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PALEOMAGNETIC STUDY ON THE DINOSAUR-BEARING STRATA OF THE TETORI GROUP, CENTRAL JAPAN

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ABSTRACT

Paleomagnetic directions of samples collected from fifteen sites of the Tetori Group (Middle Jurassic to Early Cretaceous) are found to be stable enough to discuss about the paleolatitude, tectonic migration and rotation of the Tetori Basin. Present paleomagnetic study, together with previously published data, revealed the following geotectonic history of the basin.

The sedimentary basin had initially been located in a low-latitude region about 24°N until the Itsuki "Stage", the uppermost horizon of the Itoshiro Subgroup. Sedimentation of the Kuzuryu and Itoshiro Subgroups took place in this region with an exception of the Kuwajima Formation, which records clearly higher paleolatitudes. Before the Kuwajima "Stage", which is here substantiated to postdate the Itsuki "Stage", the basin was rapidly migrated northwards up to latitudes of around 40°N. During this northward migration, the basin was rotated counter-clockwise by about 40°. Sedimentation of the Kuwajima Formation and the Akaiwa Subgroup occurred in this high latitude. After the deposition of the Tetori Group, the basin was transferred southeastward and rotated clockwise by an angle of 80° in sometime, probably in the Early Miocene when the opening of the Japan Sea took place. The paleomagnetic data of the dinosaur-bearing Tetori Group provide an important information to consider the origin and paleoecology of the Japanese dinosaurs.

Key words: paleomagnetic study, paleolatitude, tectonic rotation, northward migration, Tetori Group, Kuzuryu Subgroup, Itoshiro Subgroup, Akaiwa Subgroup, Itsuki Formation, Kuwajima Formation, dinosaur

広岡公夫・加藤正彦・森定　尚・東　洋一 (2002) 手取層群の恐竜化石包含層の古地磁気学的研究，福井県立恐竜博物館紀要 1: 54-62.

手取層群の15カ所から採集されたサンプルの古地磁気学的方位は，手取盆地の古緯度や回転を議論する上で十分に安定している．本古地磁気学的研究は，これまでの測定結果とともに次のような手取層群堆積盆地の地質構造発達史を明らかにした．

堆積盆地は，石徹白亜層群最上部の伊月層堆積までは非常に低緯度（北緯24° 付近）に位置していた．九頭竜・石徹白亜層群の堆積は，この地域で行われた．その後，桑島層が堆積する前に，堆積盆地は北緯40° 付近まで急速に北上した．

桑島層や赤岩亜層群の堆積は，高緯度で行われ，その後，堆積盆地はおそらく日本海拡大時の初期中新世に，約80° 回転しながら南東方向へ移動した．手取層群の恐竜化石包含層の古地磁気学的データは，日本における恐竜の起源や古生態にとって重要と考えられる．

INTRODUCTION

Many paleomagnetic studies of the Paleozoic-Mesozoic strata and rocks in Japan have been carried out since the beginning of 1960s when the pre-Neogene bending of the Japanese main island, Honshu, was firstly suggested by Kawai et al. (1961). The studies in 1960s, however, were very primitive and paleomagnetic reconstruction was based upon only the *in situ* magnetic directions. Accurate measurements should apply tilt correction and demagnetization, though basic concept of the bending hypothesis could fortunately survive due to the fact that the studied Paleozoic and Mesozoic sedimentary formations were mostly remagnetized by heating of the Cretaceous-Paleogene granite intrusions.

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Paleomagnetic measurements in Japan began to take tilt correction and demagnetization into account at mid-1970s, and were performed for the Permian greenstone in the Mino Belt, Central Japan (Hirooka and Hattori, 1975; Hattori and Hirooka, 1977, 1979), the Silurian (Shibuya et al., 1983) and the Permian (Sakai and Maruyama, 1984) systems in the Kurosegawa Belt (the Outer Zone of southwestern Japan). The results of these studies revealed very shallow inclinations, which correspond to the equatorial regions.

For the Mesozoic rocks in Japan, paleomagnetic measurements were carried out on the Motodo Formation (Hirooka et al., 1983a, 1985), the Kuruma (Hirooka et al., 1983a, 1983b, 1985), the Tetori (Hirooka et al., 1983a, 1983b, 1985), the Izumi (Kodama, 1986), and the Shimanto Groups (Hirooka et al., 1983a), and the Nohi Rhyolites (Itoh, 1988; Miki and Hirooka, 1990). According to the results of these studies, the Jurassic-Cretaceous systems in the Hida and the Circum-Hida Belts locating in the Inner Zone of southwestern Japan typically showed the mid-latitude inclinations, although the Motodo Formation recorded slightly shallower inclinations. On the contrary, the Shimanto Group, which consists of the southernmost tectonic belt of the southwestern Japan, recorded paleolatitudes less than 20˚ from Coniacian to Santonian stages. Such paleomagnetic evidence consistently supported the accretion tectonic history of the Japanese Islands (Hirooka et al., 1983a, 1983b, 1985; Hirooka, 1990).

The paleomagnetic evidence plays a very important role not only in drawing the tectonic history but also in determining the positions of the Islands during Mesozoic time. We report here the results of paleomagnetic measurements carried out for the Middle Jurassic to the Early Cretaceous sedimentary sequences of the Tetori Group, from which many dinosaur fossils were recently discovered (Azuma, 1991; Azuma and Tomida, 1995).

PALEOMAGNETIC SAMPLING AND GEOLOGICAL SETTING OF THE TETORI GROUP

The Tetori Group is subdivided into three subgroups, namely, the Kuzuryu, Itoshiro, and Akaiwa Subgroups in the ascending order. Paleomagnetic samples were collected from fifteen sites. One site (DLI6) is in the Kuzuryu Subgroup which is assigned to the Middle to Upper Jurassic. Five sites (DLI5, DLI4, DLI2, DLS2, and DLS3) are in the Itoshiro Subgroup correlative to the uppermost Jurassic to the lowest Cretaceous, and nine sites (DLI1, DLS1, DLK9, DLK8, DLK7, DLK6, DLK4, DLK1, and DLK0) are in the Lower Cretaceous Akaiwa Subgroup. All the sites are related to the horizons where the terrestrial vertebrate remains including dinosaurs are found (Azuma and Tomida, 1995). The type stratigraphy of the Tetori Group (Maeda, 1961) is shown in Fig. 1.

The Kuzuryu Subgroup in its type locality consists of the Shimoyama, Oidani, Tochimochiyama, Kaizara, and Yambarazaka Formations from the lower to the upper. Although

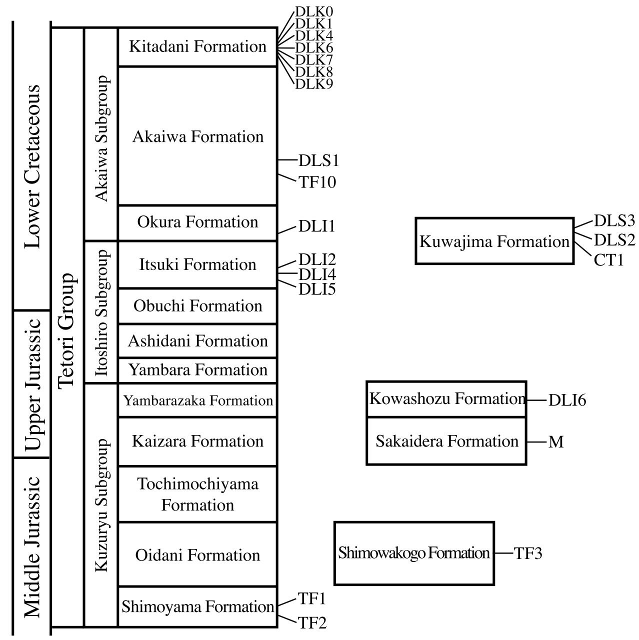

FIGURE 1. Paleomagnetic sampling horizons shown on the conventional stratigraphic classification of the Tetori Group. The stratigraphic position of the Kuwajima Formation is modified from the conventional one, based on the result of the present study.

these formations mainly consist of marine sediments, a part of the Kowashozu Formation corresponding to DL16 yielded a terrestrial reptile fossil, *Tedorosaurus asuwaensis* (Shikama, 1969). This formation was correlated to the Yambarazaka Formation. The Itoshiro Subgroup is subdivided into the Yambara, Ashidani, Obuchi, and Itsuki Formations in the ascending order. Sites DLI5, DLI4 and DLI2 are located at the type locality of the Itsuki Formation where dinosaur and bird footprints were found (Azuma et al., 1992; Azuma et al., in this volume). Sites DLS2 and DLS3 are in the Kuwajima Formation, which yields dinosaur fossils and fossil forest, and, according to Maeda (1961), Matsukawa and Ito (1995) and Ohana and Kimura (1995), is correlated with the Itsuki Formation. The Akaiwa Subgroup is composed of three formations such as the Okura, Akaiwa, and Kitadani Formations. Site DLS1 belongs to the Akaiwa Formation and rest of the sites (DLK9, DLK8, DLK7, DLK6, DLK4, DLK1, and DLK0) are to the Kitadani Formation.

The horizons of the sampling sites are also shown in the conventional stratigraphic classification of the Tetori Group (Fig. 1). Distribution of the Tetori Group and the sampling sites are plotted in Fig. 2. Name of geologic units, rock type, and strike and dip angles of bedding plane of strata at fifteen sampling sites are tabulated in Table 1.

The other six sampling sites of a previous paleomagnetic study of the Tetori Group (Hirooka et al., 1983b) are also shown in

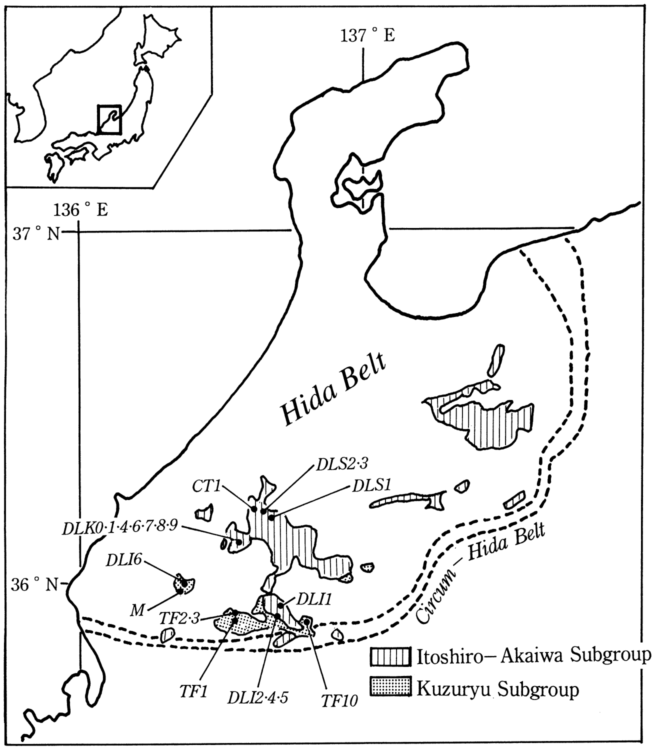

FIGURE 2. Map showing distribution of the Tetori Group and localities of the paleomagnetic sampling sites.

Figs. 1 and 2. Among the four sites of the Kuzuryu Subgroup, TF2 and TF1 are of the Shimoyama Formation, TF3 is of the Shimowakogo Formation (correlative to the Oidani Formation), and M is of the Sakaidera Formation (correlative to the Kaizara Formation). Site CT1 is of the Kuwajima Formation of the Itoshiro Subgroup. Site TF10 is of the Akaiwa Formation of the Akaiwa Subgroup.

PALEOMAGNETIC MEASUREMENTS

From every site, 10 to 11 hand samples were collected, and two or three specimens were cored from each hand sample. After measurements of natural remanent magnetization (NRM) of all of the specimens, two pilot sample sets composed of two to four specimens were provided for each site. One of those sets was subjected to the progressive alternating field demagnetization (AFD) on seven steps of 5.0, 10, 15, 20, 25, 30, and 40 mT, and the other to the progressive thermal demagnetization (TD) on five to twelve steps of about 50°C interval from 100°C up to 630°C. Those TD experiments were carried out in air.

Results of progressive demagnetization of a pilot sample set for each site were plotted on an orthogonal diagram (Zijderveld, 1967) to select the stable magnetic components and to decide the optimum demagnetizing temperature steps. No obvious component was recognized on orthogonal diagrams of AFD experiments for all the sites, while the results of TD experiments elucidate the stable remanent components. It is evident that the

TABLE 1. Locality and stratigraphic informations of the sampling sites.

Site	Locality Lat.(°N)	Lon.(°E)	Stratigraphic unit	Rock type	Bedding Strike(°)	Dip(°)
DLK0	36°07'	136°33'	Kitadani Formation	sandstone	N 2E	29E
DLK1	36°07'	136°33'	Kitadani Formation	shale	N 2E	29E
DLK4	36°07'	136°33'	Kitadani Formation	sandstone	N 2W	16W
DLK6	36°07'	136°33'	Kitadani Formation	sandstone	N 2W	16W
DLK7	36°07'	136°33'	Kitadani Formation	shale	N 2W	16W
DLK8	36°07'	136°33'	Kitadani Formation	sandstone	N 2W	16W
DLK9	36°07'	136°33'	Kitadani Formation	shale	N 2W	16W
DLS1	36°11'	136°39'	Akaiwa Formation	sandstone	N88W	10S
DLI1	35°58'	136°45'	Okura Formation	shale	N87E	27S
DLS3	36°12'	136°38'	Kuwajima Formation	sandstone	N45E	22SE
DLS2	36°12'	136°38'	Kuwajima Formation	shale	N27E	35E
DLI2	35°56'	136°42'	Itsuki Formation	sandstone	N46W	38E
DLI4	35°56'	136°42'	Itsuki Formation	mudstone	N43W	37E
DLI5	35°56'	136°42'	Itsuki Formation	sandstone	N63W	36N
DLI6	36°00'	136°22'	Kowashozu Formation	sandstone	N32E	14W

Lat. and Lon. indicate latitude and longitude of the sampling site.

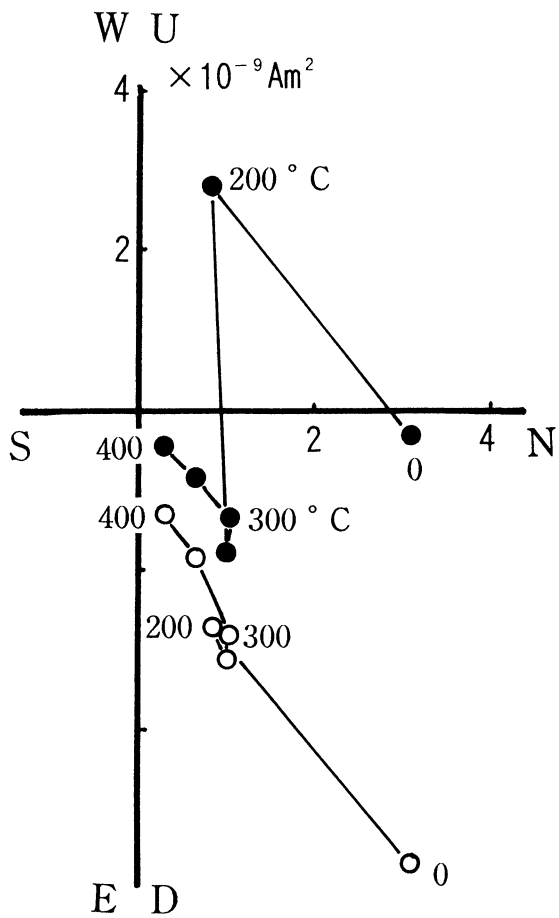

FIGURE 3. Orthogonal plot of a specimen (specimen number: DLI23a2) in Site DLI2.

thermal demagnetization is more effective to eliminate unstable secondary components of rock samples in the present study area. As for seven sites of DLK0, DLK1, DLS3, DLI1, DLI2, DLI4 and DLI5, the appropriate demagnetizing steps were decided from demagnetization of pilot samples. For these sites, remaining specimens of the sites were submitted to demagnetization on two or three progressive steps, which were appropriately judged, from the demagnetizing feature of the pilot samples. Figure 3 shows an example of the orthogonal diagram of thermal demagnetization of a specimen (DLI23a2) in Site DLI2. Above 300° C, a stable component was clearly seen (Fig. 3).

As for the rest of eight sites, three to five additional specimens selected from each site were subjected to progressive thermal demagnetization by the same procedures as their previous pilot samples.

In the above-mentioned demagnetizing procedure, the result of a step on which the smallest Fisher's angle of confidence (α_{95}) and the largest Fisher's precision parameter (K) (Fisher, 1953) are obtained, is adopted as the paleomagnetic value of the site.

The stable *in situ* paleomagnetic directions obtained from the examination of thermal demagnetization are listed in Table 2. Results of the previous work (Hirooka et al., 1983b; Sites TF2, TF1, TF3, M, CT1, and TF10) are also presented in Table 2.

CORRECTION OF PALEOMAGNETIC RESULTS

The rocks and strata in the geologically mobile belt have been suffering from geotectonism. Geotectonic motions such as tilting and folding, have changed *in situ* direction of remanent magnetization. Tectonic correction of the paleomagnetic results is, therefore, the most important function in restoring the geomagnetic field direction of the geologic time. Sedimentary strata of the Tetori Group in the present study area incline by about 15° to 40° as shown in Table 1.

The correction called 'tilt correction' or 'untilting' is the most common correction of a inclining bedding plane. This correction is made by rotating the bedding plane around the axis of the strike by the angle of dip, so that the bedding plane becomes horizontal. If the folding axis is not horizontal but plunges, 'untilting' gives wrong results in magnetic declination. In such a case, first, we must make the plunging folding axis to horizontal by rotating around a horizontal axis perpendicular to the folding axis, and then make the bedding plane to horizontal by rotating around this horizontal-folding axis. We call this procedure as 'structural correction' .

Azimuth and angle of plunge of the folding axis are obtained by using dips and strikes of bedding planes of sampling sites. For the Akaiwa Subgroup, azimuth and plunging angle of the folding axis are 120.0° (S60.0°E) and 15.0°, respectively, and those for the Itoshiro and Kuzuryu Subgroups are –33.2° (N33.2°W) and 12.7°. The tilt corrected and structurally corrected paleomagnetic declinations and inclinations of the present study are tabulated in Table 2 together with data of the previous work (Hirooka et al., 1983b). As for the data of the previous work, structurally corrected directions are newly computed by using above-mentioned azimuth and plunging angle of the folding axis. Paleolatitudes that were calculated from structurally corrected inclinations are also listed in Table 2. Figure 4 shows plots of *in situ*, tilt corrected and structurally corrected site mean directions of the Tetori Group obtained by the present study.

Following two evident facts are recognized from Table 2 and Fig. 4. One is that the concentration of paleomagnetic directions is very much improved by structural correction. The correction is so effective to recover the past geomagnetic field, that structurally corrected directions are used as the paleomagnetic results in this paper. The other is that the inclinations increase from the lower horizons (the Kuzuryu and the Itoshiro Subgroups) to the upper horizons (the Akaiwa Subgroup).

The former fact indicates that the measured directions passed the folding test which examined whether the data obtained were relied upon as the real records of the ancient geomagnetic field

TABLE 2. Site mean paleomagnetic directions of the Tetori Group.

Site	in situ				ODT	ODF	Intensity	Tilt corr.		Structural corr.		Paleo-
	N	D(°E)	I(°)	α_{95}	K	(°C)	(mT)	($\times 10^{-7}$ Am^2/kg)	Dtc(°E)	Itc(°)	Dsc(°E)	Isc(°)	latitude(°N)
DLK0	14	55.0	84.0	9.68	17.84	250	-	1.27	86.3	55.1	74.3	64.5	46.4
DLK1	8	117.2	81.9	6.25	79.47	350	-	2.32	100.3	50.2	91.8	63.0	44.5
DLK4	11	56.0	76.4	4.67	96.58	250	-	2.74	73.2	61.7	76.0	60.8	41.8
DLK6	12	71.2	73.9	7.86	31.48	300	-	3.60	81.2	58.3	82.2	57.1	37.9
DLK7	9	96.7	76.0	8.55	37.24	250	-	4.15	92.2	60.0	94.4	59.9	40.8
DLK8	12	79.5	82.0	10.81	17.09	250	-	2.71	84.8	66.0	88.3	65.1	47.1
DLK9	9	82.1	66.5	13.74	15.00	300	-	3.19	84.4	50.8	86.5	49.5	30.3
DLS1	10	48.1	54.6	20.08	6.75	400	-	0.314	59.8	61.0	72.2	54.5	35.0
TF10	10	44.2	40.9	5.00	94.36	NRM	-	16.8	72.9	64.5	72.2	57.1	37.7
DLI1	14	35.5	49.0	5.39	55.27	250	-	1.02	71.8	64.8	67.8	65.1	47.1
DLS3	12	35.6	59.8	11.02	16.48	250	-	0.73	71.6	56.4	63.8	61.1	42.2
DLS2	9	69.5	65.7	18.75	8.50	250	-	0.79	85.2	35.9	84.4	53.0	33.6
CT1	7	51.3	58.9	4.65	169.75	-	20.0	1.64	92.1	64.0	88.2	61.5	42.6
DLI2	9	269.5	74.7	31.80	3.58	300	-	0.45	11.8	62.0	13.0	59.1	39.9
DLI4	10	97.2	70.0	12.81	15.18	300	-	0.503	66.5	38.2	57.5	38.7	21.8
DLI5	13	75.3	72.3	9.81	18.82	250	-	0.77	44.7	40.5	48.2	42.0	24.2
DLI6	11	36.6	42.7	25.42	4.19	300	-	0.47	23.6	42.0	24.3	42.4	24.5
M	8	31.7	51.9	11.80	22.85	-	10.0	1.07	39.3	18.4	40.5	18.9	9.7
TF3	22	89.9	57.3	10.20	10.22	450	-	54.3	78.9	27.3	63.4	30.5	16.4
TF1	11	9.8	66.9	17.26	7.96	-	10.0	0.52	29.9	47.3	16.7	41.2	23.6
TF2	10	76.2	78.8	8.80	31.06	-	10.0	2.13	77.4	51.8	42.5	51.7	32.3

Following abbreviations were used, sample number (N), in situ declination (D), in situ inclination (I), Fisher's confidence angle (α_{95}), precision parameter (K), optimum demagnetizing temperature (ODT), optimum demagnetizing field (ODF), tilt corrected declination (Dtc), tilt corrected inclination (Itc), structurally corrected declination (Dsc), and structurally corrected inclination (Isc).

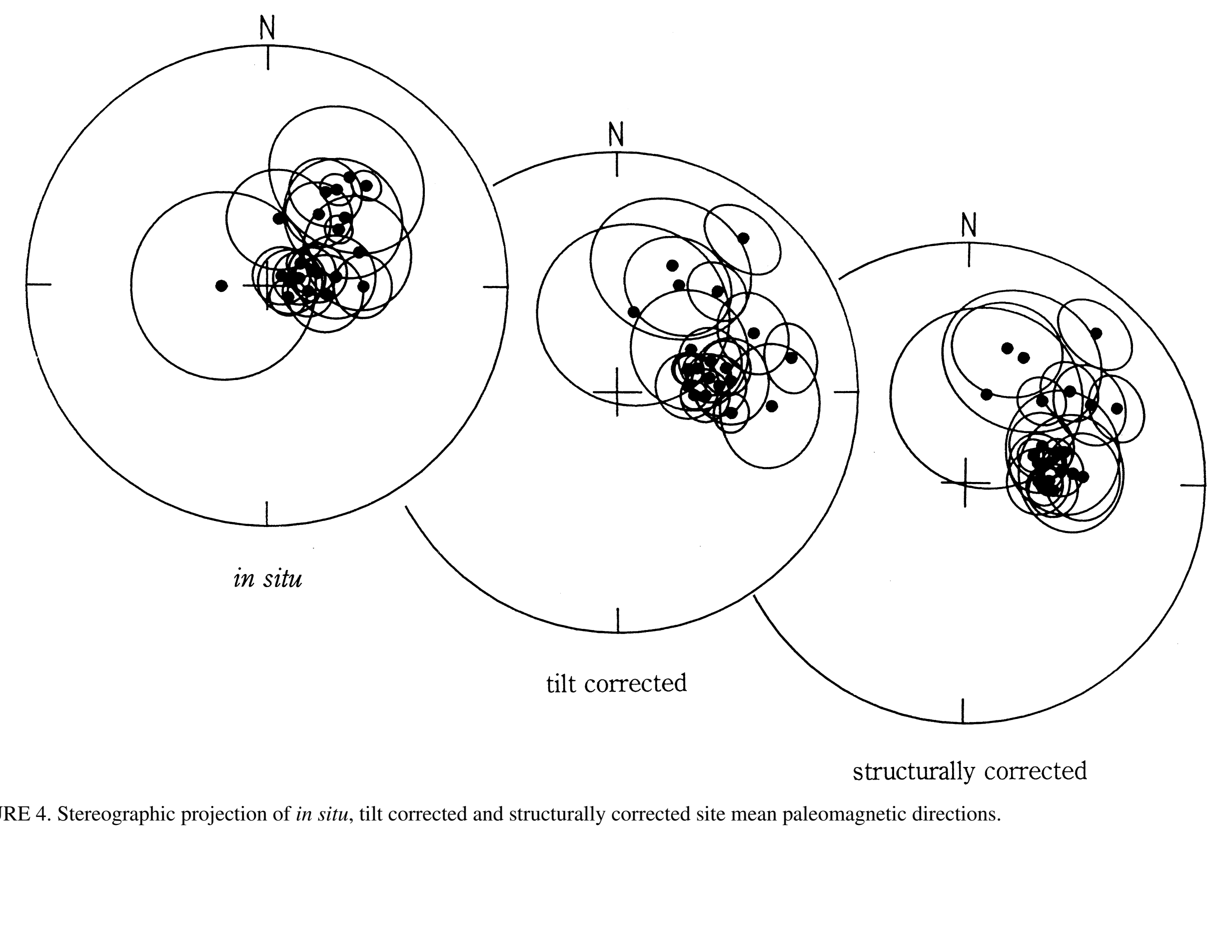

FIGURE 4. Stereographic projection of *in situ*, tilt corrected and structurally corrected site mean paleomagnetic directions.

TABLE 3. Mean paleomagnetic directions of the stratigraphic units.

		in situ				Tilt corrected				Structurally corrected			
Stratigraphy	Ns	Dm	Im	α_{95}(m)	K(m)	Dm(tc)	Im(tc)	α_{95}(tc)	K(tc)	Dm(sc)	Im(sc)	α_{95}(sc)	K(sc)
Total	21	54.4	68.7	7.25	20.2	67.7	53.9	8.08	16.4	61.5	54.8	7.72	18.0
Akaiwa SG.	10	58.1	70.0	10.47	22.3	81.7	59.7	4.92	97.4	80.7	59.9	4.12	138.3
Itoshiro SG.	6	58.8	71.2	16.31	17.8	65.9	52.6	18.97	13.4	59.0	54.9	15.28	20.2
Kuzuryu SG.	5	45.2	62.4	19.87	15.8	49.6	39.8	24.22	10.9	38.2	38.1	18.50	18.1
Itoshiro-Kuzuryu SGs.	11	51.4	67.3	11.27	17.4	57.6	47.1	13.89	11.8	47.9	47.8	12.12	15.2
Akaiwa SG.-Kuwajima F.	13	56.4	67.5	8.38	25.5	83.1	58.1	5.33	61.5	80.3	59.7	3.52	139.6
Kuzuryu SG.-Itsuki F.	8	50.6	70.6	15.48	13.8	48.3	43.2	15.83	13.2	39.9	41.9	12.76	19.8

Ns denotes number of sites. Dm, Im, α_{95}(m) and K(m) indicate mean declination, mean inclination, Fisher's confidence angle and Fisher's precision parameter of in situ remanence, respectively. Dm(tc), Im(tc), α_{95}(tc) and K(tc) indicate mean declination, mean inclination, Fisher's confidence angle and Fisher's precision parameter of the tilt corrected remanence, respectively. Dm(sc), Im(sc), α_{95}(sc) and K(sc) indicate mean declination, mean inclination, Fisher's confidence angle and Fisher's precision parameter of the structurally corrected remanence, respectively.

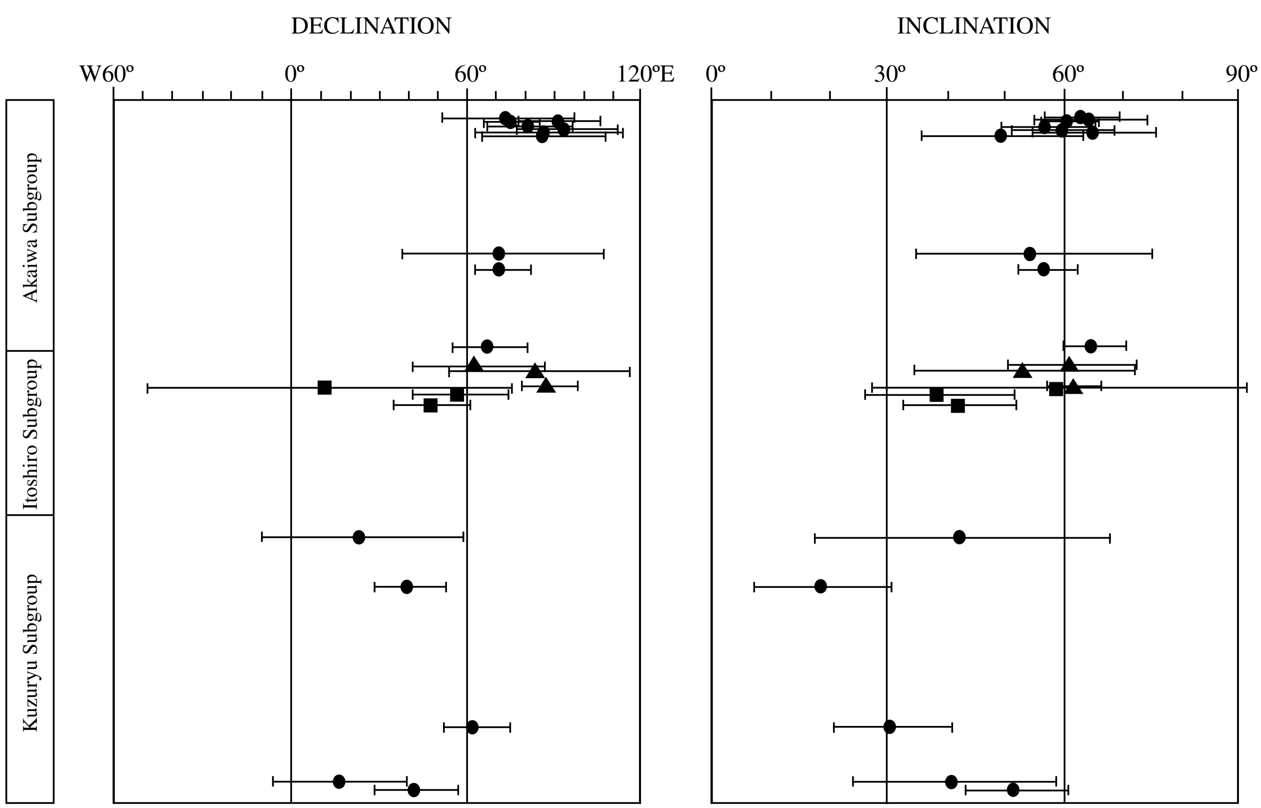

FIGURE 5. Temporal variations of mean declination and inclination at sampling sites. ▲: Kuwajima "Stage", ■: Itsuki "Stage".

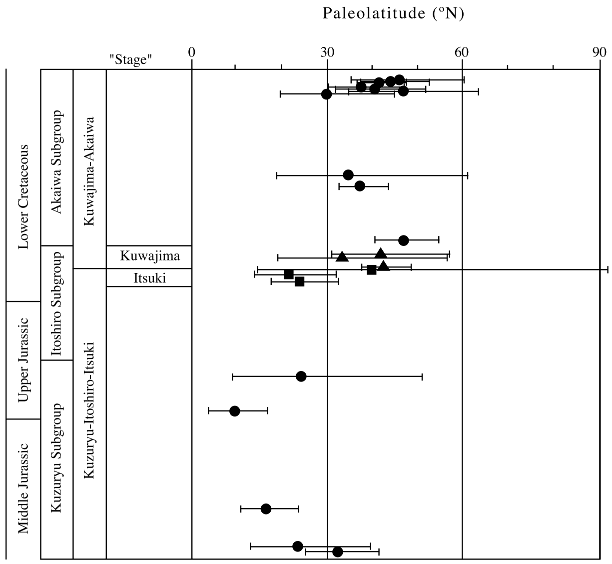

FIGURE 6. Variation of paleolatitudes of the Tetori Group.
▲: Kuwajima "Stage", ■: Itsuki "Stage".

or not. This means that the data hitherto obtained are not the remagnetized remanence but are the reliable initial one. The latter fact represents that the Tetori sedimentary basin moved probably northwards from lower latitude to middle latitude regions.

These two facts are more clearly seen from data in Table 3, in which the site mean direction, Fisher's confidence angle (α_{95}) and precision parameter (K) are separately shown for *in situ*, tilt corrected and structurally corrected paleomagnetic directions.

PALEOGEOGRAPHIC POSITION OF THE TETORI GROUP

Declination and inclination plots (Fig. 5) obviously show that the easterly declinations are remarkable in the Akaiwa Subgroup and that shallower inclinations are evident in the Kuzuryu and Itoshiro Subgroups, as compared with those of the Akaiwa Subgroup. The mean declination of the Kuzuryu and Itoshiro Subgroups is 47.9˚, while that of the Akaiwa Subgroup is 80.7˚. Figure 6 shows the paleolatitudes variation due to the stratigraphic positions. The mean paleolatitude of the sites of the Kuzuryu Subgroup indicates a low-latitude region (21.3˚N ±7.7˚), while that of the Akaiwa Subgroup is 40.9˚N±5.4˚, which is higher than the present-day latitude of the area. The paleolatitudes of the Itoshiro Subgroup seem to represent the transitive ones between the values of the above-mentioned two subgroups, indicating the mean paleolatitude of 34.1˚ N ±8.4˚ .

When we look at the data precisely, however, the paleomagnetic directions of the Itoshiro Subgroup can be grouped into two categories. One exhibits weak easterly declinations and shallower inclinations, as exemplified in the Itsuki Formation. The other is characterized by strong easterly

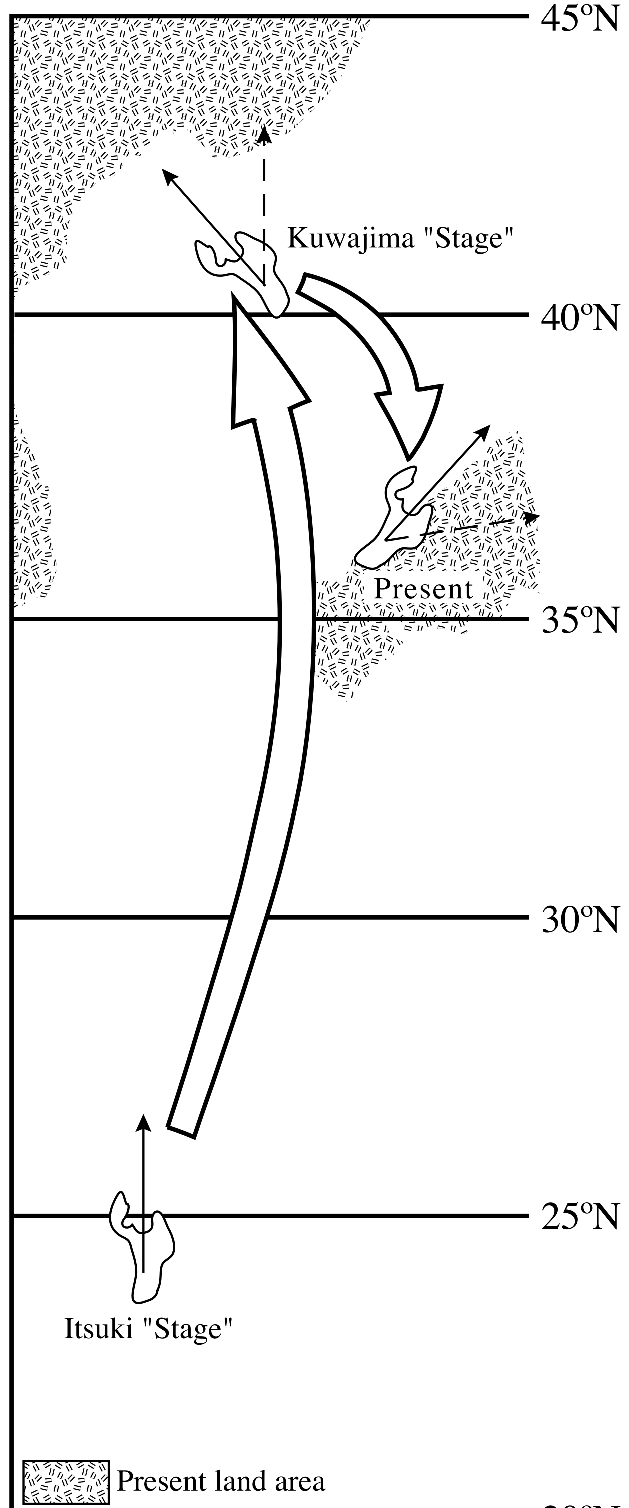

FIGURE 7. Tectonic evolution of the Tetori basin inferred from paleomagnetism. Longitudinal positions are arbitrary.

declinations and deeper inclinations, as typically seen in the Kuwajima Formation. Such magnetic characteristics of the Kuwajima and Itsuki Formations can be attributed to those of the Akaiwa and Itoshiro-Kuzuryu Subgroups, respectively.

Although the two formations have been correlated as the same stratigraphic horizon (Maeda, 1961; Matsukawa and Ito, 1995; Ohana and Kimura, 1995), it is more likely that the Itsuki and Kuwajima Formations are separately assigned to the Itoshiro and Akaiwa Subgroups, respectively, from the paleomagnetic viewpoint. If this interpretation is tenable, the Itsuki Formation was formed in a low-latitude region (24.1˚N ±8.6˚) and the Kuwajima Formation was in a higher middle latitude (40.5˚N ±5.1˚). The two are categorized as, (1) the Kuzuryu-Itoshiro-Itsuki suite and (2) the Kuwajima-Akaiwa suite, respectively. Calculated mean declination and inclination for each category are shown in Table 3.

We can draw a tectonic history of the Tetori basin based on the results of the present paleomagnetic study as follows. The sedimentary basin of the Kuzuryu and Itoshiro Subgroups was situated at a region of a low latitude around 24˚N. The basin drastically migrated northwards about 1800 km up to the latitude of 40˚N inbetween the Itsuki and Kuwajima "Stages". As the mean declination of the Kuzuryu-Itsuki and the Akaiwa-Kuwajima suites are 39.9˚ and 80.3˚, the basin was rotated counter-clockwise by about 40˚ during its northward migration. This rotation might be related to the significant left-lateral NE-SW faulting initiated at the Early Mesozoic as proposed by Tazawa (1993). Then, the basin was rotated clockwise relative to the geographic meridian by an angle of 80˚ as migrating southeastward some 500 km to the present-day latitude, probably accompanied by the Early Miocene opening of the Japan Sea (Otofuji, 1983). The schematic history of geotectonic drifts of the Tetori basin is illustrated in Fig. 7. The longitudinal scale of Fig. 7 is arbitrary because we are not able to detect longitudinal transfer of terranes from paleomagnetic data.

CONCLUDING REMARKS

Paleomagnetic remanences obtained from sedimentary sequences of the Middle Jurassic to Early Cretaceous Tetori Group are stable and reliable enough to reconstruct the geotectonic history of the Tetori Basin.

During the deposition of the lower Tetori Group (the Kuzuryu and Itoshiro Subgroups), the basin was located in low latitudes near an equatorial region. On the contrary, the Akaiwa Subgroup, the uppermost subgroup, was formed in a region of higher latitude. The paleolatitude obtained from mean inclination of the Akaiwa Subgroup reaches about 40˚N, which is about 4˚ higher than the present-day latitude.

The discrepancies in paleomagnetic inclination and declination found between the Itsuki and Kuwajima Formations is most probably attributed to difference in age, and disagree with the previous stratigraphic framework suggesting that the two formations are correlated each other. The Kuwajima Formation should have postdated the Itsuki Formation.

The sedimentary basin of the Tetori Group had been located at about 24˚N until the Itsuki "Stage". After the demise of the Itsuki Formation, the basin began to have migrated northward rapidly up to about 40˚N accompanied by counter-clockwise rotation of about 40˚. This drastic northward migration was completed before the Kuwajima "Stage", and the Tetori Basin had been staying at latitude of about 40˚N from the Kuwajima upto Kitadani "stages".

The terrane including the Tetori basin migrated southeastward, reached the present-day latitude, and simultaneously rotated clockwise by about 80˚. The migration and rotation happened sometime after the deposition of the Kitadani Formation, and it was most probably in the Early Miocene time when the opening of the Japan Sea took place.

Many terrestrial vertebrate fossils including dinosaurs have been recovered from the Tetori Group. Thus, the paleogeographic position of the Tetori basin provides an important clue to untangle the origin and paleoecology of the dinosaurs found from the Tetori Group.

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* : in Japanese with English abstract

＜地名・地層名＞

Akaiwa Subgroup …………赤岩亜層群
Akaiwa Formation………………赤岩層
Ashidani Formation………………葦谷層
Circum-Hida Belt …………飛騨外縁帯
Hida Belt …………………………飛騨帯
Itoshiro Subgroup ………石徹白亜層群
Itsuki Formation…………………伊月層
Izumi Group…………………和泉層群
Kaizara Formation………………貝皿層
Kitadani Formation………………北谷層
Kowashozu Formation………小和清水層
Kurosegawa belt………………黒瀬川帯
Kuruma Group…………………来馬層群
Kuwajima Formation……………桑島層
Kuzuryu Subgroup………九頭竜亜層群
Nino Belt …………………………美濃帯
Motodo Formation………………本戸層
Nohi rhyolites……………濃飛流紋岩類
Obuchi Formation………………大淵層
Oidani Formation……………大井谷層
Okura Formation …………………大倉層
Sakaidera Formation……………境寺層
Shimanto Group……………四万十層群
Shimowakogo Formation ……下若生層
Shimoyama Formation …………下山層
Tetori Group…………………手取層群
Tochimochiyama Formation …栃餅山層
Yambara Formation………………山原層
Yambarazaka Formation………山原坂層