Tokamachi area, about 80 km south of Niigata City, north central part of Honshu, the Early Pleistocene Uonuma Group is widely distributed. Since Ikebe (1940) studied detailed stratigraphy of the Uonuma Group, many investigations have been made on the Late Cenozoic sections including the Uonuma Group.

The lower part of the Uonuma Group consists of coarse-grained sandstone and conglomerate, and the middle and upper parts consist of an alternation of sandstone and mudstone. According to the analysis of diatom and foraminiferal assemblages, it is indicated that the sedimentary environments have changed from marine water to brackish and then to fresh water condition in ascending stratigraphic order (Niigata Plain Collaborative Research Group, 1970).

Pollen analyses have been made on the Uonuma Group developed in the Tokamachi area about 10 km south of the Oguni area, and based upon the pollen floral change a correlation with the Osaka Group was attempted (Yamanoi, 1970; Yamanoi and Nitobe, 1970). Macroscopic plant fossils collected from the Tokamachi area have been also examined by Ueno (1969), and some characteristic floral changes have been pointed out by Yamanoi et al. (1970).

On the other hand, Nitobe and Niitsuuma (1971) established the magnetostratigraphy of the Uonuma Group and subjacent formations. They measured the remanent magnetization of sedimentary rock samples collected from the Late Cenozoic section including the Uonuma Group in the Oguni area according to the lithostratigraphy by Miyashita et al. (1970). Magnetostratigraphic investigation was made on the Uonuma Group also in the Tokamachi area, and the result was reported together with the pollen stratigraphy by Nitobe (1977). In Figure 18, the results of magnetostratigraphic and paleobotanical investigations of the Uonuma Group are summarized. On the basis of these results, an attempt was made to correlate the Uonuma Group with the Yamato Group of the Aizu Basin.

The results of magnetostratigraphic investigations indicate that the Uonuma Group is mostly characterized by the reversed polarity. In the Oguni area, two magnetozones, NUOG-A normal polarity zone and NUOG-B reversed polarity zone are established in the Uonuma Group (Nitobe and Niitsuuma, 1971). The normal polarity zone NUOG-A was defined in the uppermost part of the Oguni Formation, and two normal polarity subzones, B-2 and B-4 were defined in the subjacent NUOG-B reversed polarity zone (Fig. 18). In the Tokamachi area, almost consistent polarity succession is recognized. Namely, the most part of the Uonuma Group has reversed polarity, and the lower part is characterized by the normal polarity magnetization. In the upper half of the Tokamachi section a short normal polarity interval is recognized just above the key tuff Sz. There are many tuff layers at several horizons of the Uonuma Group, and some of them are widely traced as a key bed (Miyashita et al., 1970). The polarity sequence of the To-
The characteristic change in floral composition of the Uonuma Group occurred at the horizon about 50 m below the Tsukanoyama volcanic ash layer which is the continuation of Sz tuff layer. The floral assemblage of the section below this horizon, which was designated as the lower flora of the Uonuma Group, is characterized by the temperate tree elements associated with extinct elements such as Metasequoia, Glyptostrobus, Juglans megacineria and Pterocarya paliurus. Whereas the flora above this horizon, the upper flora of the Uonuma Group, is mostly characterized by the cool-temperate elements accompanied with subalpine elements, which also contain some extinct elements such as Juglans mandshurica.

The feature of this floral change recognized in the section below the Tsukanoyama volcanic ash layer (Sz tuff layer) is similar to the floral change from the Otezawa Floral Assemblage Zone to the Osawa Floral Assemblage Zone in the Aizu Basin. On this evidence, the reversed polarity zone NUOG-B was correlated with AZ-B reversed polarity zone of the Yamato Group. NUOG-B-2 and NUOG-B-4 subzones were also correlated with AZ-B-1 and AZ-B-2 subzones, respectively (Fig. 18).

The correlation of these magnetozones indicates that the Uonuma Group is nearly correlative with the Nanaorizaka Formation of the Yamato Group. It seems to be consistent with the similarity in sedimentary facies between them which are characterized by coarse-grained sediments including many conglomerates.

c. Correlation with the Polarity Time Scale

There is no micropaleontological evidence for correlating the magnetozones in the present areas with the polarity time scale established in deep-sea sediments. Therefore, an attempt was here made to correlate the magnetozones with the polarity time scale published by Cox (1969), on the basis of K-Ar dates of the welded tuff (Fig. 19).

On the basis of the K-Ar dates of 1.4–1.6 m.y. of D1 tuff of the Shirakawa Formation, AZ-B reversed polarity zone was correlated with the Matuyama reversed epoch of Cox (1969), and AZ-B-1 subzone and AZ-B-2 subzone are also correlated with the Jaramillo and Oldevai (or Gilsa of Cox (1969)) events, respectively.

It seems quite reasonable that the boundary between AZ-A zone and AZ-B zone is correlative with the Brunhes-Matuyama boundary, because the Todera Floral Assemblage Zone is characterized by a periodical changes in floral composition which can be attributed to an oscillation between cold and warm climates, which suggests the duration parallel to a glacial age.

The dacitic welded tuff of the Izumi Formation which is correlative with AZ-D-1 normal polarity subzone was dated to 3.8 m.y. in K-Ar age, which is in good agreement with the age of the Cochiti event within the Gilbert reversed epoch. AZ-D reversed polarity zone was correlated, therefore, with the Gilbert reversed epoch of Cox (1969). AZ-D-2, AZ-D-3 and AZ-D-4 normal polarity subzones are also correlated with the Nunivak, unnamed C1 and C2 events, respectively, according to their stratigraphic positions.

Koizumi (1972, 1973b) examined the diatom assemblages from the Tatsunokuchi Formation corresponding to the reversed polarity magnetozone SD-D which was herein correlated with the uppermost portion of AZ-D polarity zone of the Yamato Group. According to Koizumi (1972), the diatom flora of this formation in Fukushima...
Fig. 19. Correlation of established magnetozones with polarity time scale (Cox, 1969; Talwani et al., 1971, for early part of the Gilbert epoch and Epoch 5), and rate of sedimentation deduced from the gradient of fit line.

Prefecture is characterized by the concurrent occurrence of *Denticula kamtschatica* and *D. seminae*, which is assignable to the *D. seminae var. fossilis* - *D. kamtschatica* Zone of Koizumi (1973a).

In the pacific coastal region from Northeast Honshu through Hokkaido to Sakhalin, strata yielding *Fortipecten takahashii* (Yokoyama) are distributed and constitute a marker horizon for inter-regional correlation (Fujie, 1958; Kitamura and Takayanagi, 1977). *F. takahashii* is a characteristic species in the Tatsunokuchi Formation together with some other species.

On the other hand, a combined biostratigraphical, paleomagnetic and sedimentological study of Late Cenozoic sedimentary section of northwestern Hokkaido has been carried out by Ujiie et al. (1977).

In the coastal area north of Shosanbetsu a thick and nearly continuous section of Neogene sediments was studied. From the results obtained, *Fortipecten takahashii* was found in the middle part of the Mochikubetsu Formation of the Shosanbetsu section and the associated diatom flora is indicative of the *D. seminae var. fossilis* - *D. kamtschatica* Zone. The *F. takahashii* horizon of the Mochikubetsu Formation, moreover, was correlated with the reversely magnetized interval above the Nunivak event of the Gilbert reversed epoch of Opdyke (1972).

Taking this for the evidence, the reversed magnetozone SD-D of the Sendai Group is considered to be correlative with the latter half of Gilbert reversed epoch. It seems also reasonable that the reversed polarity magnetozone AZ-D of the Yamato Group, an equivalent to SD-D reversed polarity zone, is correlated with the Gilbert reversed epoch based on the K-Ar date, though the polarity time scale is based on a different principle from that of Opdyke (1972).

In Figure 19, an attempt was made to correlate the magnetozones of the studied sections with the geomagnetic polarity time scale. Both the normal polarity magnetozones AZ-C and SD-C were correlated with the Gauss normal epoch based on their stratigraphic positions and polarities, though there is no positive evidence. The correlation of these magnetozones with the geomagnetic time scale enables us to date various horizons and estimate of the rate of sedimentation. The averaged rates of sedimentation deduced from the Late Cenozoic sections of the Aizu Basin and the Sendai area are illustrated in Figure 19. Changes in sedimentation rate were recognized at several
In the Aizu Basin, remarkable increase of sedimentation rate can be recognized about 4.5 and 1.8 m.y. ago, which are labeled as "a" and "b" in the figure, respectively. The former change at about 4.5 m.y., labeled as "a", corresponds to the extension of the sedimentary basin in the Paleo-Aizu Basin I stage established by Suzuki et al. (1977a). The latter change at about 1.8 m.y. also corresponds to the commencement of the Paleo-Aizu Basin II stage which is coincident with the beginning of deposition of the Nanaorizaka Formation, and then the sedimentary basin has been extended. The changes in sedimentation rate thus detected magnetostratigraphically are considered to be related to the geological development of the Aizu Basin.

CONCLUSION

The result of combined magneto- and biostratigraphic study of the Late Cenozoic sedimentary sections, leads to the following conclusions.

In the Aizu Basin, the magnetic polarity sequences were observed in fifteen sections, and magnetozones were classified on them. Four magnetozones, AZ-A, AZ-B, AZ-C and AZ-D, were established in the Yamato Group in descending order. AZ-A normal polarity zone is coincident with the Todera Formation and AZ-B reversed polarity zone coincides with the Nanaorizaka Formation and upper half of Izumi Formation. AZ-C normal polarity zone is nearly coincident with the middle part of the Izumi Formation, and AZ-D reversed polarity zone coincides with the lower part of the Izumi Formation and the Fujitoge Formation. The Shiotsubo Formation, which occupies the uppermost part of the underlying Yamasato Group, has dominant normal polarity and the upper half of the formation was discriminated as AZ-E normal polarity zone.

The relation of these magnetozones to floral assemblage zones which have been established by Suzuki (1976) was examined in order to establish one of the standard successions for magnetostratigraphic correlation in the inland area of Northeast Honshu.

An attempt was made to correlate the magnetozones with the polarity time scale of Cox (1969) on the basis of K-Ar ages of the welded tuff. The upper part of the Nanaorizaka Formation is considered to be contemporaneous with D1 tuff of the Shirakawa Formation of which K-Ar ages are 1.4 - 1.6 m.y. Consequently, AZ-B reversed polarity zone was correlated with the Matuyama reversed epoch of Cox (1969). The dacitic welded tuff of the Izumi Formation which is correlative with AZ-D-1 normal polarity subzone is 3.8 m.y. in K-Ar age, therefore, AZ-D reversed polarity zone was correlated with the Gilbert reversed epoch of Cox.

On the other hand, magnetostratigraphic investigation of the Sendai Group revealed three magnetozones, SE-B, SD-C and SD-D, and they are correlative with those of the Yamato Group in the Aizu Basin. The SE-B reversed polarity zone coincides with the Dainenji and Mukaiyama Formations, SD-C normal polarity zone with the upper one-third of the Tatsunokuchi Formation, and SD-D reversed polarity zone with the rest of the Tatsunokuchi Formation and the Kameoka Formation.

Taking paleobotanical evidence into consideration, the magnetozones of the Sendai Group were correlated with these of the Yamato Group. SE-B reversed polarity zone of the Sendai Group was correlated with the lower part of AZ-B reversed polarity zone of the Yamato Group, and SD-C normal polarity zone with AZ-C zone. SD-D reversed polarity zone of the Sendai Group was correlated with the upper part of
AZ-D reversed polarity zone which is correlated with the Gilbert reversed epoch of Cox (1969) on the basis of the K-Ar age.

Referring to the study of the Late Cenozoic sedimentary section of Hokkaido reported by Ujiie et al. (1977), SD-D magnetozone of the Sendai Group is correlated with the latter half of the Gilbert reversed epoch of Opdyke (1972). An attempt was made to correlate the magnetozones of the Uonuma Group in the Tokamachi area with those of the Yamato Group. The characteristic change in floral composition of the Uonuma Group occurred at the horizon just below the Tsukanoyama volcanic ash (Sz tuff) layer. This change is quite similar to the floral change between the Otezawa and Osawa Floral Assemblage Zones in the Aizu Basin. On this evidence, the reversed magnetozone NUOG-B was correlated with AZ-B reversed polarity zone of the Yamato Group (Fig. 18).

Using the magnetostratigraphically derived dates of the Yamato and Sendai Groups, the rate of sedimentation was estimated in these basins. In the Aizu Basin, two intervals of remarkably high sedimentation rates of about 63 and 46 cm per 1000 years were deduced to have taken place about 4.5 and 1.8 m. y. ago, respectively. These changes in sedimentation rate seem to be related to the development of the sedimentary basin.

The stability of the magnetization of sediments and the validity of the magnetostratigraphy were examined by means of both laboratory and field tests. The results of consistency check and fold test indicate minimal effects of post-depositional remagnetization and sufficient removal of unstable components by demagnetization treatment.

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