REPORT No. 150
GEOLOGICAL SURVEY OF JAPAN
Tomofusa MITSUCHI, Director

A Study of Fossil Turritella in Japan

By
Kazuyoshi IDA

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TOKYO 1952, OCTOBER

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Résumé

To determine the biostratigraphic significance of the forms of the gastropod *Turritella* in the Cenozoic deposits of Japan, the taxonomy of this group is revised on the basis of a detailed analysis of characteristics of the shell structure that may be regarded as diagnostic for species and subspecies of this genus. Among these diagnostic features the relative height of the shell (H/D), the apical angle (θ) and the relative height of the whorl (k) are valuable in distinguishing closely related species and subspecies; the form of the growth lines is used to distinguish subgenera as well as species, and is useful also tracing lineages.

Thirty-three species and subspecies of *Turritella* are recognized, including the following new forms:

Turritella *kurosio* n.sp.
T. *neiensis* n.sp.
T. *oyasio* n.sp.
T. *chichibuensis* n.sp.
T. *nipponica nojimaensis* n.subsp.
T. *nipponica miyata* n.subsp.
T. *nipponica mitsunashii* n.subsp.
T. *kadonosawaensis tsudai* n.subsp.
T. *huziokai* n.n.

The results of this taxonomic revision are applied in local biostratigraphic zoning of some districts of Japan.

A Study of Fossil Turritella in Japan

By

KAZUYOSHI IDA

Introduction

Many species of *Turritella* have been recorded from the Cenozoic of Japan by various authors, but the present writer believes that there has been considerable confusion in the taxonomic treatment of these forms and that the problem is made more complex by palaeoecological factors. This conclusion was reached after detailed studies of fossil *Turritella* in many areas of Japan conducted with a view to determining the stratigraphic value of the many species of this genus in the hope that they might be of use in zoning the Cenozoic of Japan. The present study is concerned only with the species of the Neogene and Quaternary, although the genus has a range from Mesozoic to Recent in Japan. The present report is based on research interrupted by World War II and continued since the cessation of hositilities.

I desire to acknowledge here my gratitude to the following for their advice and assistance during the course of this research: to Dr. JIRO MAKIYAMA for many helpful suggestions; to Dr. KINJI KANEHARA, Mr. KATURA OYAMA, Mr. AKIRA ONO, Mr. YASUFUMI ISHIWADA and Mr. TORAO OTSUKA for valuable advice; to Mr. SUNAO OGOSE, Mr. KIYOSI KOIKE, Mr. NOBUO IKEBE, Mr. KAZUO HUZITA, Mr. KARYU TSUDA, Mr. KAGETAKA WATANABE, Dr. KAZUO HUZIOKA, and others who kindly supplied me with specimens; and to Mr. T. UYEKI who prepared the photographs illustrating this report.

§ 1. MORPHOLOGICAL FEATURES OF THE SHELL OF TURRITELLA

(1, 1) Review of Diagnostic Features Applied Formerly.

Originally the principal diagnostic features used in distinguishing species of *Turritella* were the form of the spire and the whorls, and the ornamentation of the shell; many subgeneric names were proposed also by workers in Europe and Australia on the basis of these same morphological features, but this led to somewhat contradictory results because of the great variability in some species of such features as the development of the spiral ribs and the shape of the whorls.

In 1912 COSSMANN[1] first recognized that the form of the growth lines is an important feature of the shell for taxonomic purposes.

Using this morphological character GUILLAUME (1924)[2] classified the European forms of *Turritella* into the following five groups:

"Groupe de *T. turris* Bast." single arcuated growth line.

"Groupe de *T. terebralis* Lmk." double arcuated and single inflected growth line.

"Groupe de *T. subangulata* Br." "Grope de *T. imbricataria.* Lmk."

"Groupe de *T. hybrida* Desh."

all with double arcuated and double inflected growth lines, distinguished by the location of the inflected points.

This grouping may be applicable to the European species but is not satisfactory for species of the Far East; in fact, some conchologists pointed out inconsistencies in GUILLAUME's grouping, but the following subgeneric names, quoted with the type species of the subgenera, gained rather general acceptance:

T. (*Haustator*) *imbricataria* Lmk.............Groupe de *T. imbricataria* Lmk.

T. (*Eichwaldiella*) *bicarinata* Eich. ....Groupe de *T. subanlgulata* Br.

T. (*Turritella*) *terebra* (Linné) .... }
T. (*Zaria*) *duplicata* (Linné) .... } Gronpe de *T. terebralis* Lmk.

T. (*Archimediella*) *archimedis* Bron. ......Groupe de *T. turris* Bast.

In his admirable work of 1941 MERRIAM[3] classified the genus *Turritella* of the Pacific coast of North America into 12 "stocks" based chiefly on the characters of the nuclear primary spiral complement and the growth-line trace, in conjunction with other features such as the whorl profile, apical angle, pleural angle, and nodosity. The present writer follows MERRIAM's principles, but discovered that some of the Japanese forms of *Turritella* do not belong to any of MERRIAM's 12 stocks; therefore he has found it necessary to propose new stocks and to adjust the subgeneric nomenclature accordingly.

(1, 2) The Spire.

Three types of spire are recognized: concave conical; conical; convex conical. The apical angle of a concave conical spire is smaller than its pleural angle and the diameter of the whorls becomes proportionately greater in successive growth stages as, for example, in *T.* (*Turritella*) *terebra* (Linné). In forms with a strictly conical spire the increase in diameter of the whorls is constant and the apical angle is equal to the pleural angle; the generating line of such a cone is a straight line. The apical angle of the convex conical spire is greater than the pleural

1) Cossmann, M., 1912. Essais de Paléoconchologie Comparée, Vol. 9, pp. 106—130.
2) Guillaume, Louis, 1924. Bull. Soc. Geol. France, Ser. 4, Vol. 24, p. 281.
3) Merriam, C. W. ,1941. Univ. California Publ., Bull. Dept. Geol. Sci. Vol. 26, No. 1.

angle and the diameter of the whorls becomes proportionately less in successive growth stages, e.g. *T. kiiensis* Yokoyama.

(1, 3) Relative Height of Shell (H/D)

The relative height of the shell is generally expressed as the ratio of the axial length (H) and the greatest diameter (D). A true value for this character can be obtained only with perfect specimens which do not lack the apex or the outer lip; such specimens are not too common in Recent samples and even less so in the fossil state. In the case of the conical spire the ratio H/D is constant, but with the concave or convex conical types this value of H/D varies according to the growth stage of the individual shell. A statistical analysis of 17 perfect specimens of a form with a conical spire is presented:

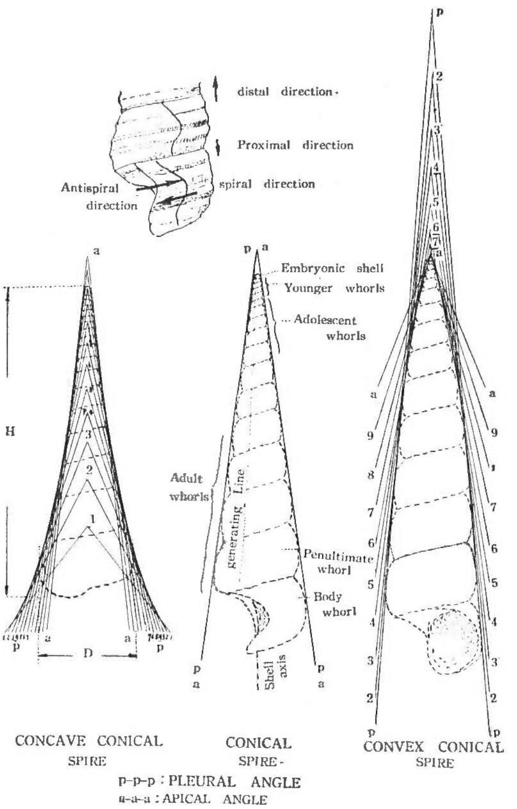


Fig. 1

Sample (I) *Turritella nipponica* (s. l.)

Locality: Kami-miyata, Minami-shimoura-mura, Miura-gun, Kanagawa Pref., (Miyata formation, Pliocene)

Sample No.	H(mm)	D(mm)	H/D
221022-1	40.05	10.30	3.89
-2	35.85	9.85	3.64
-4	34.75	8.25	4.21
-6	28.00	8.15	3.44
-7	28.25	7.90	3.58
-8	20.95	5.90	3.55
-9	18.65	5.50	3.39
-10	21.45	5.95	3.61
-11	26.25	6.90	3.80
-12	26.90	7.20	3.74

Sample No.	H(mm)	D(mm)	H/D
221022-13	24.75	6.45	3.84
-14	23.30	6.60	3.53
-15	23.20	6.65	3.49
-18	25.30	6.95	3.64
-19	25.55	7.05	3.62
-20	24.25	6.20	3.91
-21	16.80	5.05	3.33

$N=17$, $u^2=0.00481$
Mean of $H/D=3.659$
Confidence limit of population mean (degree of significance : 0.05)
$$3.680 \geqq m \geqq 3.638$$

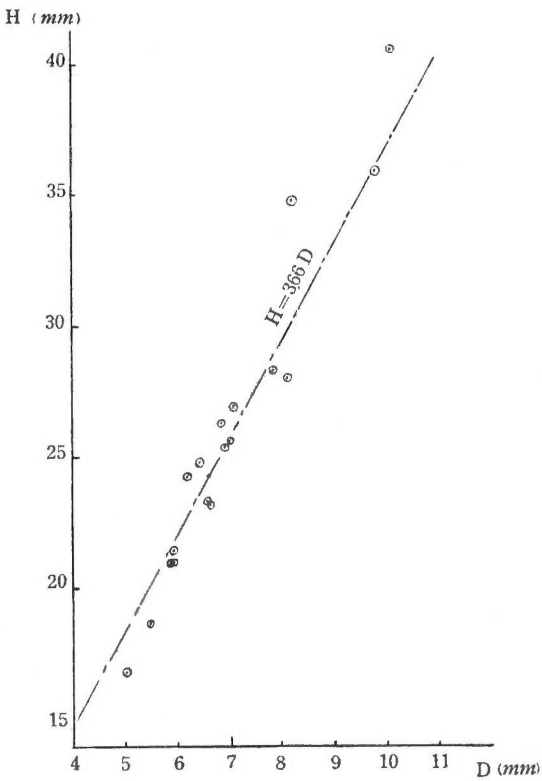


Fig. 2 Turritella nipponica (s. l.)
Sample (I)
Locality : Kami-miyata, Reg-no. (521.265)
Loc. No. 1.

(1, 4) The Apical Angle (θ)

Although it is impossible to determine the ratio H/D of an imperfect specimen, the apical angle (θ) can be estimated even if the younger whorls are lacking. The apical angle of a *Turritella* with a concave conical spire is smaller than the pleural angle ;* for *Turritella* with a convex conical spire the apical angle is larger than the pleural angle. Except in the case of *Turritella* with a strictly conical spire, where the apical angle equals the pleural angle, the pleural angle of younger whorls bears some relation to the apical angle, and varies successively in the whorls from the nepionic to the adult stage. Some authorities have used the value of θ as a specific character and have regarded it as being statistically constant for the species. Table I presents

* (Pleural angle : The angle subtended by two tangents to the adolescent and mature whorls. The tangents lie in a plane which includes the shell axis. (Merriam, 1941))

TABLE 1

Sample	Species	Locality	Loc. No.	Horizon	$\bar{\theta}$	N	u^2	Confidence limit of population mean ($\alpha=0.05$)
A	*saishuensis*	Anrakuji, Minamitani-mura, Nishi-tonami-gun, Toyama Pref.	521. 422-1	Himi Group Pliocene	13.79	13	0.742	$14.31 \geqq m \geqq 13.27$
B	*saishuensis*	Manganji, Akita-Pref.	521. 148-1	Wakimoto form. Pliocene	16.54	7	2.023	$17.86 \geqq m \geqq 15.22$
C	*perterebra*	Dainichi, Ugari-mura, Suchi-gun, Shizuoka Pref.	type 521. 616-611	Kakegawa Group. Pliocene	14.40	10	1.266	$15.21 \geqq m \geqq 13.59$
D	*huziokai*	Off the coast of Erimo-saki, Hokkaidō	type 524	Recent	17.75	11	1.840	$18.58 \geqq m \geqq 16.84$
E	*ikebei*	Tambara, Makuda-mura, Kimitsu-gun, Chiba Pref.	521. 288-81	Jizōdo 3 foss. zone Pleistocene	14.44	10	1.569	$15.34 \geqq m \geqq 13.54$
F	*nipponica* (s. l.)	The beach at Koshiba, Yokohama	521. 263-2	Koshiba sand Pleistocene	17.73	8	1.316	—
G	*nippo··ica* (s. l.)	The north cliff at Koshiba, Yokohama	type 521. 263-3	Koshiba sand Pleistocene	18.20	6	0.220	$18.69 \geqq m \geqq 17.71$
H	*nipponica* (s. l.)	Imaizumi, Ōfuna, Kanagawa Pref.	521. 265-2	Ōfuna mud. Pliocene	17.90	5	3.620	—
I	*nipponica* (s. l.)	Kami-miyata, Miura Peninsula	type 521. 265-1	Miyata form. Pliocene	16.17	10	1.295	—
J	*nipponica* (s. l.)	Osabanai, Kasuge-mura, Yamamoto-gun, Akita Pref.	521. 142-2	Osabanai form. Pliocene	17.94	10	0.296	—
K	*saishuensis etigoensis*	Ogi, Niigata Pref.	521. 41	Nishikoshi form. Pliocene	17.42	8	1.087	$18.29 \geqq m \geqq 16.53$

the results of statistical analysis of the value of θ for several forms of *Turritella* from different localities.

For samples A and B (*T. saishuensis* Yok.) from two widely separated localities:

Test of equal variance: $F_0=2.72<F^{6}_{12}(0.05)$

Test of difference of sample means:

Common mean square: $w^2=1.17$, $F_0=2.94>F^{1}_{18}(0.05)$

The difference between the mean values of samples A and B is therefore significant. *T. saishuensis* Yok. is a prominent member of the "Omma-Manganji Fauna" described by the late Y. OTUKA, but specimens from the two localities studied differ in their shape.

For samples F, G, H, I, J (*T. nipponica* Yok. (s. l.)) from four localities in the vicinity of Tokyo Bay and one locality in northeastern Honshū:

(1) Test of equal variance: ($\alpha=0.05$)

F : G	$F_0=5.98>F^{7}_{5}$
F : H	$F_0=2.75<F^{4}_{7}$
F : I	$F_0=1.01<F^{7}_{9}$
F : J	$F_0=4.44>F^{7}_{9}$
G : H	$F_0=16.45>F^{4}_{5}$
G : I	$F_0=5.88>F^{9}_{5}$
G : J	$F_0=1.34<F^{9}_{5}$
H : I	$F_0=2.79<F^{4}_{9}$
H : J	$F_0>10>F^{4}_{9}$
I : J	$F_0=4.37>F^{9}_{9}$

These five samples can be separated into two groups: (F, H, I) and (G, J).

(2) Test of homogeneity of population mean:

F : H : I——Analysis of variance.

Factor	SS	DF	MS
J	14.97	3-1	7.48
R (J)	51.75	23-3	2.58
JR	66.72	23-1	

$F_0=2.89<F^{2}_{20}$ The difference is not significant; the rejection limit ($\alpha=0.05$) of the population mean in sample F, H, I is: 17.09 ± 2.78. A new group of forms, represented by the F, H, I samples can therefore be recognized within *T. nipponica* Yok. (s. l.), this conclusion from statistical analysis is supported by stratigraphic evidence.

(1,5) **Whorl Profile**

In individual specimens of adult *Turritella* the whorl profile changes more or less according to the growth stage. For convenience of description the following types of whorl profile (see Figure 3) are recognized:

C-type: convex, regularly arcuate

D-type: convex, with rounded shoulders near both proximal and distal sutures

J-type: slightly convex, with rounded shoulder developed only near proximal suture

L-type: straight or slightly convex, with angular shoulder developed close to proximal suture

H-type: straight profile, with no prominent shoulders

V-type: obtuse angle, often with keel at the angle (e.g. *T. angulata* Sow.)

U-type: concave profile; this type (e.g. *T. declivis* Ad. & Rv.) is not represented in Japan.

Transitional forms between these basic types are expressed by combining the letter designations, e.g. JC-type.

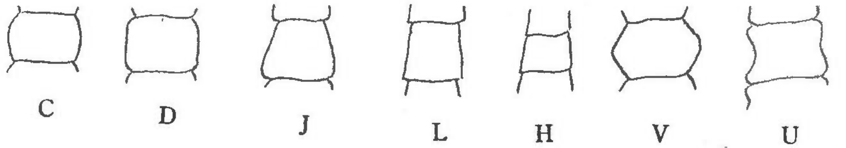


Fig. 3. The types of whorl profile.

(1, 6) **Relation between Whorl Number and Height of Shell.**

The whorl number is the number of the whorls that revolve about the axis of the shell beginning with the protoconch. In perfect specimens this can be counted along the "original generating line" (see figure 4) which begins at the initial expression of the suture in the earliest whorl.

To test the degree of constancy in the relation between whorl number (W) and height of shell (H), 22 specimens of *T. nipponica* (s. l.) (Sample I) were measured:

Specimen No.	Height (H) mm	Whorl number (W)
Holotype 221022-1	40.0	18
Paratype 221022-2	35.9	17
-4	34.7	17
-6	28.0	16
-7	28.2	16

Specimen No.	Height (H) mm	Whorl number (W)
221022-8	21.0	14
-10	21.3	14
-11	26.1	15
-12	26.8	16
-13	24.8	15
-14	23.9	15
-15	23.7	15
-19	26.0	16
-20	24.3	15
-21	17.0	13
-22	18.7	13
-23	19.5	14
-24	12.7	12
-25	9.2	10
-27	11.7	11
-29	14.5	12
-30	12.9	12

1) Test of co-variance in W and H :

$y = \log_e (H/9.2)$

$x = W - 14$

factor	SS	d.f.	V
Regression	$C/S_x = 2.002$	1	$C^2/S_x = 2.002$
Residual	$\Delta = 0.533$	$N-2=7$	$\Delta/N-2 = 0.076$
Total	$S_y = 2.535$	$N-1=8$	

$F_0 = (C^2/S_x)(N-2)/\Delta = 26.3 > F_7^1\ (0.01)$

From this it can be said that most of the variance of y may be caused by x.

2) Regression co-efficient in sample.

$$H = e^{0.183\,W + 0.43}$$

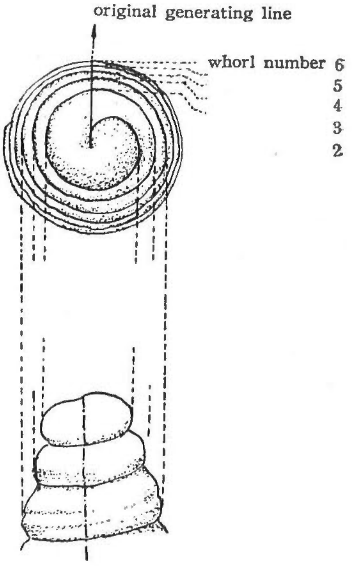


Fig. 4 Younger whorls of a spire, showing the original generating line and whorl numbers.

(1, 7) Relation(k) between Height(h) and Diameter(d) of Whorls.

The simple relation $h/d = k$ was examined statistically from the following material:

Sample (M) *Turritella nipponica kazusana* Ida (MS)

Loc.: Hinosaka, Tana-mura, Kōza-gun, Kanagawa Pref.

Horizon: Ōtsuka formation, Nakatsu Group (Suzuki, 1932), Pliocene

No. of specimens: 36 (No. 54~90)

Sample (A) *Turritella saishuensis* Yokoyama

Loc.: Anrakuji, Minamitani-mura, Nishi-tonami-gun, Toyama Pref.

Horizon: Himi Group (Ikebe, 1948), Pliocene

No. of specimens: 94 (No. 231023-1~231023-94)

Sample (L) *Turritella nipponica nojimaensis* n. subsp.

Loc.: Muronoki, Yokohama (Type locality)

Horizon: Nojima formation, Miura Group (Otuka), Pliocene

No. of specimens: 48

Sample (C) *Turritella perterebra* Yokoyama

Loc.: No. 611 of J. Makiyama (1931), Dainichi, Suchi-gun, Shizuoka Pref.

Horizon: Dainichi Sand, Kakegawa Group (Makiyama, 1928), Pliocene.

No. of specimens: 107 (No. 163~269)

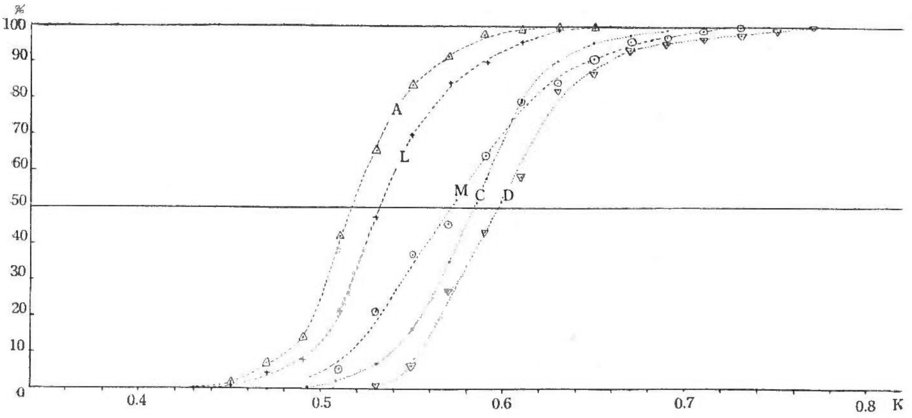
Sample (D) *Turritella huziokai* n. n.

Loc.: Off Erimozaki, Hokkaido, Recent.

No. of specimens: 11

Frequency Distribution of k

Values of k	Samples				
	M	A	L	C	D
	(*nipp. kazusana*)	(*saishuensis*)	(*nipp. nojima.*)	(*perterebra*)	(*huziokai*)
0.340—0.359		1			
0.360—0.379		0			
0.380—0.399		0			
0.400—0.419		0	1		
0.420—0.439		0	3		
0.440—0.459		6	3		
0.460—0.479		18	5	1	
0.480—0.499		23	8	3	
0.500—0.519	4	90	33	8	
0.520—0.539	11	78	62	19	1
0.540—0.559	11	58	55	43	4
0.560—0.579	6	27	34	81	16
0.580—0.599	13	19	14	98	12
0.600—0.619	10	7	16	96	12
0.620—0.639	4	1	5	45	13
0.640—0.659	5	1	1	22	5
0.660—0.679	3		0	10	4
0.680—0.699	1		1	7	5
0.700—0.719	1		0	0	1
0.720—0.739	1		0	0	1
0.740—0.759			1	0	1
0.760—0.779				2	1
0.780—0.799				0	1
0.800—0.819				0	
0.820—0.839				1	
(Total)	70	329	242	436	77



A....*T. saishuensis* Yok. number of sample : 329
L....*T. nipponica nojimaensis* n. subsp. : 242
M....*T. n. kazusana* (MS) : 70
C....*T. perterebra* Yok. : 436
D....*T. huziokai* n. n. : 77

Fig. 5 The cumulative frequency curves of k.

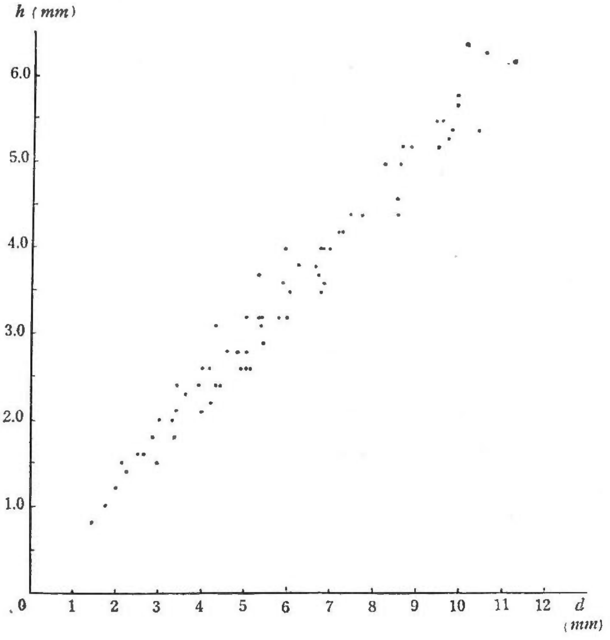


Fig. 6 *T. nipponica kazusana* (MS) No. 54~90

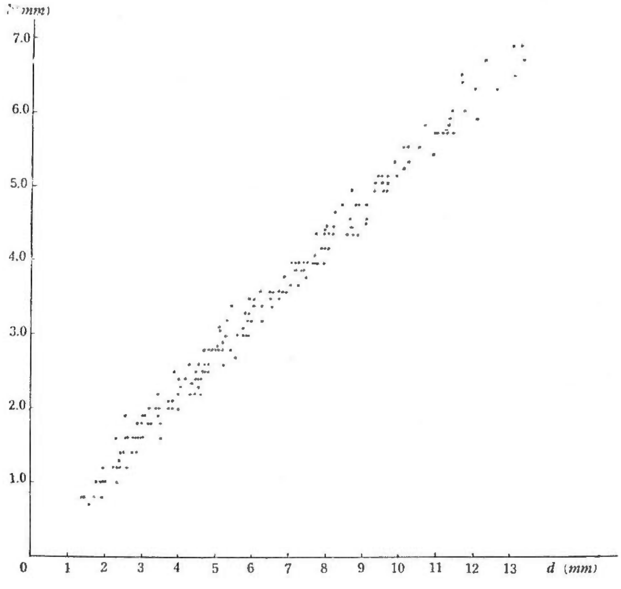


Fig. 7 *Turritella saishuensis* Yok. No. 231023-1~231023-94

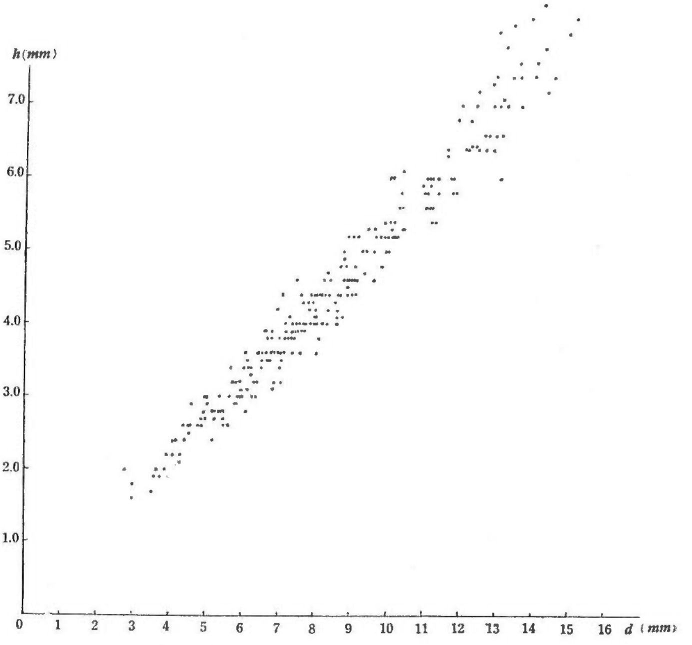


Fig. 8 *Turritella nipponica nojimaensis* n. subsp.
No. 241020-1~241020-54

The frequency curves of samples A, C and L can be made to conform to a normal distribution, but those of M and D show some deviation. The deviation are affirmable by means of a "probability paper". When the distribution of k is not normal, k changes with the diameter within a limited range; in such cases, the mean value itself is not significant.

Sample	Species	Number	$\bar{k}$	V
A	*saishuensis*	329	0.529	0.00126
L	*nipponica nojimaensis*	242	0.545	0.00174
C	*perterebra*	436	0.593	0.00162

Test of equal variance: ($\alpha=0.05$)

A : L $F_0=1.38>F_{329}^{242}$

L : C $F_0=1.08<F_{436}^{242}$

A : C $F_0=1.28>F_{329}^{436}$

Test of the difference of sample mean:

L : C $w^2=0.00166$

$F_0\fallingdotseq 220>F$

He can therefore be said that k shows a characteristic value for taxonomic units.

The result shown in Fig.9 was obtained by measuring a specimen of *T. terebra* (Linné), presumed to have come from the Riukiu Islands. The relation between H and $\sum d$ is shown by line I; line II is separated from line I by h (height of whorl). The two lines indicate the form of the shell if the spiral were unwound and stretched out in one plane; it is of interest that the resultant figure agrees closely with the form of scaphopod shells.

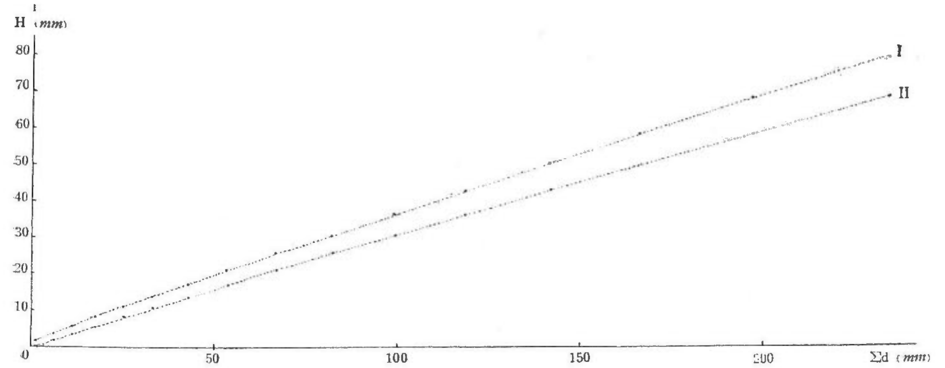


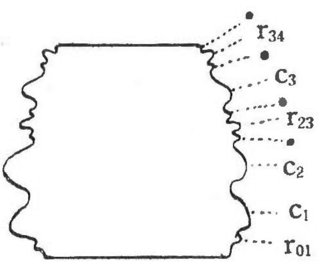
Fig. 9

(1, 8) Spiral Sculpture

To represent conveniently for descriptive purposes the complex spiral sculpture found in *Turritella*, three categories of raised spiral ornamentation, depending on the degree of prominence of the ribs, are distinguished as follows:

C : Cord (main rib); the most conspicuous rib or ribs
r : Interstitial ribs between main ribs or accessory ribs between a suture and main rib
. : Threads; the finest ribs between the more prominent types

According to their order of appearance ribs are also classified into primary, secondary and tertiary ribs. Primary spiral ribs appear on the earlier whorls, and are followed later by interstitial or accessory ribs. On the adult whorls, the primary spiral ribs are usually prominent and the secondary or tertiary ribs are faint, but well-developed secondary ribs are often indistinguishable from the primary ribs. The primary ribs are numbered consecutively from the proximal suture as follows: 1, 2, 3, 4, 5, etc.; the secondary ribs are designated 01, 12, 23, 34, 45, 56, etc.; and the tertiary ribs 001, 011, 112, 122, 223, 233, 334, etc. By combining the symbols for degree of prominence and order of appearance of ribs, the following types of formula are obtained;



J [$r_{01}C_1C_2 \cdot r_{23} \cdot C_3\ r_{34} \cdot$]

Fig. 10 The profile of a whoal and its spiral rib formula.

Primary spirals r_1, r_2, r_3, r_4, etc.
Secondary spirals r_{01}, r_{12}, r_{23}, r_{34}, etc.
Tertiary spirals r_{001}, r_{011}, r_{112}, r_{122}, r_{223}, r_{233}, r_{334}, etc.

When a few ribs appear at the same time between primary or secondary spiral ribs, they have the same symbols; when cords or ribs have nodules, they are represented by $\overset{\circ}{C}$ or $\overset{\circ}{r}$. In the generalized spiral rib formula of a species, thread symbol is omitted to avoid complication. The spiral rib formula for specific whorls of an individual specimen is shown below, combined with the symbols for whorl profile and whorl number; this indicates also the progressive changes according to the growth stage:

3rd whorl	$C(C_1C_2)_{n=3}$
4th whorl	$JC(C_1C_2C_3)_{n=4}$
5th whorl	$J(.C_1.C_2.C_3.)_{n=5}$
10th whorl	$J(.C_1.r_{12}.C_2.r_{23}.C_3.)_{n=10}$

(1, 9) The Early Development of Spiral Sculpture.

The embryonic shell of *Turritella* is orthostrophe, paucispiral; the first volution is semi-planispiral. Usually the embryonic shell consists of two smooth whorls with no rib (the nuclear stage). At this stage, specific or even group features cannot be distinguished. In the postnuclear stage an angulation appears at first in the middle of the whorl or near the proximal suture ((C_1) stage). In many species, this original angulation in the later nuclear stage changes into a carina on the next whorl, although it may not be prominent on the later whorls (e.g. *T. neiensis, T. fascialis, T. kurosio* in Japan; *T. subangulata, T. turris* in Europe). Other forms of *Turritella* have a pair of keels on the younger whorls, and it is difficult to find the first (C_1) stage. (*T. tanaguraensis, T. kadonosawaensis*). All other Japanese *Turritella* have no carinate postnuclear stage, but have sharp V-type whorl profiles.

The differentiation of the ribs in *T.terebra* from Formosa is as follows:

C(—)
V(r_1)
V($C_1r_2r_3$)
V($C_1C_2r_{23}C_3r_{34}$)
J($r_{01}C_1C_2r_{23}C_3r_{34}$)

The secondary rib appears between the primary ribs as an interstitial rib or on the subsutural part as an accessory rib (CrC), and tertiary ribs appear faintly between them (C.r.C).

If they are all perfect, the whorl profile will be C-type, and the formula would then be as follows:

2 ribs type C (r C r C r)
3 ribs type C (r C r C r C r)
4 ribs type C (r C r C r C r C r)

These ideal types, however, are comparatively rare; in different individuals some of the secondary ribs may not appear, and the appearance of the tertiary ribs is even more variable. The whorl profile of shells lacking a few of the secondary spirals will differ from that of individuals possessing complete spirals.

In general it may be said that the ribs which appear in the earlier stages become the more prominent ribs in the later stages.

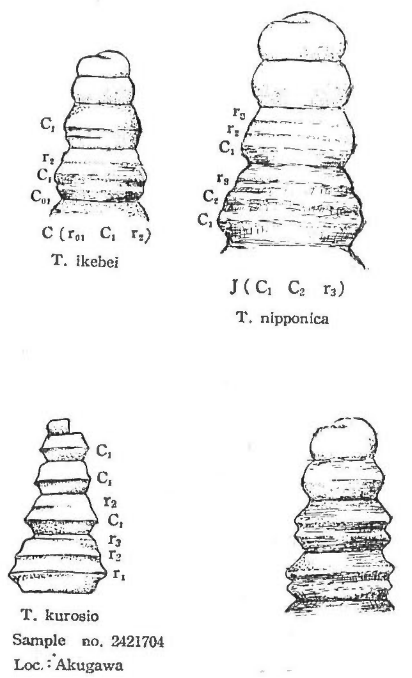


Fig. 11

In some species there is rapid differentiation from the C_1 stage to the third stage. Even in the adolescent or adult whorls of some species, the number of spiral ribs increases successively with growth, (e.g. the adult whorls of *T. perterebra* and *T. terebra* have very numerous faint ribs) but the adolescent whorls and even the adult whorls of *T. nipponica* usually have only four ribs. In these simple types, the progressive increase in number of ribs stops at the early adolescent stage.

The range of variation which may appear in the accessory or interstitial spiral ribs is as follows:

2 main ribs

no accessory or interstitial rib ········· (C C)

one accessory or interstitial rib ········· (r C C)
(C r C)
(C C r)

two accessory or interstitial ribs ········· (r C r C)
(r C C r)
(C r C r)

three accessory or interstitial ribs ········· (r C r C r)

Total number 8

3 main ribs ········· 16

4 main ribs ········· 32

5 main ribs ········· 64

In general the number of variation is expressed by the following formula:

$$1+\sum_{n=1}^{m+1} {}_{m+1}C_n$$

Individuals of a single species may show several similar but somewhat different forms of spiral ornamentation. For example, among 39 individuals of *T. saishuensis* Yok. (Sample A) collected from the Himi Group (Pliocene), the following 12 types of spiral ornamentation were found:

Spiral rib formula of individuals	frequency
(C C r C r)	13
(C C r C)	6
(C C C)	4
(C C C r)	4
(C C r r C r r)	3
(C r C C)	2
(C C r C r r)	2
(C r C r C r)	1
(C r C C r)	1
(C C C r r)	1
(C r C r r C)	1
(C r C r C)	1
Total	39

In 38 individuals of *T. nipponica nojimaensis* n. subsp. (Sample L) from the Nojima formation (Pliocene) at Muronoki, Yokohama, the following 7 types of spiral ornamentation were found:

Spiral rib formula of individuals	frequency
$(C_1C_2r_3r_4r_{45})$	16
$(C_1C_2r_{23}r_3r_4r_{45})$	7
$(C_1C_2r_{23}r_3r_4)$	5
$(C_1C_2r_3r_{34}r_4r_{45})$	4
$(C_1C_2r_3r_4)$	4
$(C_1r_{12}C_2r_{23}r_3r_4)$	1
$(C_1r_{12}C_2r_{23}r_3r_4r_{45})$	1
Total	38

Those individuals with the formula $(C_1\ C_2\ r_3\ r_4)$ can not be distinguished from *T. nipponica nipponica* by the spiral formula alone.

MERRIAM has divided nuclear ornamentation into 4 types: mesocostate, bicostate, cingulate and tricostate; the nuclear ornamentation, however, may vary somewhat within these 4 types, but this feature is constant within a single species.

It was stated earlier in this paper that Japanese *Turritella* develop in three stages, (C_1), (C_1C_2), and $(C_1C_2C_3)$; the rate of development differs, however, in different groups of *Turritella.*

There is considerable variation also in the adding of interstitial threads or ribs. Some of these features may be distinctive for certain species.

In *T. saishuensis,* the spiral ornamentation is virtually complete at the early stage of three ribs, although several faint threads appear later on the adult whorls; in other species of this same group, the number of ribs may increase in the later stages. In the group of *T. kurosio* n. sp., however, there is relatively little variation in the form of spiral ornamentation compared to that in other groups. (Fig. 12)

The process of increase in the number of spiral ribs has a great influence upon whorl profile. The ribs on the anterior part of the J-type whorl may increase in number or occasionally diverge. The form of a whorl with equally developed ribs belongs to the normal C-type.

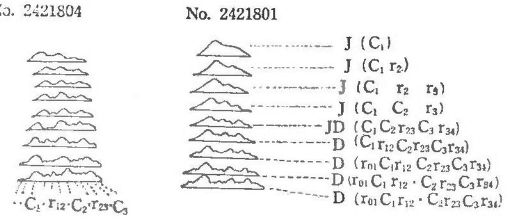


Fig. 12 The development of spiral sculpture. (*T. kurosio* n. sp.)

Earlier in the paper the apical angles (θ) of some forms of *T. nipponica* were discussed. According to the statistical results they were divided into two groups, Samples F, H, I, and samples G, J; these two groups differ also in ornamentation, as shown below:

Samples F, H, I ························ JC (C_1 C_2 C_3 C_4)
Sample G (topotype) ························ J (C_1 C_2 r_3 r_4)
Sample J ························ J (C_1 C_2 r_{23} r_3)

The spiral ribs r_3 and r_4 of sample G are slender and lie close together; its whorl profile is J-type. The four ribs of samples F, H, I, however, are regularly arranged, and their whorl profiles are of the JC-type. Although the colour of fossil shells is not a reliable feature, some well-preserved samples of the topotype have white grooves and light brown ribs like those of recent specimens, whereas the colour of well preserved specimens in samples F, H, I is light yellowish or reddish brown. On the basis of these differences it is therefore possible to separate a new subspecies *Turritella nipponica miyata* from *T. nipponica nipponica.*

If the surface of a conical spire is spread out on a plane, the result is an eddy figure (Otsuka's spiral). (Plate 7, Fig. 1) A fan shape (AOB) is equivalent to a single cone; the whole figure consists of a lot of equal fans, the center angles of which are Θ. In a polar co-ordinate which has a pole at the center (O) of the spire, the length of r as the radius vector is as follows:

φ	r_1	r_2	r_3
0	3.80	2.62	1.00
$\pi/6$	4.12	2.88	1.10
$2\pi/6$	4.60	3.19	1.22
$3\pi/6$	5.05	3.54	1.30
$4\pi/6$	5.60	3.90	1.48
$5\pi/6$	6.12	4.36	1.68
$6\pi/6$	—	4.82	1.88
$7\pi/6$	7.23	5.34	2.14
$8\pi/6$	7.95	5.92	2.27
$9\pi/6$	—	—	2.50
$10\pi/6$	—	—	2.75

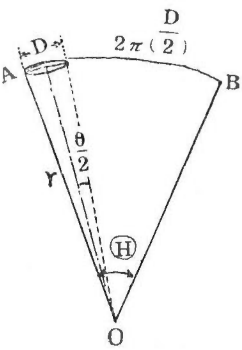


Fig. 13

Sample 1 *T. huziokai* sample No. 15 The main rib C_1
Sample 2 *T. s-hataii* No. 297-24692 C_1
Sample 3 *T. ikebei* No. 521.28-11A C_1

The logarithms of these values (r) are in proportion to those of φ.

$$\log r = a\varphi + b$$

By the transformation of the co-ordinate, it changes to:

$$\log r = a\varphi$$

$$r = e^{a\varphi}$$

Sample 1 $\quad r = e^{0.1833\varphi}$

Sample 2 $r=e^{0.1946\varphi}$

Sample 3 $r=e^{0.1932\varphi}$

They are "equiangular spirals", which resemble one another. The angle between Op and a tangent at a point P (r, φ) on the curve is ρ.

$$\tan\rho=r/r'=e^{a\varphi}/ae=1/a$$

$$\cot\rho=a$$

$$r=e^{\varphi\cot\rho}$$ [4]

$$\cot\rho_1=0.1833 \qquad \rho_1=79°37'$$

$$\cot\rho_2=0.1946 \qquad \rho_2=78°59'$$

$$\cot\rho_3=0.1932 \qquad \rho_3=79°04'$$

The value of ρ on a suture line is equal to the inclination of the whorl. Various spiral ribs on a whorl or a suture will be shown as a group of the equiangular spirals which have several similar coefficients (a). The length of are AB in the unit fan (AOB) is approximately as follows (where D represents the diameter of a whorl):

$$2\pi(D/2)=\frac{\Theta}{360}\cdot 2\pi r$$

$$\sin\frac{\theta}{2}=\frac{D/2}{r}=\frac{\Theta}{360}$$

As the angle of Θ in sample I (*T. huziokai*) is 52.7 degrees, the calculated apical angle 16°52′ is obtained from the above formula. The actual measurement value of the same sample is 17 degrees; these two values are almost equal.

Although every rib has a different value of inclination, it is a fact that the value of ρ on a distal rib is greater than that on an proximal rib, but in the genus *Turritella* there is not so much deviation in this value, as compared to other genera, e. g. *Tonna*, where the value of ρ deviates from 85° to as low as 45°.

From these considerations it is concluded that every part of a spire consists of numerous spirals which are different in the values of ρ and Θ. The shape of the aperture or inclination of the axis, the rate of increase of whorl diameter, and other features of the shell are governed by the velocities of their growth; these relative velocities are statistically constant in relation to taxonomic units. H. LUMER's theory of "Evolutionary Allometry"[5] supports this general conclusion.

(1, 10) The Growth Line

The form of the growth line is the most significant taxonomic character for this genus; the writer distinguishes two primary types:

A) single arched growth line trace. e. g. *T.* (*Turritella*) *terebra* (Linné)

B) double arched growth line trace. e. g. *Turritella nipponica* Yokoyama

4) J. Makiyama (1942) reported the same formula for the shell of Cephalopoda. (*Danubites naumanni*)

5) Lumer, H.: Amer. Nat. Vol. 74, pp. 439-467, 1940

In the double arched type, there is a sinus of spiral direction near the proximal suture and an antispirally directed sinus in the middle part of the whorl.

These types are further considered after being projected on a plane parallel to the axis and at right angles to the axial plane (see Fig. 14); The axial plane passes through the distal end of the growth line (point A). The inclined line AB is constructed as a tangent from "A" to the spirally directed sinus on the same growth line. The growth line inclination is the angle between the generating line (OX) and the inclined line (AB); the angle BAX $=\beta$. The depth of the sinus (S) $=$ PP′/AB, where P is the maximum point of the sinus and PP′ is perpendicular to AB. The skewness of the sinus (δ) is the degree of skewness in the distal direction.

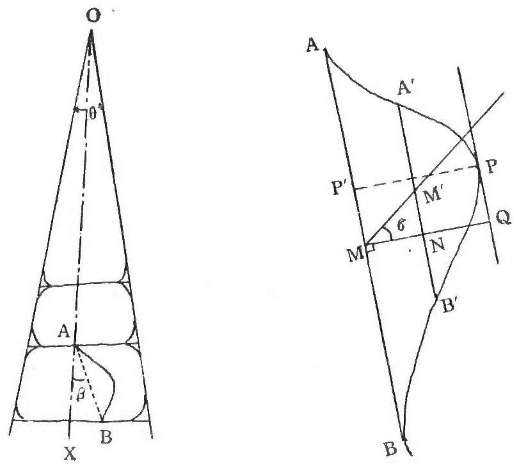


Fig. 14.

Measurement of S in samples A and D:

Sample A		Sample D	
Turritella saishuensis		*Tnrritella huziokai*	
	S		S
No. 231023-1	31.4	No. 5	32.2
-2	29.4	7	39.7
-3	31.5	11	39.1
-4	26.8	12	34.4
-5	32.5	14	30.7
-6	30.3	15	32.1
		16	32.5
		18	37.0

Size of sample:	$M=6$	$N=8$
Sample mean:	$\bar{S}_1=30.3$	$\bar{S}_2=34.8$
Mean square:	$u_1^2=5.32$	$u_2^2=12.93$

Test of equal variance:

$$F=u_2^2/u_1^2=12.93/5.32=2.43<F_5^7(0.05)=4.88$$

Test of the difference of sample mean:

$$W=9.76$$

$$F=\frac{(S_1-\bar{S}_2)}{W}\left(\frac{MN}{M+N}\right)=6.80$$

$$n_1=1,\ n_2=M+N-2=12$$

$$F^1_{12}(0.05)=4.75 < F_0$$

There is a difference between the two mean values. It is therefore concluded that the sinus of *T. huziokai* is deeper than that of a form of *T. saishuensis* though it cannot be decided yet whether it is a typical form.

Measurement of δ in Sample A:

	T. saishuensis	δ (in degree)
Sample A	No. 231023-1	15.0
	-2	21.0
	-3	16.0
	-4	23.0
	-5	19.5
	-6	17.0
	N=6	$\bar{\delta}=18.6$
	$u^2=1/N-1\left\{\sum\delta^2-N\bar{\delta}^2\right\}=8.90$	

(Test) $n_1=1,\ n_2=N-1=5,$ $F^1_5(0.05)=6.61$

$$6.61=F\geqq(\bar{\delta}-m)^2N/u^2=(18.6-m)^2 6/8.90$$

Confidence limit of population mean ($\alpha=0.05$):

$$21.7\geqq m\geqq 15.5$$

In some recent papers on the genus *Turritella* the growth line inclination (β) has been regarded as an important feature for distinguishing groups; the writer believes that this feature can also be applied to the distinction of species.

Measurement and test of β in Samples G, I, E, L, C, P, N, A, D, O,

Sample	Sp.	N.	$\bar{\beta}$	u^2	Rejection limit ($\alpha=0.05$)	Confidence limit of population mean
G	*T. nipp. nipponica*	5	6.20	2.700	6.20±4.96	6.20±2.64
I	*T. nipp. miyata*	8	6.87	2.125	6.87±3.65	6.87±1.22
E	*T. ikebei*	7	6.07	4.286	6.07±5.40	6.07±1.91
L	*T. nipp. nojimaensis*	10	8.40	1.377	8.40±2.77	8.40±0.80
C	*T. perterebra*	7	37.30	2.560	37.30±4.22	37.30±1.48
P*	*T. s-hataii*	5	11.60	1.245	11.60±3.50	11.60±1.43
N**	*T. fortilirata*	5	18.80	0.700	18.80±2.50	18.80±1.03
A	*T. saishuensis*	10	16.60	5.155	16.60±5.45	16.60±1.64
D	*T. huziokai*	10	12.30	6.230	12.30±5.90	12.30±1.78
O***	*T. kadono. tsudai*	6	10.30			

* From Mizunami, Gifu Pref. (Mizunami Group, Miocene)

** Recent

***Holotype and paratypes.

Among these samples *T. perterebra* (sample C) has the greatest value of β and it can be distinguished from other species only by measuring β.

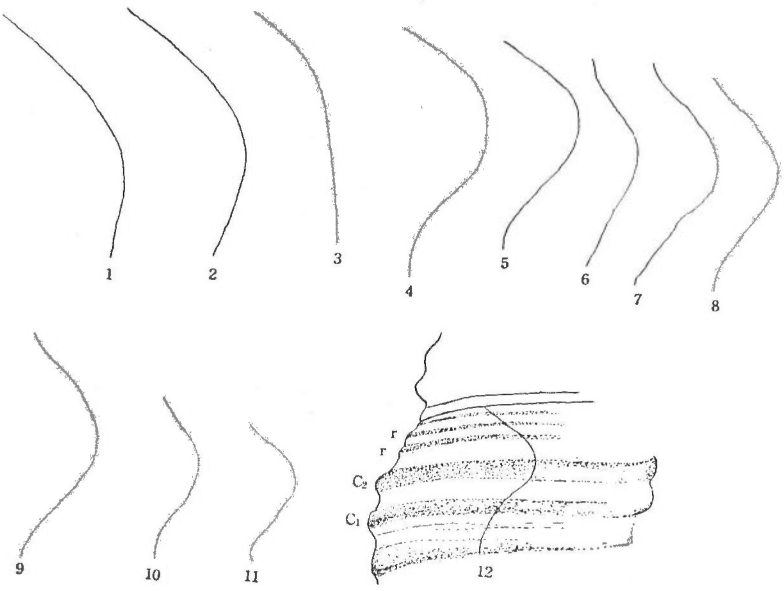


Fig. 15. Growth line trace (by camera lucida × 5–10)
1) *T.* cfr. *bacilum* Yok. (Takanabe Group, Pliocene)
2) *T. perterebra* Yok. (Kakegawa Group, Pliocene.) Topotype
3) *T. kiiensis* Yok. (Yatsuo Group, Mioc.) No. 23713
4) *T.* sp. (Ogikubo from. Nagano, Plioc.) No. 231110-1
5) T. *nipponica miyata* n. subsp. (Miyata form. Plioc.) No. 221022-3
6) *T. saishuensis* Yok. (Himi Group, Plioc.) No. 231023-3
7) ditto. No. 231023-5
8) ditto. No. 231023-6
9) ditto. No. 231023-1
10) *T. nipponica miyata* n. subsp. (Miyata form, Plioc.) No. 231020-1
11) *T. kadonosawaensis* Otuka (Mizunami Group, Mioc.) No. 231020
12) *T. nipponica nipponica* Yok. (Koshiba form. Pleistocene) Topotype No. 527. 367-2

§ 2 DISTRIBUTION OF FOSSIL TURRITELLA.

Neogene marine sediments are found in the following 9 districts: Kantō, Jōban, Tōkai-Nankai, "Togarian Inland Sea", San-in, Hokuriku, Shin-etsu, Tōhoku ahd Central Hokkaidō; the locations of these are shown in Fig. 16.

(2,1) Kantō District

Oligocene (?)

A specimen from the Itsukaichi Group (Nishi-tama, Tokyo) was identified by the writer as *T. karatsuensis* Nagao; this form is a characteristic species of

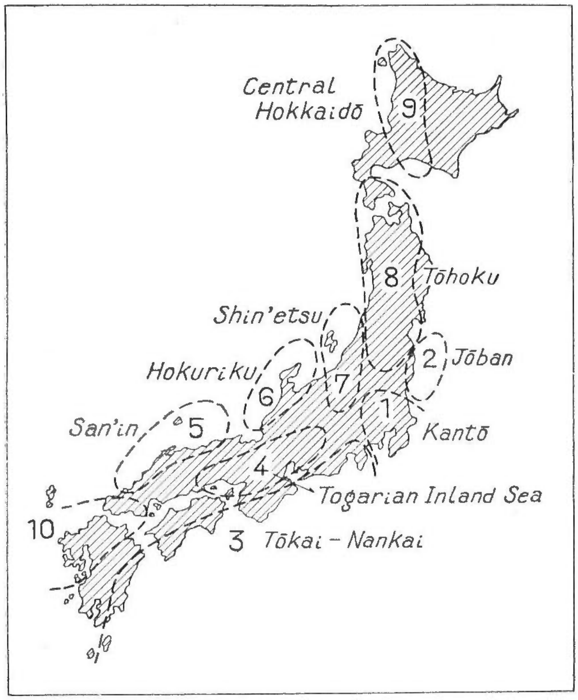


Fig. 16.

the Genkai Series (Oligocene) in north Kyūshū, and is also found in the Nichinan Group of south Kyūshū, but was previously unknown in any of the Tertiary formations of Honshū. The writer therefore believes that at least a part of the Itsukaichi Group may belong to the Oligocene, although this conflicts with the earlier age determination of Miocene age made by H. YABE.[6]

Miocene.

The oldest Tertiary formations in the north Kantō region are believed to be the Akahira Group in Chichibu and the Yorii Group near Ōsato, Saitama Pref. The late Y. OTUKA asserted that the Akahira Group belonged to the Oligocene. There is no positive evidence to indicate that these groups in the north Kantō region differ in age from the Itsukaichi Group. The *Turritella* found in the Akahira and Yorii Group is a new species, *T. chichibuensis.* C. HAYAKAWA[7] and H. HUZIMOTO[8] recorded *T. tokunagai* from the Akahira Group, but the writer could not confirm this in the field. The common species in the Fukuda Group (Miocene) and the lower part of the Itahana subgroup in Gumma Pref. is *T. tanaguraensis;* this was identified by others as *T. kadonosawaensis.* He has no information about the occurrence of this genus in the Miocene of south Kantō, except for a fragment of *T. kiiensis* (?) collected by K. KOIKE in the Hota Group of the Bōsō Peninsula.

Pliocene. (a) Tokyo Basin

K. SUZUKI[9] recorded "*T. perterebra*" in the lowest part of the Nakatsu formation of Kanagawa Pref., but this may be a new species.

6) Yabe, H.: Jour. Geol. Soc. Japan Vol. 34, No. 407, p. 309, 1927
7) Hayakawa, C.: ditto. Vol. 35, No. 412, p. 15-32, 1928
8) Huzimoto, H.: ditto, Vol. 43, No. 508, p. 41, 1936
9) Suzuki, K.: ditto. Vol. 39, No. 461—462. 1932

The Pliocene sediments of the Tokyo Basin are called the Miura Group; the distribution of these sediments is shown in Fig. 17. The sediments of the Miura Group unconformably overlie the Toyooka Group (Miocene) in the Bōsō Peninsula, the Misaka Group (Lower Miocene) at Atsugi and the Itsukaichi Group (Lower Miocene-Oligocene) at Hachiōji; the Miura Group is the thickest at the eastern part of the Bōsō Peninsula. *T. nipponica mitsunashii* and *T. nipponica kazusana* are found in the lowest part of the Miura group. "*T. fortilirata* var.", recorded by K. SAKAKURA (1935)[10] from two fossil beds (Kaburai and Hosono) exposed in the valley of the Obitsu River in the central part of the Bōsō Peninsula, is probably *T. nipponica kazusana*. In the next zone, we find an advanced form, *T. nipponica nojimaensis*, which is chiefly distributed in the Miura Peninsula. The third zone contains *T. nipponica miyata* which is a common subspecies in the Tokyo basin. The forms in the uppermost zone are *T. nipponica nipponica* and *T. ikebei*; this zone corresponds to the upper part of the Koshiba and Nakazato members in the Miura Peninsula, and to Kakio member in the Tama Hills. *T. ikebei* is a member of a different series from that of *T. nipponica*; it invaded the Tokyo basin and replaced *T. nipponica nipponica* in early Pleistocene time. This succession of species in the Pliocene and Pleistocene sediments of the Tokyo basin may have been due to changing ecologic factors; these six species and subspecies appeared successively in the basin without coexisting with each other, except as transported fossils.

Figure 18 is biostratigraphic interpretation of the distribution of *Turritella* in the southern part of the Tokyo Basin. The *Turritella* facies lies between the *Limopsis uwadokoi* Oyama, (MS) facies and the shallow water deposits; between

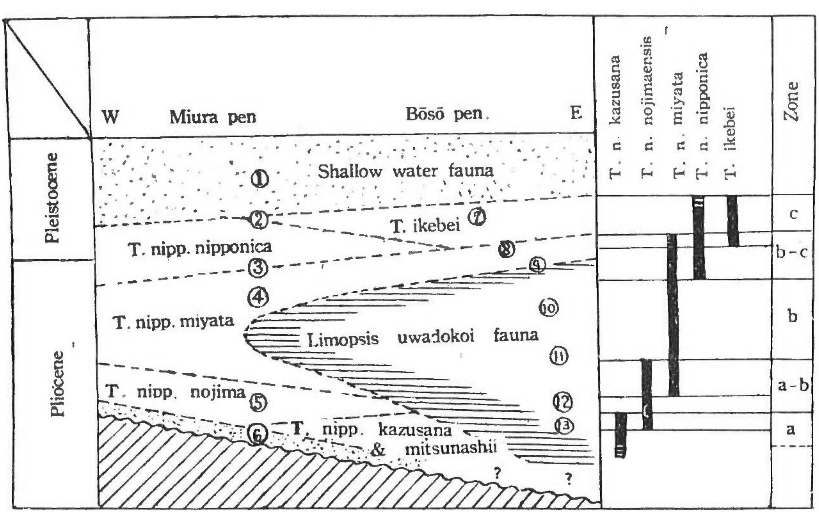
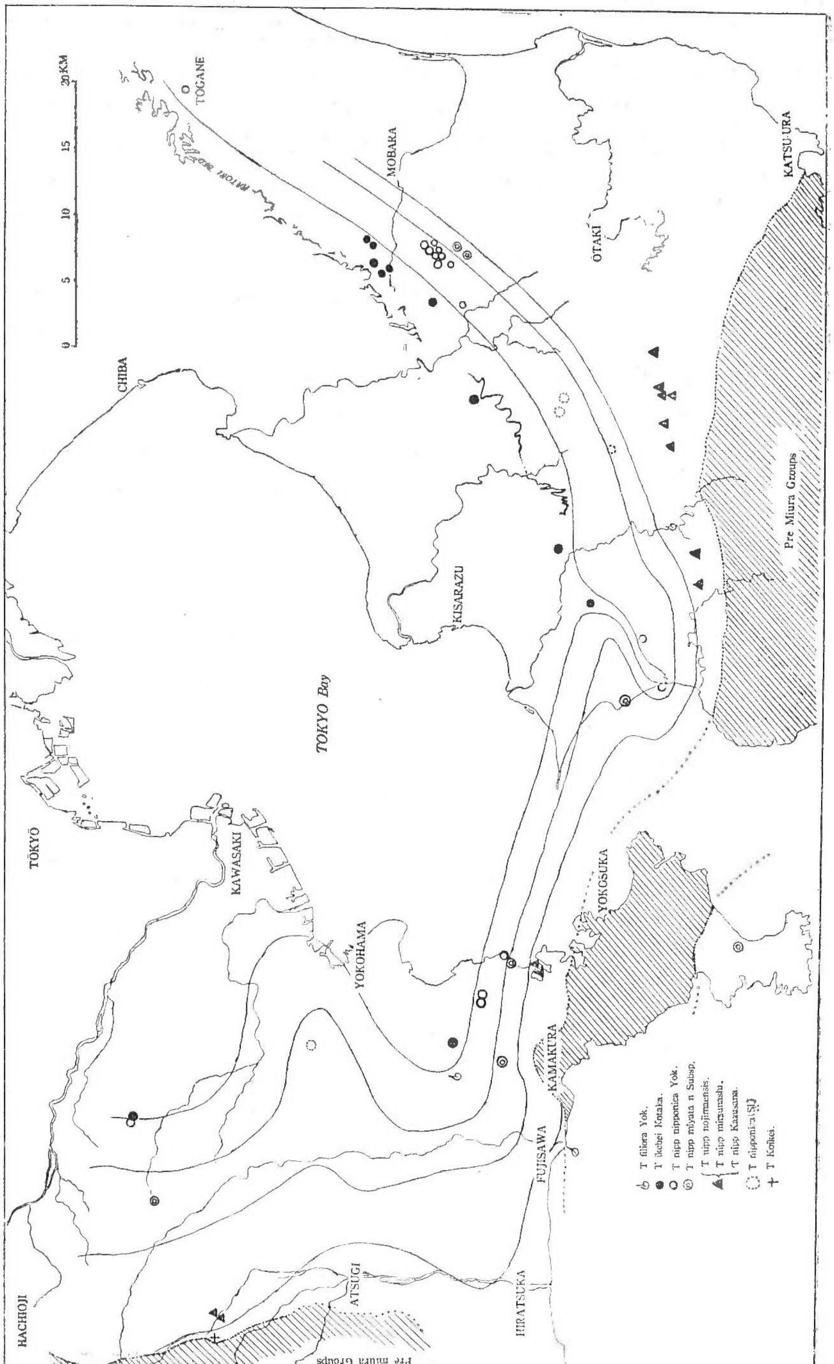


Fig. 18

10) Sakakura, K.: Jour. Geol. Soc. Japan, Vol. 42, No. 506—507. 1935



20KM
0 5 10 15
TOGANE
MOBARA
CHIBA
OTAKI
KATSU-URA
KISARAZU
TOKYO Bay
Pre Miura Groups
TŌKYŌ
KAWASAKI
YOKOHAMA
YOKOSUKA
KAMAKURA
FUJISAWA
HIRATSUKA
ATSUGI
HACHIOJI
Pre miura Groups
T filiora Yok.
T ikebei Kotaka.
T nipp nipponica Yok.
T nipp miyata n Subsp.
T nipp nojimaensis.
T nipp mitsuraslu.
T nipp Kazusana.
T Koikei.

Fig. 17

these, each species or subspecies of *Turritella* occupies a small sphere.

T. filiora was also discovered at a few localities in the Tokyo basin.

(b) Tateyama Area.

The area occupied by the southern parts of the Bōsō and the Miura Peninsulas is spearated from Tokyo basin by an uplift in which Miocene formations are exposed. In this area the type locality of *T. nipponica miyata* is found. *T. nipponica* (s.l.) was once reported by Y. OTUKA[11] from the Ninomiya area, west of Kamakura.

(2, 2) Jōban District

The Ceonozoic sediments of this district consist of 4 groups, Shiramizu, Yunagaya, Shirado and Takaku. Several localities where the Asagai, or upper part of the Iwaki formation in the Shiramizu group, contain numerous specimens of *T. tokunagai* and *T. importuna*, which are common species in the lower Miocene of Hokkaidō and Karafuto.

K. KANEHARA[12] reported the occurrence of *T. omurai* and *T. "tokunagai"* from a formation of Yunagaya Group; the writer found *T. s-hatai* in this same group. The records of *T. "nipponica"* from this group are, however, doubtful.

T. numanouchiensis Ida (MS) is found in the Takaku group. The disribution of *Turritella* in the Jōban district therefore appears to be as follows:

	Group	Species
Miocene	Takaku	*T. numanouchiensis* (MS)
	Shirado	*T. iwakiensis*
	Yunagaya	*T. kaneharai* (MS) *T. omurai*, *T. s-hataii*
	Shiramizu	*T. tokunagai*, *T. importuna*

(2, 3) Tōkai-Nankai District

Neogene sediments are found in several regions of the Pacific Coast, e.g. in Shizuoka Pref., Kii Peninsula, Kochi and Miyazaki Prefectures. J. MAKIYAMA reported of *T. s-hataii* from the Kurami Group (middle Miocene) in Shizuoka Pref. It is questionable whether the specimen found in the Ina Valley by Y. OTUKA is *T. s-hataii* or not. The occurrence of *Turritella* in the Neogene of Shizuoka is summarized below:

11) Otuka, K.: Jour. Geol. Soc. Japan Vol. 36 No. 433, pp. 435–456, 1929
12) Kanehara, K.: Bull. Imp. Geol. Surv. Jap. Vol. XXVII, No. 1. 1937

	(Stage)		(Species)
Pleistocene	—	(J)	*T. kurosio*
Pliocene	Ketienzian	(H_2)	*T. filiora*
	Dainichian	(H_1)	*T. perterebra*
Miocene	Yuian & Tozawan	(F_3, G)	—
	Kuramian	(F_2)	*T. s-hataii*
	Oigawan	(F_1)	—

T. perterebra is a typical Pliocene species and in Shizuoka Prefecture it is found around the northern margin of the Kakegawa basin. *T. filiora* Yok. was also found by the writer in the Nangō Beds (lower Ketienzian). "*Turritella*" *totomiensis* described by J. MAKIYAMA from the Dainichi beds belongs to *Mathilda*. *T. kurosio* was found in a well drilled for natural gas at Takabe, near Shizuoka; the gas reservoir consists of Quaternary marine gravel beds. *Turritella* is apparently absent from the Pleistocene deposits of the Atsumi Peninsula, because its occurrence is not mentioned by T. OINOMIKADO in his voluminous work (1933).

T. TAKEYAMA (1929)[13] found *T. kurosio* in the Pleistocene deposits of the Shima Peninsula and the Akugawa formation near Tanabe, but he wrongly identified it as *T.* cfr. *multilirata*. The type locality of *T. kiiensis* is on the west coast of Tanabe, on the west side of the Kii Peninsula; this species was also discovered in the Miyai coal bearing formation. The Tōnohama formation in Shikoku and the Takanabe formation in Kyūshū which are correlated with Kakegawa Group of Shizuoka Pref., both contain *T. perterebra*.

(2, 4) "Togarian Inland Sea" District.

During middle and upper Miocene times the "Togarian Inland Sea" occupied a narrow area between Ina in Nagano Pref. and the present Inland Sea. The distribution of species throughout this area is tabulated below:

Group or formation	Prefecture	Species
Mizunami	Gifu	*T. s-hataii* *T. tanaguraensis* *T. kadonosawaensis* *T. omurai ?*
Awa	Mie	*T. s-hataii* *T. kadonosawaensis*
Ayukawa	Shiga	*T. s-hataii*

13) T. Takeyama: Globe, Vol. XI, No. 3, p. 222–224, 1929

Isshi	Mie	*T. s-hataii*
Tsuzuki	Kyōto	*T. s-hataii*
Fujiwara	Nara	*T. oyasio*
Shidara	Aichi	*T.* sp.
Chita	Aichi	*T.* sp.
Uezuki-Tsuyama	Hiroshima, Okayama	*T. kiiensis*

(2, 5) **San-in District**

The little that is known of the occurrence of *Turritella* in this district is summarized as follows:

Age	Formation	Locality	Species
mid. or up. Mioc.	Karakane	Hamada	*T. kad. kadonosawaensis*
mid. Miocene	Kimachi	Matsue	*T. "nipponica"*
mid. Miocene	Fujina	Matsue	*T. "nipponica"* *T.* cfr. *sahalinensis*

(2, 6) **Hokuriku District**

Neogene sediments (Yokawa Group and Himi Group) were deposited Toyama, Ishikawa and Fukui Pref. on the Japan Sea coast. This area has been studied in some detail since 1947.

T.kiiensis, which is characteristic of the Miocene on the Pacific Coast of Japan and in the Togarian Inland Sea area, is also found in the Miocene of the Hokuriku district. Other species such as *T. neiensis, T. kadonosawaensis yoshidai* are characteristic of the Miocene of this district. *T. saishuensis* and its subspecies are distributed widely in the Pliocene of the Japan Sea coast. J. MAKIYAMA and N. IKEBE recognized three biozones of *Turritella* in the Pliocene of the Hokuriku district, the *T. saishuensis motidukii* zone, the *T. saishuensis* zone, and the *T. saishuensis etigoensis* zone.

Y. OTUKA[12] recorded *T. kurosio* as *T. "fascialis"*, from the Pleistocene Miyainu and Hiradoko shell beds.

The Yokawa Group is divided into two subgroups (Yatsuo and Otokawa) in the southern part of Toyama Pref. K. OYAMA and A. ONO, who studied the stratigraphy of the Yatsuo Group, recognized several fossil horizons and analysed the assemblages.

Table 2 shows the vertical and horizontal transitions of these faunal assemblages. Among these four fossil zones of Turritella are recognized: the *kiiensis-neiensis* zone, the *kadonosawaensis yoshidai* zone, the *oyasio* zone, and the *saishuensis motidukii* zone.

Table 2. Stratigraphic distribution of *Turritella* and associated fossils in southern part of Toyama Basin.

T= *Turritella*; *T. kad. yosh.*= *Turritella kadonosawaensis yoshidai.*
Vic.= *Vicarya*; *Vic. yatsuo.*= *Vicarya yatsuoensis.*

Foss. / Beds	(by K. Ida, 1947)	(by A. Ono, K. Oyama and Y. Shinada, 1947)						(by A. Ono, K. Oyama and T. Makino, 1948)	
	Yamada-gawa	Nezumi-gawa	Gobō, Kanaba	Besso-gawa	Kubusu-gawa	Higashisakoki	Jintsū-gawa	Ichinose	Seto, Makino
8	Uwase *T. saishu. motidukii*								
7	Daira *T. oyasio*						Jōnou *T. oyasio*		
6	Yamadanaka *Operculina*			Mommyoji(N) *T. kad. yosh.*		Jyōyama *T. kad. yosh.* *Operculina*			
5					*Operculina*				
4		Tsusaka *Vic. yokoyamai* *Protorotella*	Yasojima *Operculina*	Oharajima	Kasio *Protorotella*	Ikuridani *T. kad. yosh.* *Protorotella* *Operculina*			Nunome *Protorotella* *T. kad. yosh.* *Operculina*
3			Gobō *T. kiiensis*	Shimizu *T. kiiensis* *T. neiensis*	Iwaya *T. kiiensis* *Vic. yok.*	Higashisakoki *Vic. yokoyamai* *Operculina*	Iwakishin *T. kiiensis* *V. yokoyamai* *Operculina*	Ichinose *T. kad. yosh.* *Operculina* *Protorotella*	
2					Hompōji *Protorotella*	Dō *Vic. yatsuo.* *Protorolella*	Gebuse *Vic. Protorotella*		
1					Kakehata *Vic. yatsuo.* *Protorotella*				

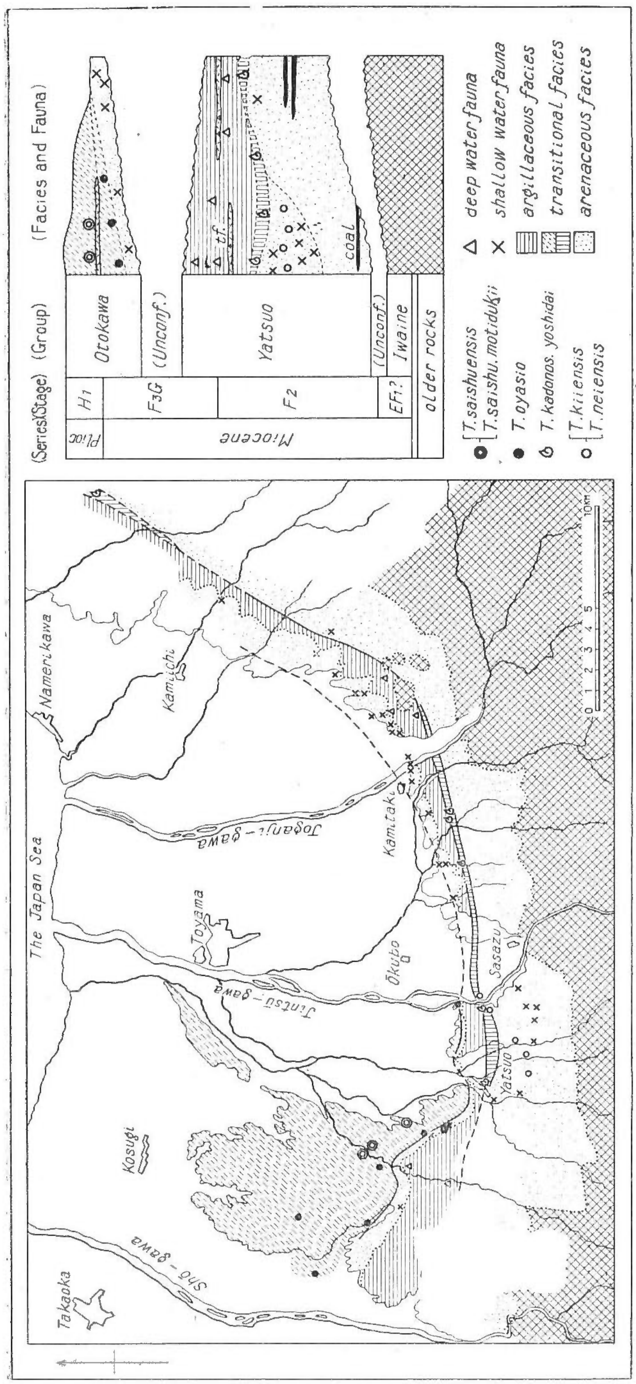

(Series)(Stage) (Group) (Facies and Fauna)
Plioc.
Miocene
H1
F3G
F2
EF1?
Otokawa
(Unconf.)
Yatsuo
(Unconf.)
Iwaine
older rocks
t.f.
coal
T. saishuensis
T. saishu. motidukii
T. oyasio
T. kadonos. yoshidai
T. kiiensis
T. neiensis
deep water fauna
shallow water fauna
argillaceous facies
transitional facies
arenaceous facies
The Japan Sea
Namerikawa
Kamiichi
Jogangi-gawa
Kamitaki
Toyama
Ōkubo
Sasazu
Jintsu-gawa
Yatsuo
Kosugi
Shō-gawa
Takaoka
0 1 2 3 4 5 10km

Fig. 19

The first, second and third zones belong to the Miocene and the fourth to the Pliocene. The facies relations of these assemblages are indicated in Figure 19.

(2, 7) Shin-etsu District

T. chichibuensis is found in the lowest formation of the Neogene in the Shin-etsu district, the Moriya formation. The vertical range of this species in the Chichibu basin of north Kantō is limited to the lower members, and therefore the Moriya formation can be correlated with this area. J. MAKIYAMA reported *T. fortilirata* from the Shigarami formation, and K. OYAMA discovered *T. saishuensis motidukii* with *T.* n.sp. in the Ogikubo formation. *Turritella* is not known from the Miocene of Niigata Pref., but in the Pliocene sediments *T. saishuensis* and *T. saishuensis etigoensis* are commonly found, and a horizon of *T. s. etigoensis* exists in the uppermost Pliocene.

(2, 8) Tōhoku District

The well-known Miocene species are *T. s-hataii* in Akita, Yamagata and Miyagi Pref., and *T. kadonosawaensis* in Iwate Pref. *T. saishuensis* is found in the Pliocene. In the uppermost Pliocene of the Tōhoku district *T. saishuensis etigoensis,* of the Shin-etsu District, is absent and is replaced by *T. andenensis ogashimaensis.*

In the type exposures of the oil-bearing Tertiary formations in the Oga Peninsula of Akita Pref. the species of *Turritella* are distributed as shown below :

(formation)	Oga Peninsula (North Coast)	(South Coast)
Katanishi	—	non marine ?
Shibikawa	upper fossil bed *T. andenensis*	Tayazawa fossil bed *T. andenensis* *T. nipponica miyata* *T. fortilirata tibana*
	middle fossil bed *T. andenensis* *T. and. ogashimaensis*	
	lower fossil bed *T. nipp. nojimaensis* *T. fortilirata*	
Wakimoto	*T. saishuensis*	—
Kitaura	—	—
Funakawa	—	—

14) Otuka, Y. : Bull. Earthq. Res. Inst. Tokyo. Imp. Univ. Vol. 13, 1935
15) Makiyama, J. : Globe, Vol. 8 No. 3, p. 181—188, 1927

Minamihirasawa	—	—
Onnagawa	—	—
Nishikurosawa	—	*T.* sp.
Daijima	non marine?	non marine?

(2, 9) Central Hokkaidō District

The distribution of the species of *Turritella* in the Neogene of central Hokkaidō is shown below:

(Series)	(Stage)	(Turritellas)	(Chief loc.)
Pleistocene	Tokachi	—	
	Kushiro	—	
Plio-Pleistocene	Takikawa	*T. fortilirata* Sow. *T. nipponica* Yok.	Setana
Pliocene	Oiwake	*T. saishuensis* Yok.	Kitami, Teshio
	Wakkanai	—	
Miocene	Kawabata	*T. kadonosawaensis* *T. s-hatai* Nom. *T.* n. sp.	Uryū Ishikari
	Poronai	*T. tokunagai* Yok. "*T.*" *importuna* Yok. *T. poronaiensis* Nagao & Huzioka (MS)	Ishikari Coal Field

§ 3 ECOLOGICAL NOTES ON RECENT SPECIES

Two studies have been made which include data on the distribution of *Turritella* in Wakasa Bay. HABE, KAWAGUCHI and YAMANE (1945)[16] dredged at 71 stations in Obama-wan, an inlet of Wakasa Bay, and studied chiefly the communities of mollusca. At 13 stations, they found faded specimens of *T. fascialis*, and considered that the species was living in the inlet.

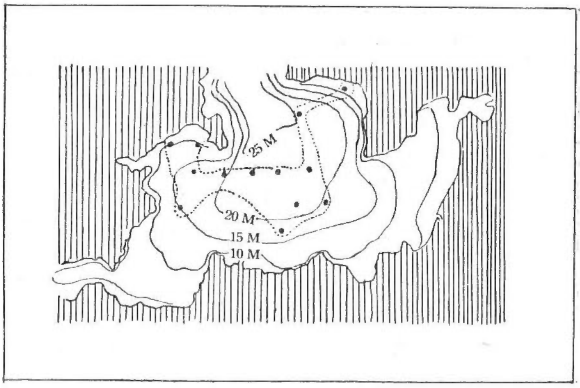


Fig. 20 Distribution chart of the stations from which T. fascialis Menke was dredged by Habe, Kawaguchi and Yamane (1945), in Obama-wan.

16) Habe, Kawaguchi & Yamane: Jour. Physiology and Ecology, Kyoto Imp. Univ. No. 32, 1945.

The writer analyses the data in Figure 20 as follows:

Seven classes are established according to depth (X_1–X_7) and two classes on the basis of the absence (Y_1) or presence (Y_2) of *T. fascialis* at these depths; the frequency distribution based on these data is as follows:

depth		X_1	X_2	X_3	X_4	X_5	X_6	X_7	
		0-4m	5-9	10-14	15-19	20-24	25-29	30-34	
Y_1	absent	7	20	13	8	6	3	1	58
Y_2	present	0	0	3	5	4	1	0	13
total		7	20	16	13	10	4	1	71

The existence of correlation between X and Y is then tested. The probability of obtaining a frequency distribution equal to or biassed against the above mentioned frequency distribution is as follows:

$$Pr = 0.0075018$$

It cannot be decided that X is independent of Y, because the probability value is small. In other words, as far as Obama-wan is concerned, the distribution of the shells of *T. fascialis* is closely related to the depth of the sea bottom, the actual value is between 10m and 26m, and the sample mean is 18m.

The bottom sediments at the 13 stations where *T. fascialis* was found are as follows:

Bottom sediments	No. of stations	Frequency
Mud	9	65%
Mud and shells	2	15
Fine sand and mud	1	8
Coarse sand	1	8
(total)	13	96

The habitat of living *T. fascialis* cannot be decided only by the result of this analysis. The distribution relations may be caused merely by current transportation, judging from the shape of the distribution area and the fact that the shells are not dredged alive.

H. NIINO (1950)[17] reported *T. fascialis* from 20 stations dredged by him in Wakasa Bay. Figure 21 shows the locations of these stations in relation to the depth and character of the bottom sediments and distinguishes the occurrence of fresh or faded shells of *T. fascialis* at these stations. Figure 22 is a plot of the fresh and faded occurrences according to the depth and bottom temperature at

17) NIINO, H. Jour. Tokyo. Univ. Fisheries Vol. 37, No. 1, (1950)

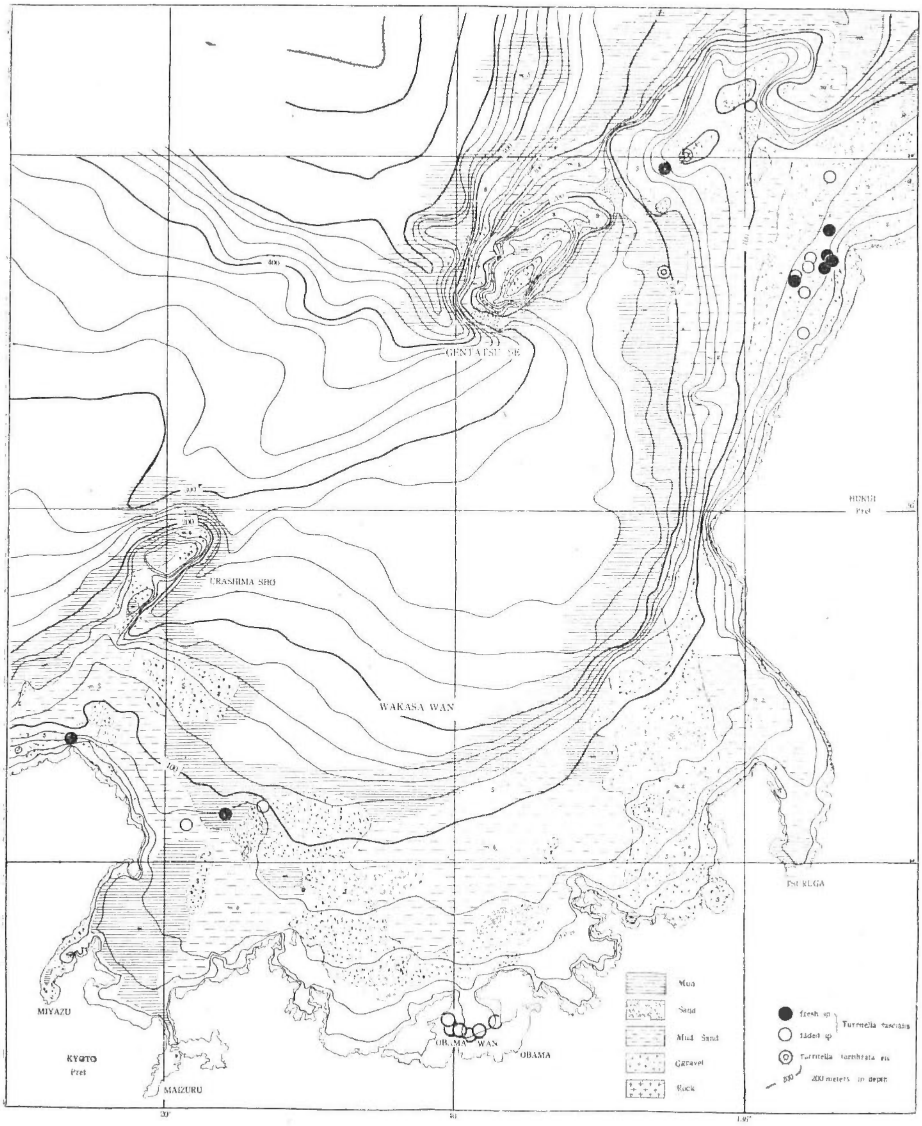


Fig. 21 Distribution chart of bottom sediments in Wakasa bay.

18 of these stations. Assuming that the occurrences of the fresh shells indicate the habitat of *T. fascialis*, the temperature and depth of their habitat can be derived.

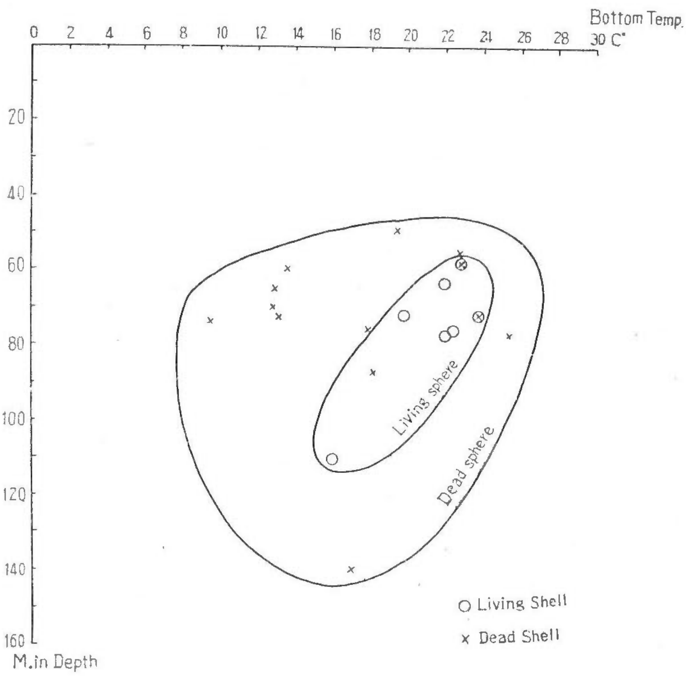


Fig. 22

Wakasa Bay has two banks (Urashima-sho, and Gentatsu-se) which jut out from the mouth of the bay, and it has a continental shelf extending from 0–120m

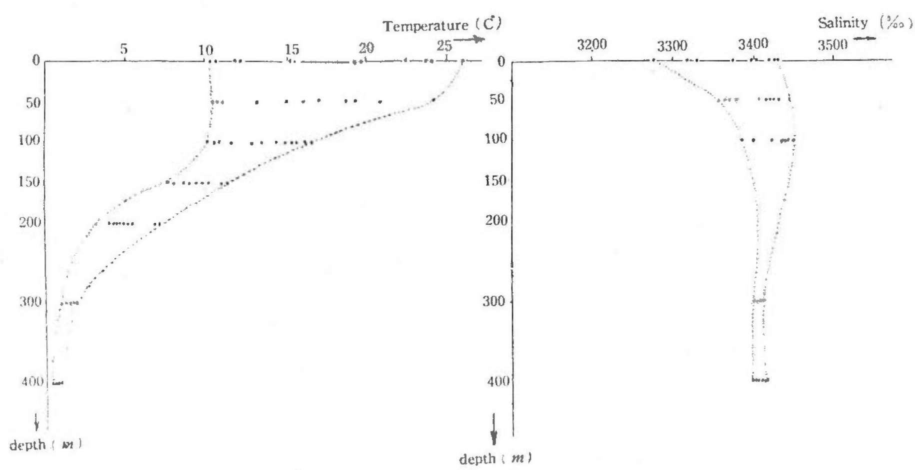


Fig. 23 Annual Variation of Temperature and Salinity.
40 Miles 17° NW off Tateishizaki (1933–1941)

in depth. The central part of the bay is a muddy flat bottom, 200–400 meters in depth. The shells of *T. fascialis* are distributed principally on the shelf and are rare on the banks. In summary it may be said that *T. fascialis* lives within the influence of the warm Tsushima current in terrigenous shallow water deposits, and its habitat is not related to the grain size of the bottom deposits. Annual variations of temperature and salinity are shown in the following figure. (Fig. 23)

§4 STRATIGRAPHIC SIGNIFICANCE OF FOSSIL TURRITELLA

(4, 1) Differentiation of β.

After the angle β is recognized as a bio-character, and of phyletic value, an interesting fact was discovered concerning the changes in the value of β.

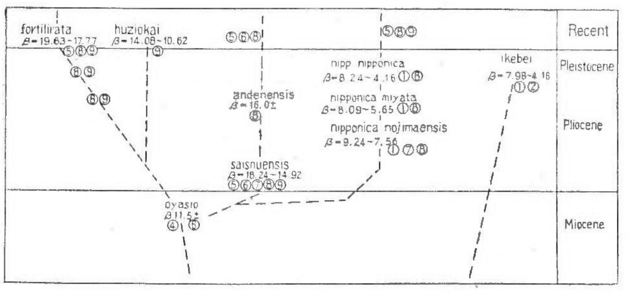


Fig. 24. The systematic range chart of *Neohaustator* and an estimate interval of population mean about growth line inclination (β). Number shows "District" in Fig. 16

In the *saishuensis* series, the value of β in general progressively increases, while it decreases in the *nipponica* series. They diverge in two directions, but are not always orthogenetic. Though the characters of *T. huziokai* resemble those of *T. saishuensis*, the value of β is smaller in the former than in the latter; the angle in both these series therefore varies in opposite directions. The series of *T. ikebei* apparently diverged from the main series in Miocene time.

(4, 2) The change in ornamentation.

In the series of *T. saishuensis* the monotonous form of adult *motidukii* has the adolescent whorls of *saishuensis* (s. s.) and the younger whorls of *etigoensis, ogashimaensis* and *andenensis;* but each form of the adult whorls in the older stage is not repeated on the surface of the whorl in the younger stage. This phenomenon may be called hypermorphosis; in this case not a whole but only a part of the features in ontogeny is recapitulated in the next phylogenic stage.

It does not necessarily follow, however, that all series of *Turritella* differentiate hypermorphogenetically. The series of *T. nipponica* develops neotenically in general, and at the middle stage of the Pliocene a differentiated form (*T. nipponica nojimaensis*) appears. The adult whorl of *T. nipponica* (s. s.) in the Pleistocene, however, resembles the adolescent whorl of the Miocene form *T. kadonosawaensis,* which is probably an ancestral form of *nipponica.* In the series of *kadonosawaensis,* this same phenomenon is evident, that a differentiated form

Table 3. A differentiation of sculpture in the series of *T. saishuensis* Yok.

	T. saishuensis motidukii	*T. saishuensis saishuensis*	*T. saishuensis etigoensis*	*T. andenensis ogasimaensis*	*T. andenensis*
nuclear stage	(—)	(—)	(—) ·····	(?)	····· (—)
	(C)	(C)	(r) ·····	(?)	····· (C)
adolescent stage	(C r r)	(C r r)	(r r r) ·····	(?)	····· (C r r)
	(C C r)	(C C r)	(C C r) ·····	(?)	(C r·r·)
	(C C C)	(C C C)	(C C C) ·····	(?)	(·C·C·C·)
	(C C C)	(C C C)	(C C C) ·····	(?)	(r C r C r C r)
	(C C C)	(C C·C·)	(C C·C·)	(C C·r·)	(r C r C r C r)
adult stage	(C C C)	(C C·C·)		(C C r r r)	(r C r C r C r)
	(C C C)	(C C·C·)	(··C···C·····C···)	(C·C·r·r r)	(r C r C r C r)
	(C C C)	(C C·C·)	(·····C····C····C·r··)	(·C·C·r·r·r)	(r·C·r C r C·r·)
		(C C···C·)		(·C·C·C·C·C)	
		(C C···C·)		(·C··C·C·C·C)	
	lower-Pliocene	l. & m. Pliocene	up. Pliocene	up. Pliocene	uppermost Pliocene

like *T. s-hatai* was represented at the same time, or earlier than the age of the simple form.

Thus differentiation and simplification were repeated in the process of evolution. Differentiated species do not necessarily continue in later geological ages. Species of simple type that developed neotenically continued and produced a new differentiated form in the next geological age.

(4, 3) Segregation of Turritella and struggle for habitat.

In the lower Pliocene formation of the Tōhoku district, a form of *T. nipponica* exists with *T. saishuensis*. If this form of *nipponica* is assumed to be an ancestor of its series, *nipponica* must have been replaced in the district by *T. saishuensis.* The hemera of *T. saishuensis* was in the middle Pliocene. *T. nipponica* appeared in the Kantō district at that time; afterwards it flourished and produced several subspecies. But in the later Pliocene when the *T. saishuensis* series, represented by *T. saishuensis etigoensis* in the Shin-etsu and Hokuriku districts and by *T. andenensis ogashimaensis* in the Tōhoku district, declined in the Japan Sea area, *T. nipponica* invaded the Tōhoku district.

In the early Pleistocene, however *T. ikebei* immigrated into the Kantō district expelling *T. nipponica nipponica. T. nipponica* is found Recent in Japan, but not *T. ikebei.* Therefore *T. ikebei,* which probably immigrated from the Jōban district, must have been exterminated at the close of the Pleistocene.

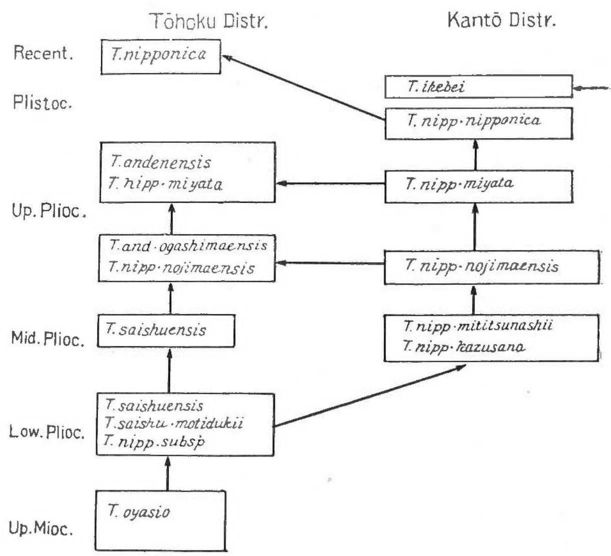


Fig. 25. Stratigraphical distribution and suggested lines of migration of *Turritella* in Tōhoku and Kantō Districts.

Among the many morphological characters of *Turritella* which are discussed in this paper, some may be characteristic of a species or of a genus, but others may merely characterize an individual. One of the prime objects of this study is to determine the taxonomic value of these morphological features. Some peculiarity gradually becomes transformed in the process of the growth of an individual, but the changes in other peculiarities may take place in very slow stages, and every species which belongs to the same group has this same peculiarity. In one stratigraphic stage, the variation of a bio-character is restricted to certain limits, but through several successive stages even the stablest character may undergo many changes.

The differentiation of morphological characters is expressed by quantitative description not by fixed knowledge. From the taxonomic point of view, we must grasp an unfixed character among the shifting vicissitude, and must establish the natural system of taxonomy. When we recognize the variable character we can get a comparatively reliable phyletic-tree.

Pleistocene -Recent	I_2JK	*T. fascialis fascialis, T. fascialis gracillima, T. fortilirata, T. fortilirata tibana, T. huziokai, T. nipponica nipponica, T. andenensis, T. anden. tsushimaensis, T. binaestriata* (MS)
		T. kurosio, T. andenensis, T. ikebei, T. nipponica nipponica, T. fortilirata, T. fortilirata tibana
Pliocene	H_2I_1	*T. filiora, T. ogashimaensis, T. nipponica miyata, T. fortilirata, T. fortilirata tibana, T. saishuensis, T. saishuensis etigoensis, T. nipponica nojimaensis.*
	H_1	*T. nipponica mitsunashii, T. nipp. kazusana* (MS)[3] *T. perterebra, T. saishuensis, T. saishuensis motidukii.*
Miocene	F_3G	*T. numanouchiensis* (MS)[3], *T. matsuii* (MS)[3], *T. oyasio, T. tsudai, T. neiensis, T. iwakiensis.*
	F_2	*T. kiiensis, T. neiensis, T. tanaguraensis, T. s-hataii, T. omurai, T. kadonosawaensis, T. kadonos. yoshidai.*
	$E F_1$	*T. chichibuensis, T. poronaiensis* (MS)[1], *T. importuna, T. tokunagai.*
Ooligocene	D	*T. infralirata, T. sakitoensis, T. karatsuensis, T. karatsuensis var. plicostata* (MS)[2]
	C	*T. karatsuensis.*
Eocene	B	*T. shiranui* (MS)[3]
	A	*T. okadai, T. miikensis, T. miikensis ariake* (MS)[3]
? Palaeocene	A_0	

Table 4. A summarized stratigraphical distribution of *Turritella* in Japan.
1) by NAGAO and HUZIOKA.
2) by MATSUMOTO
3) by IDA

Conclusion

Before Japanese Cenozoic stratigraphers could establish a reliable biostratigraphic correlation of the Tertiary formations in the various sedimentary basins of this country, economic geologist began to require the correlation of minute stratigraphic divisions and their correlation.

Micropalaeontological methods are too sensitive for widespread correlation, although they are important for local correlation. Of course, the present method is not perfect for this object, but the writer believes that biostratigraphic correlation in the Cenozoic will be assisted by this investigation of fossil *Turritella*.

The members of *Turirtella* (s. s.) and *Kurosioia* have flourished since the Miocene in southeastern Asia. As the immigrant species do not leave a continuous record in the Cenozoic deposits in this country, they are not so useful for biostratigraphic purposes. The species and subspecies of *Neohaustator* and the *tanaguraensis* group, however, which have occupied the Japan area since Oligocene time, appear frequently in numerous formations; the ranges of the members of this subgenus and group can therefore be applied for stratigraphic purposes, because their vertical range is comparatively short.

The important taxonomic features of *Turritella* are as follows:

1) For the shells with a conical spire, H/D and θ are of value.
2) The relative height of the whorl (h/d) has a characteristic value for every taxonomic unit.
3) The spiral ribs and the whorl profile are the most variable features. If the development of the spiral sculpture is studied from the early stages, it can be recognized that they express the characters of species or subspecies as well as of individuals.

§ 5 TAXONOMIC DESCRIPTION

Class	Gastropoda
Subclass	Prosobranchia
Order	Ctenobranchiata
Superfamily	Cerithiacea
Family	Turritellidae
Genus	*Turritella* Lamarck, 1799

Type (Haplotype): *Turbo terebra* Linné

1799 Mem. Soc. Hist. Nat. Paris, Ser. 1, T. 1, p. 74.

Original description (translated by H. Dodge.)

"Turriclate; aperture rounded, entire, but having a sinus on the outer lip."

The writer proposes to classify the Japanese forms of *Turritella* into three subgenera, *Turritella* (s. s.), *Kurosioia*, *Neohaustator*, and one species group designated by *T. tanagraensis* Kot.

The species of *Turritella* (s. s.) that has increased in south eastern Asia and is now represented by a few recent species, immigrated to the Japanese region and flourished during some geological stages, but later disappeared from this region.

Kurosioia is also known in southeast Asia and Japan; one species migrated to the Hokuriku District in Miocene times and another species became established on the Pacific coast of Japan during the Pliocene.

Neohaustator, represented by several species or subspecies, is characteristic of the Neogene in Japan, although its full range is Paleogene to Recent.

Turrtella (s. s.)

Turritella (s. s.) is represented in Japan by *Turritella perterebra* Yokoyama. The shell is in the form of a large, concave-conical spire. The nepionic volution possesses a pair of ribs, V (C C), and the spiral ribs increase steadily with growth. In this respect it is like *T. terebralis* Lam., but the growth line of *T. perterebra* is characterised by having a negative skewed single-arched sinus and a large inclination angle. This species is restricted to the lower Pliocene (H_1) of the Pasific coast of western Japan.

The shell of *T. kiiensis* Yok. is convex conical and large; the growth line is of the single arched type, the inclination angle is large, and the skewness is positive. *T. kiiensis* is found in the lower or middle Miocene of the western part of Japan. There is some doubt as to whether this species belongs to *Turritella* (s. s.), because the character of the growth line differs from that of *T. terebra* (Linné).

Turritella (Turritella) perterebra Yokoyama, 1923

Pl. 1, Figs. 2, 3; pl. 7, Fig. 2.

1923 *Turritella perterebra,* Yokoyama, Jour. Coll. Sci. Imp. Univ. Tokyo, Vol. XVL, Art. 2, p. 11, pl. II, figs. 2-5

1927 *Turritella perterebra,* Makiyama, Mem. Coll. Sci. Kyoto Imp. Univ., Ser. B, 3, 1, p. 68.

1928 *Turritella kiiensis,* Yokoyama, Jour. Fac. Sci. Imp. Univ. Tokyo, Sec. II, Vol. II, pt. 7, p. 333.

1934 *Turritella perterebra,* Otuka, Bull. Earthq. Res. Inst. Tokyo Imp. Univ., 12, 3, p. 622, pl. 51, fig. 101.

1938 *Turritella perterebra,* Otuka, Venus, VIII (I), p. 38, fig. 16.

not 1929 *Turritella perterebra,* Yokoyama, Jour. Fac. Sci. Imp. Univ. Tokyo, Sec. II, Vol. II, Pt. 8, p. 363.

not 1930 *Turritella perterebra,* Yokoyama, ditto., Sec. II, vol. II, Pt. 10, p. 400.

Original description:

"The shell is high turrete consisting of many whorls which are rounded and spirally whorls is always in their lower half, the upper half being generally more or less sculpture consists of unequal threads, the coarser ones being six to eight, alternating with the finer ones. Aperture rounded."

Shell a very large, concave conical spire; whorl profile C-type (or JC-type);

mature shells have 20 or more volutions, deep sutures and a roundish base.

Development of sculpture:

The younger volutions have 3 ribs, r_1 on the proximal part of the whorl, r_2 at the middle, and r_3 situated close to the distal suture; at this stage, the whorl profile is C-type. Adolescent whorls have strong primary ribs with secondary spirals: J (C C C r r r)

In the next stage, several tertiary threads are developed: JC (C C C C r r r)

The adult whorls (D=20 mm) possess also a lot of quarternary threads; at this stage, the secondary and tertiary ribs become slender and there is no difference between them. The breadth of the interstitial grooves is about equal to that of the spiral ribs. The base of the shell also has many spiral ribs.

The growth line is of the single arcuated type; inclination about 36 degrees; asymmetrical, negative skewed, of moderate depth. The growth line runs approximately in axial direction from the proximal suture, passing into the sinus from which it curves gently to the distal suture.

Variation:

Shell muddy or calcareous; the outer lip is usually thin, but some specimens have thick lips (1 mm) and stout shells. The number and shape of the tertiary and quaternary threads are very variable.

Spiral rib formula:

Adolescent whorl: JC [C C C r r r]

Distribution:

Dainichi, Ugari-mura, Suchigun, Shizuoka Pref. (Dainichi formation, lower Pliocene, H_1) (Type locality). Kakegawa and vicinity, Shizuoka Pref. (Dainichi and lower Horinouchi formations, lower Pliocene, H_1). Tōnohama, Yasuda-mura, Aki-gun, Kōchi Pref. (lower Pliocene, H_1). Hagenoshita, Kamie-mura, Koyu-gun, Miyazaki Pref. (Takanabe formation, lower Pliocene, H_1).

Geological Age: (Lower Pliocene, H_1)

Comparison: The height of the whorl in *T.* (*Turritella*) *terebra* (Linné) is lower than that of the present form. The growth lines of both species are similar. The ornamentation of *terebra* is very prominent in the adult whorls, but the adolescent whorls have the same formula.

Turritella (Turritella ?) kiiensis Yokoyama, 1923

Plate 1, Fig. 4; Pl. 2, Fig. 3; Pl. 6, Fig. 8; Pl. 7, Fig. 8.

1923 *Turritella kiiensis*, Yokoyama, Jap. Jour. Geol. Geogr., Vol. 2, p. 52, pl. VI, fig. 9, 10.

1929 *Turrittella perterebra*, Yokoyama, Jour. Fac. Sci. Imp. Univ. Tokyo, Sec. II, Vol. II, pt. 8, p. 363.

not 1929 *Turritella kiiensis*, Yokoyama, Jour. Fac. Sci. Imp. Univ. Tokyo, Vol. II, pt. 9, p. 384, pl. LXXII, fig. 7.

Original description:

"Shell large, solid, many-whorld. Whorls about fifteen (?), convex when young, weakly bicarinate when full grown, spirally corded. The carinas are obtuse and present near the sutures, the one near the upper suture and the other near the lower, with intervening space usually flat, though somewhat concave in the full grown whorls. Spiral cords distinct on the younger whorls, but gradually becoming indistinct on the older; varying in number from seven to ten; equal or somewhat inequal, usually with one or more finer ones between. On the bodywhorl and the one preceding it, the cord, found on the carina and the one above it, are somewhat larger than others; while, on the former, there are two smaller cords below the carinal one. Base smooth, or varying finely spirally striae. Aperture ovate. The height attained is more than 80 mm."

Description:

The shell is a convex conical spire; the whorl is D-type and has a shoulder; the middle part of the whorl is flat or slightly concave; sutures deep.

Spiral rib formula: D [C C·r r·r·r]

In 1948, a new locality discovered in Toyama Pref. yielded specimens from which data on the growth line, minute ornamentation, and other features, could be obtained.

The growth line is of the single arched type with positive skewness, and broad convexity; inclination about 30 degrees. The growthline trace curves in the axial direction on the subsutural part.

Variation: The ornamentation is rather variable; the whorl profile is usually D-type but varies to some extent.

Specimens from Wakayama Pref.	a)	D (CC·rr·r·r) (not well preserved)
	b)	D (·r··C··r·r·r·r) (,,)
from Toyama Pref.	c)	D (····r···r·r·r·r·r·)
	d)	D (r·r·r·r·r·r·r·)
from Okayama Pref.	e)	D (·····r···r·r·r·r·r·r·)

The strong cords (C_1 and C_2) on the proximal part often change into weak ribs (r_1 and r_2). The proximal parts of whorls which have C_1 and C_2 are swollen. The threads on the proximal parts of the whorls are variable.

Comparison: The spire of *T. perterebra* Yok. is concave conical, and the growth-line has negative skewness, and greater inclination (36°). *T. terebra* (Linné) has a concave conical spire and C-type whorl profile. There are several species of this group in South-eastern Asia. Almost all of which have concave conical spires and whorl profiles of C or J-type; for example,

T. terebra bandongensis Martin	is	J-type;
T. terebra spectrum Reeve	is	C-type;
T. terebra kendengensis v. Reg. Alt.	is	C-type.

T. bacillum Kiener is D-type in whorl profile but has a smaller apical angle than that of *kiiensis*. Some forms of *T. ocoyana* Conrad resemble this species in the shape of spire or whorl, but the growth line inclination is greater in *T. ocoyana* (40° ±).

Distribtion: Takinai and Niigishi, the coast of Tanabe, Wakayama Pref. (Kanayama formation, middle Miocene F_2). Iwakishin, Iwaya, Shimizu and Gobō, Toyama Pref. (Yatsuo Group, middle Miocene F_2). Hōjyō Satokata, Inaoka-mura, Kumegun, Okayama Pref. (Uetsuki-Tsuyama formation, middle Mioceme, F_2). Shijukkan, Tōkaichi-machi, Futami-gun, Hiroshima Pref. (ditto.)

Subgenus Kurosioia subgen. nov.

Type: *Turritella kurosio* n. sp.

The shell is small, thin and delicate. The growth line has a moderately embayed antispirally directed sinus of the double-arched type. A keel appears at an early stage, situated somewhat proximally on the middle part of the whorl, V (C_1). On the 4th whorl, a faint spiral rib appears in the distal part; V (C_1C_2). Successively, the third rib, r_3, appears in the distal part at some distance from r_2; later, C loses its character as a keel and resembles the other ribs; J ($r_1r_2r_3$). Some of the ribs on the adolescent whorls have fine granules. *Kurosioia* ranges from Miocene to Recent in Japan. The species of this subgenus and their geological ranges are as follows:

T. neiensis n. sp. (Miocene)
T. fascialis fascialis Menke (Recent)
T. fascialis gracillima Gould (Recent)
T. kurosio n. sp. (Pleistocene)
T. filiora Yokoyama (Pliocene-Pleistocene)

T. neiensis is the sole representative of this subgenus in the Miocene. It has a double-arched, comparatively shallow sinus in the growth line. In the nepionic stage the whorl has a strong cord (C_1) in the middle of the whorl, but the cord is not as strong a feature as the keel which characterizes the nepionic whorl of *T. kurosio*. Even in the adolescent stage, the primary cord does not move aside. Although the whorl profile of the young stage is V-type, it gradually becomes flat on the adult whorl.

Turrltella (Kurosioia) kurosio, n. sp.

Pl. 1, Fig. 7, 12, 13, 14; Plate 2, Fig. 2.

1929 *T.* cfr. *multilirata*, Takeyama: Globe XI, 3
1935 *T.* cfr. *multilirata*, Oinomikado: Glove XIX No. 4 pp. 62–64.
1935 *T. fascialis*, Otuka Bull. Earthq. Res. Inst. Tokyo XIII Part. 4, p. 855 pl. LIII fig. 51.

Holotype: Geol. Surv. Jap. Palaeont. No. 2412702

Type Loc.: Gas well No. 15 in Iida-mura, Shizuoka Pref. (Mine formation, Pleistocene J)

Description: Shell fairly small, conical, consisting of 12 whorls. Surface of nuclear whorl is smooth; the proximal part of the whorl is expanded on the second whorl V (C_1); two ribs are added on the distal part of the fourth whorl.; V ($r_1r_2r_3$); and several secondary spiral threads appear on the fifth whorl. On the sixth whorl fine, closely spaced nodes appear on the heavy main ribs; the interspaces between the ribs are narrow. Suture channeled. Aperture subquadrate. Outer lip thin. Growth line of double arched type; distal inflexion point exisits near suture, and it is slightly curved. Deep antispirally directed sinus, with maximum slightly anterior to C_2; spirally directed sinus is in sutural furrow.

Dimensions: Holotype: H=21.25 mm, D=5.80 mm.

Variation: Tubercles may be absent, or may vary in number and degree of development. The ratio H/D is also variable; for the holotype and paratypes of *T. kurosio*, H/D (mean)=3.86 (N=14, u^2=1.0253)

The specimens repoted by Y. Otuka have the following spiral formulae:

Paratype 2412714

V (C_1) n=3

J ($C_1 r_2$) n=4

J ($C_1 r_2 r_3$) n=5

D ($\cdot C_1 \cdot r_2 r_3$) n=6

D ($\cdot \mathring{C}_1 \cdot r_{12} C_2 C_3$) n=7

D ($r_{01} \mathring{C}_1 \cdot r_{12} \cdot \mathring{C}_2 \cdot \mathring{C}_3 \cdot$) n=8

C ($r_{01} C_1 r_{112} r_{12} r_{122} C_2 r_{23} C_3 r_{34}$) n=14

C ($r_{01} C_1 r_{112} r_{12} r_{122} C_2 \cdot r_{23} \cdot C_3 r_{34}$) n=15

Miyainu

C (–) n=1

V (C) n=2

V (C) n=3

J (C r r) n=4

J (C r r) n=5

J ($C \cdot \mathring{C} \cdot \mathring{C}$) n=6

JD ($\cdot C \cdot \cdot \mathring{C} \cdot \mathring{C} \cdot$) n=7

D ($\cdot \cdot C \cdot r\, r \cdot \mathring{C}\, r\, \mathring{C}\, r$) n=11

Specimens from Wakayama and Mie have the following spiral formulae:

D ($r \cdot C \cdot r \cdot \mathring{C}\, r \cdot \mathring{C} \cdot r$); D ($r \cdot \cdot C \cdot r \cdot \mathring{C}\, r \cdot C \cdot r$); D ($\cdot r \cdot \mathring{C} \cdot r \cdot \mathring{C}\, r \cdot \mathring{C} \cdot r$);
D ($r \cdot \mathring{C} \cdot \mathring{r} \cdot \mathring{C} \cdot \mathring{r} \cdot \mathring{C} \cdot \mathring{r}$)

Distribtion: Kiba, Isobe-mura, Shima-gun, Mie Pref. (Furusato formation, Pleistocene, J). Akugawa, Nishitonda-mura, Nishimuro-gun, Wakayama Pref. (Akugawa Formation, Pleistocene, J.). Miyainu, Ishikawa Pref. (Pleistocene, J).

Turritella (Kurosioia) filiora Yokoyama, 1928

Pl. 1, Fig. 5, 9; Pl. 7, fig. 7.

1928 *Turriella filiora*, Yokoyama, Imp. Geol. Surv. Jap. Rep., No. 101, p. 57, pl. IV, fig. 7.

Original description:

"Shell small. Whorls about sixteen, flattish, receding near the sutures, spirally ridged. Ridges several, of which three are especially strong, equally distributed. Of the weaker ridges, the one above the uppermost main ridge and the one below the lowest may grow large and become prominent on the older whorls. Incremental line coarse, often making ridges appear tuberculate on crossing them. Aperture quardratic".

Additional Description: Spire rather convex, fairly high; whorl high; whorl flat with 3 predominant spirals C_1, C_2, C_3 and faint secondary spiral ribs. Growth line with small inclination angle, and narrow distally directed sinus.

Comparison: *T. fascialis* and its subspecies have higher spires and finer ornamentation than in the present species, but the apical angle of this species is larger than in *T. fascialis*. The spiral ribs of *T. kurosio* develop rapidly, and the profile of the adult whorl is C-type or D-type; the spire, however, is lower than that of *T. filiora.*

Distribution: Tombe, Sakuragi-mura, Ogasa-gun, Shizuoka Pref. (Nangō formation, upper Pliocene, H_2). Nishihigasa, Akimoto-mura, Kimitsu-gun, Chiba Pref. (upper Pliocene, H_2). Kaigara-zaka, Naganuma, Yokohama (Naganuma formation, Pleistocene, J).

Turritella (Kurosioia) neiensis, n. sp.

Pl. 1, Figs. 8, 9.

Holotype: G. S. J. No. KI-149.

Type loc.: Shimizu, Unohana-mura, Nei-gun, Toyama-Pref. (Kasio formation, Yatsuo Group, middle Miocene, F_2).

Description: Shell moderate in size, and thin. Pleural angle moderate, rather narrow. The younger whorls have a strong carinal primary spiral rib at the middle of the whorl; the whorl profile at this stage is V-type; the adolescent whorls have several faint secondary threads; the adult whorls have a more or less subcarinate spiral near the proximal suture. Suture shallow. Growth line of double arched type, Base flat. (see § 2, p. 40)

Distribution: Gobō, Unohana-mura, Nei-gun, Toyama Pref. (Kasio formation, Yatsuo Gronp, middle Miocene, F_2). Futamata, Asakawa-mura, Kahoku-gun, Ishikawa Pref. (Sunagozaka formation, Yokawa Group, middle Miocene, F_2). Ohara, Kiyose and Nishi-ichinose, Kanazawa City (ditto.)

Turritella (Kurosioia) fascialis fascialis Menke, 1828

Pl. 1, fig. 11.

1828 *Turritella fascialis*, C. T. Menke, Syn. Teth. Moll., 83.

1849 *Turritella fascialis*, Reeve, Conch. Icon., 13, pl. 10, fig. 47.

1886 *Turritella fascialis*, Tryon, Man. Conch., 8, p. 197, pl. 59, fig. 36, not 37.

Type Loc.: unknown.

Description by REEVE (1849):

" Turr. testâ lanceolato-acuminatâ, gracillimâ, anfractibus octodecim, convexis, exiliter quadriliratis, suturis subcontractis; lutescente, anfractum parte superiori rubido-fasciatâ."

Shell small, thin; spire slender and high, slightly obtuse; whorls short, slightly concave; three predominant spiral ribs. The nuclear whorls have a light yellow, semi-transparent smooth surface. The whorl profile of the second whorl is V-type; on the fourth whorl, C_1 removes to the proximall part and C_2 appears on the distal part; on the fifth whorl C_3 appears near the distal suture; when C_2 and C_3 develop gradually, the profile of the sixth whorl becomes J-type, but as C_3 develops the profile changes to D-type on the seventh whorl; the tenth whorl has several secondary spiral threads, $D(r_{01}\cdot C_1\cdot C_2\cdot\cdot C_3\cdot)n=15$

The growth line is of double arched type; the inclination angle is small, and somewhat skewed in the proximal direction, with moderate kurtosis; the maximum point of the antispirally directed sinus is on the second main rib C_2. The colour in the sutural parts is reddish brown, but in the middle part of the whorl it is light yellowish brown.

Distribution: Coast of Wakayama City, Wakayama Pref. (Recent) *T. fascialis gracillima* has a larger apical angle and pleural angle than the present species, and it also has yellowish sutural bands and indistinct ribs. *T. fascialis* has a grater ratio of H/D than that of any other member of *Kurosioia.*

Turritella (Kurosioia) fascialis gracillima Gould, 1846

Pl. 1, Fig. 10.

1846 *Turritella gracillima,* Gould, Otia Conchologica, pp. 140–141

1886 *Turritella fascialis,* Tryon. Man. Conch., 8, p. 197, fig. 37.

Original Description:

" T. parva, gracillima, acicularis, tenuis, dilute fulva, fascia pallida cincta; anfr. 18–20 convexiusculis, filis volventibus et antrorsum nonnullis minoribus sculptis; basi convexo, nitido: apertura circularis. Axis 20; diam 4 millim. Inhabits Kagoshima Bay. Very common."

The spire of this subspecies is smaller in size and has a larger apical angle than the typical form. The whorl suface is evenly convex (D-type). Surface is ornamentated with three broadly spaced spiral ribs and several faint threads:

$$D[r_{01}\cdot C_1\cdot r_{12}\cdot C_2\cdot r_{23}\cdot C_3\cdot\cdot]$$

In living specimens the sutural part is light yellow and the middle part of the whorls is white.

Comparison: Since 1886, *gracillima* has been regarded as a synonym of *fascialis,* but the writer believes the former must be distinguished from the latter, because GOULD's definition fully agrees with our specimens. *T. fascialis gracillima* is commonly found on the coast of western Japan, but *fascialis fascialis* is quite rare.

Distribution: Sagami Bay (Recent).

T. filiora is prominent in the Pliocene formations of Formosa and the Riukiu Islands, but in central Japan, it is found in the upper Pliocene or lower Pleistocene. *T. fascialis gracillima* is found Recent along the coast of Japan, but is not known as a fossil. The writer has developed the following phyletic series based on the value of H/D:

Species	H/D	Neogene				Quarternary
		F_2	F_3G	H_1	H_2I_1	I_2JK
fasc. fascialis	5.5–5.9					
fasc. gracillima	5.0±					
filiora	4.2–4.8					
kurosio	3.6–3.9					

Subgenus **Neohaustator** subgen. nov.

Type: *Turritella nipponica* Yokoyama

The growth line is of the double-arched type, and has a moderate positive inclination. The antispirally directed sinus is comparatively broad and moderate in depth. The spirally directed sinus is not exposed on the surface of the whorl. The first slender rib appears on the third volution somewhat proximal to the middle part of the whorl, and the second and third ribs successively appear on the distal part. Consequently the whorl profile in the young stage is J-type: J ($C_1r_2r_3$). The third rib (r_3) in the young stage of *T. nipponica* appears on the distal side of the second rib (r_2). The inclination angle is comparatively small (β=4–10°).

In *T. ikebei*, the first rib appears on the middle of the whorl, and the second rib (r_{01}) on the proximal side; on the next volution the third rib (r_2) appears on the distal side. The first rib is the most prominent. The whorl profile is C-type. Both these types of development lack the keel which is so conspicuous in the nepionic stage of *Kurosioia*.

The development of the sculpture in *Turritella saishuensis* Yok. is similar to that of *T. nipponica*, but the inclination angle of the growth lines (β=10°–20°) is larger. The species of this subgenus and their geological ranges are:

T. nipponica Yok. (Pliocene—Recent)

T. saishuensis Yok. (Pliocene)

T. andenensis Otuka (Pleistocene—Recent)

Neohaustator differs from the subgenus *Haustator* in the features of the nuclear whorl or younger whorls, although the character of the growth line is similar in both subgenera. The whorl profile of *T. imbricataria* Lam. in the young stage is flat, and ornamented by slender spiral ribs.

Turritella (Neohaustator) nipponica nipponica Yokoyama, 1920

pl. 5, Figs. 12, 13.

1920 *Turritella nipponica*, Yokoyama; Jour. Coll. Sci. Imp. Univ. Tokyo, Vol. 39, Art. 6, p. 71, pl. IV, Fig. 16, not 17–19.

Lectotype: Tokyo Univ. Coll. No. Kf-428a (YOKOYAMA (1920) Fig. 16) From YOKOYAMA's cotypes the writer selects the above mentioned lectotype.

Description:

Shell moderate in size, with conical spire; whorl J-type; distal half of whorl nearly flat. There are four spiral ribs, $(C_1C_2r_3r_4)$; r_3 and r_4 are slender, sharp, and closely spaced; C_1 and C_2 are sharp except on adult whorl, and more widely spaced, with indistinct threads.

The growth line is double arched; the antispirally directed sinus attains its maximum at the distal edge of C_2 and is fairly deep; distal part linear. The maximum point of the spirally directed sinus is not exposed on the outer whorl surface; the growth line curves in the direction of shell axis on the sutural furrow; Inclination angle about 6 degrees. Rib formula; $J[C_1C_2r_3r_4]$

Distribution:

The north-east cliff in Shiba, Yokohama. (Koshiba formation, Miura Group, Pleistocene, I. (Type locality). Gensukeda, Taneumura, Yamamoto-gun, Akita Pref. (?) (Pleistocene). The Pacific coast of Tōhoku and south Hokkaidō District (Recent). (see Fig. 17)

Variation: Samples from Akita have a rib formula of $J[C_1C_2r_{23}r_3]$ and are not typical but have the same value of θ.

Turritella (Neohaustator) nipponica nojimaensis, n. subsp.

Pl. 3, Figs. 2, 3, 4. Pl. 5, Fig. 6.

1920 *Turritella nipponica*, Yokoyama (part), Jour. Coll. Sci. Imp. Univ. Tokyo, Vol. 39, Art. 6, p. 71, Pl. IV, Fig. 17, (18?) not 16, 19.

Holotype: G.S.J. No. 24102001; Muronoki, Yokohama (Nojima formation, Pliocene)

Description: Differs from the typical form in the presence of several conspicuous secondary and tertiary ribs that are not visible on the surface of *T. nipponica nipponica*. The thick shell is a slightly convex conical spire; spire high. moderate in size; apical angle (θ) 19°. Whorl profile C-type in younger whorls, gradually changing to JC-type in adult whorls. The proximal half of the whorls is swollen. The shape of growth line is similar to that of the typical form, but the inclination angles β of the subspecies is greater. (8.4°*)

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* See § 1, (1, 10) p. 20.

Spiral rib formula of holotype: $(-)n=1, 2$

$(C_1)n=3$

$(C_1C_2)n=4$

$(C_1C_2r_3)n=5, 6, 7$

$(C_1C_2r_3r_4)n=8$

$(C_1C_2r_{23}r_3r_4)n=9, 10$

$(C_1C_2r_{23}r_3r_4r_{45})n=11, 12, 13$

$(\cdot\cdot C_1\cdot C_2r_{23}r_3r_4r_{45}\cdot)n=14$

Comparison: The subspecies can be distinguished from *nipponica* (s. s.) on the characters of the adolescent or adult whorls, but not from the younger whorls, because secondary spirals appear on the adolescent whorl. The primay spiral ribs are well developed even on the adult whorls.

Variation: In some specimens the spire is conical and the whorl profile is often J-type. Secondary spirals may be developed as follws: J (r C r C r r r r), JC (·C·C r r r), JC (C C r r r)

Turritella (Neohaustator) nipponica miyata, n. subsp.

Pl. 2, fig. 1; pl. 3, fig. 1; pl. 5, fig. 5

1920 *Turritella nipponica*, Yokoyama (part). Jour. Coll. Sci. Imp. Univ. Tokyo, Vol. 39, Art. 6, p. 71, pl. IV, fig. 19. (Univ. Tokyo Coll. No. Kf. 425a)

Holotype: G.S.J. Palaeont. No. KI. 221022-1. Loc. 8, (by Suzuki, 1932) Kamimiyata, Minami-shimoura-mura, Miura-gun, Kanagawa Pref. Pliocene.

Description: Shell moderate in size; spire conical high; apical anglesmall; whorls slightly swollen; whorl profile J-type in younger and adolescent whorls, gradually changing to JC-type in adult whorls. Four spiral ribs with interspaces broader than the breadth of the ribs. Sutural furrow deep and broad. Growth-line of double arched type; sinus deep; inclination angle small. Aperture subquadrate.

Comparison: The growth-line inclination angle of this subspecies is smaller than that of *T. nipponica* (s. s.).

Variation: Fine secondary threads often appear.

Distribution: South Kantō, (Miura Group, Pliocene) (see Fig. 17, 18). Tayazawa, Wakimoto-mura, Minamiakita-gun, Akita Pref. (Shibikawa formation, upper Pliocene).

Turritella (Neohaustator) nipponica chikagawaensis Hatai & Kotaka, 1950

1950 *Turritella nipponica chikagawaensis*, K. Hatai & T. Kotaka. Jour. Geol. Soc. Japan, Vol. LVI, No. 654, p. 103.

Hatai and Kotaka record that the apical angle is 14 degrees; this value is much smaller than in typical *nipponica* (18 degrees). The value of the relative height of the spire (H/D) is greater than 3.6 which is larger than that of *nipponica miyata*. The ornamentation resembles closely that of the typical form.

Turritella (Neohaustator) nipponica mitsunashii, n. subsp.

Pl. 6, Fig. 3, Pl. 7, Fig. 9.

Holotype: G.S.J. Pal. No. KI-5161220. River bank of Minato-gawa, Seki, Tamaki-mura, Kimitsu-gun, Chiba Pref. NWW 1km from a bench-mark 199.2m in height. (Miura Group, Pliocene)

Description:

Shell moderate in size, high-turreted, conical, eight whorls preserved; whorl profile fairly convex and of JC-type. Surface with four flat-topped, narrowly spaced, spiral cords. The value of h/d is small. Fine interstitial or accessory striae appear on the adolescent whorls. Growth line double arched, with moderately broad antispirally directed sinus; curved in the axial direction on the proximal part of the whorl; inclination angle moderate, skewed distally. The spirally directed sinus is broad and has its maximum at the proximal suture.

Variation: The whorl profile may be C or JC-type. The primary spirals are constant, but the development of the secondary spiral is variable.

Holotype	J (CCrr) d=2.5 mm	Paratype	JC (CCrr) d=5.0 mm
No. 5161220	J (CCrr)	No. 5161216	JC (CCCC)
	J (CCrr)		C (C·C·CC)
	J (CCrr)		C (C·CrCC)
	JC (CCrr)		C (C·CrCC)
	JC (CCrr)		C (CrCrCC) d=11.2 mm
	JC (CCCC)		
	JC (CCCC)		
	JC (·CCC·C·) d=8.5 mm		

Comparison: Differs from *T. nipponica nipponica* in the character of secondary ribs, the narrow grooves, flat-topped cords, whorl height, whorl profile, and the value of β.

Turritella (Neohaustator) saishuensis Yokoyama, 1923

Pl. 6, Fig. 1, 4, 6.

1923 *Turritella saishuensis*, Yokoyama. Jour. Col. Sci. Imp. Univ. Tokyo, Vol. XLIV, Art. 7, p. 3, pl. 1, fig. 2.

Original Description:

"Shell turrete. Whorls numerous, somewhat convex, weakly angulate a little above the suture, three-ridged. Ridges elevated, more or less sharp on the younger whorls, and flattened on the older; the lowest occupies the angle and is the largest, the middle is nearly as large and in the middle of the whorl, while the upper is the weakest of all and somewhat more distant from the middle one than the middle one is from the lower. There is also a fourth ridge close to the lower suture which, though usually small and inconspicuous, is on the body-whorl nearly as large as the others and forms the angulate periphery. The spaces between the ridges are usually provided with a few unequal spiral striae. Base flattened, with about two spiral ridges near the periphery and diminishing in size toward the caudal end. Spiral striae also present not only between the ridges, but also beyond the last one. Aperture roundly subquadrate. Outer lip thin, sinuous, with a broad and shallow notch below the suture. They are only a few specimens, all lacking the apex. The entire number of the whorls may be about eighteen. Apical angle about 18."

The inclination angle of the growth line is small, narrow and fairly deep.

Distribution: Saishu Island (Type), Shimane, Ishikawa, Niigata, Nagano, Yamagata, Akita, Aomori and Hokkaidō. (Pliocene)

Turritella (Neohaustator) saishuensis motidukii Otuka, 1935

1935 *Turritella fortilirata motidukii*, Otuka, Jour. Geol. Soc. Japan, Vol. 42, No. 503, p. 508.

1935 *Turritella fortilirata motidukii*, Otuka, Bull. Earthq. Res. Inst., Vol. XIII, Part 4, p. 856, pl. LIV, Fig. 53.

Original Description: "Specimens of *T. saishuensis* Yok. which have no interstitial striae between the main cords, are named "*motidukii*". Whorls a little less than 1 cm in diameter, have only 3 distinct spiral ribs". (translated from Japanese)

Turritella (Neohaustator) saishuensis etigoensis Ikebe, 1940

Pl. 6, Figs. 2, 7; Pl. 7, Fig. 4.

1940 *Turritella saishuensis etigoensis*, N. Ikebe, Jour. Jap. Ass. Petroleum Tech., Vol. 8, No. 5, p. 367.

1940 *Turritella saishuensis etigoensis*, N. Ikebe, ditto., Vol. 8, No. 5, p. 339.

1940 *Turritella saishuensis etigoensis*, N. Ikebe, ditto., Vol. 9, No. 2, p. 178.

Neotype: G.S.J. No. KI-25092. Ogi, Nishikoshi-mura, Santō-gun, Niigata Pref. (Kamiogi fossil zone, Funabashi sand, Chuetsu Group, upper Pliocene).

Original Description:

" Secondary or tertiary spirals are present between the three primary spirals of *T. saishuensis*. It seems that this is a conspicuously differentiated form." (translated from Japanese)

Spiral rib formula of the neotype: C (−) n=1

C (−) n=2

J (r_1) n=3

J ($r_1 r_2 r_3$) n=4

J ($C_1 C_2 r_3$) n=5

J ($C_1 C_2 C_3$) n=6

J ($C_1 C_2 C_3$) n=7

$$JD\ (\cdot\cdot C_1\cdot\cdot\cdot C_2\cdot\cdot\cdot C_3\cdot\cdot\cdot)\ n=10$$

$$CD\ (\cdot\cdot\cdot\cdot\cdot\ddot{C}_1\cdot\cdot\cdot\cdot\cdot\ddot{C}_2\cdot\cdot\cdot\cdot\cdot\ddot{C}_3\cdot r_{34}\cdot\cdot)\ n=18$$

The difference between the typical form of the species and the two subspecies lies chiefly in the fine ornamentation which is an uncertain character in the fossils because the surface of the fossil shell is often defaced and the threads are not distinguishable. *T. saishuensis hanzawai**, the subspecies proposed by K. HATAI & T. KOTAKA (1950), is questionable, because the variation in individuals was not described.

Turritella (Neohaustator) andenensis Otuka, 1934

1926 *Turritella kiiensis*, Yokoyama, Jour. Fac. Sci. Imp. Univ. Tokyo, Sec. II, Vol. 1, pt. 9, p. 379.

1934 *Turritella andenensis*, Otuka, Earthq. Res. Inst., Vol. XII, Part 3, pl. LI, Figs. 113, 100.

Original Description:

Shell high turreted, consisting of many whorl (19 in the type specimens) which consist of two more or less flat surfaces, making a spiral keel. The keel is always on the lower third of the whorls. Surface of the upper two third ornamented with fine unequal threads, coarse ones of which there are about 8 alternating with finer ones on the penultimate, and ultimate whorl. Spiral sculpture are broaded on the subsutral area and the keel. Finer spiral sculptures are supurimposed on the broad sculptures. The lower third of the surface ornamented with two coarse spiral threads with secondary and tertiary finer spiral threads.

Aperture sub-ovoidal, upper end of the aperture angurate. Lower part of the outer margin of the aperture produced foreward."

Sample No. 2466-2 (Recent)

Loc.: Off the west coast of Tsushima (Sōyo-maru, Loc. 462)

Description:

Nuclear whorl convex, profile smooth. The second whorl has an angulation on its proximal part. The third whorl has three ribs, and the later whorls have the following rib formulae:

$$J\ (C_1\, r_2\, r_3)\ n=3$$

$$J\ (C_1\, C_2\, C_3)\ n=5$$

$$J\ (r_{01}\, C_1\, r_{12}\, C_2\, r_{23}\, C_3\, r_{34})\ n=10$$

$$J\ (r_{01}\, \ddot{C}_1\, r_{12}\, \ddot{C}_2\, r_{23}\, \ddot{C}_3\, r_{34})\ n=12$$

In later stages the main ribs diverge into two or three threads.

$$J\ (r_{001}\, r_{01}\, r_1\, r_1\, r_1\, r_{12}\, r_2\, r_2\, r_{23}\, r_3\, r_3\, r_3\, r_{34})\ n=14$$

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* Hatai & Kotaka, Jour. Geol. Soc. Jap. Vol. LVI No. 654, p. 104, Fig. 4. (1950)

The adult whorls also have a lot of fine spiral threads. Colour of the shell white; outer lip thin.

Turritella (Neohaustator) andenensis ogasimaensis Otuka, 1947

1947 *Turritella andenensis ogasimaensis*, Otuka, Shizenkenkyū, Vol. 2, No. 6-7, p. 7.

1951 *Turritella otukai*, Kotaka, Saito Ho-on Kai Mus. Res. Bull., No. 21, p. 7, Pl. 1, Figs. 8-15, 22.

Original Description:

"This subspecies differs from the species in the presence of four or five conspicuous main ribs and the roundish whorl." (translated from Japanese)

Turritella binaestriata Kuroda (MS)

Pl. 4, Fig. 5, 6

1934 *Turritella* sp. (cf. *perterebra* Yok. var.), Kinoshita & Isahaya, Hokkaido Fisher. Exper. Stat. Res. Rep., No. 33, p. 6, pl. 3, fig. 21.

1951 *Turritella andenensis*, Kotaka, Short Papers Inst. Geol. Pal. Tohoku Univ., No. 3, pl. II, figs. 5, 6.

Sample No. 2475, Loc.: Off the coast of Tango, Kyoto Pref. (Recent.)

Description:

Shell moderate in size; colour orange. The younger whorls have three ribs: $J(C_1C_2r_3)n=4$; the adolescent whorls have the rib formula: $J(C_1C_2r_{23}r_3)n=5$, $J(r_{01}C_1r_{12}C_2r_{23}r_3r_{34})$, and the adult whorls are: $C(\cdot r_{01}\cdot C_1\cdot r_{12}\cdot C_2r_{23}\cdot r_3\cdot r_{34}\cdot)$ The growth line has a shallow, distally directed, symmetrical sinus; inclination angle small; linear between sinus and the maximum point. Operculum round, multispiral, concentric.

Comparison: The sinus in the growth line of typical *T. andenensis* is moderate in depth, but that of the present species is shallow. The main ribs do not diverge.

Turritella fortilirata Sowerby, 1914

Pl. 4, Fig. 1.

1914 *Turritella fortilirata* Sowerby. Ann. Mag. Nat. Hist., Ser. 8, Vol. XIV., p. 36, pl. II, fig. 12.

Original Description:

"Testa turrita, ferruginea, versus apicem albida; anfractus 13, declives, vix convexi, infra angulati, liris 4 spiralibus crassiusculis cingulati; anfractus ultimus 1/4 longitudinus testae aequanus, infra biangulatus; basis leviter convaxa, unilirata; apertura subquadrata; peristoma tenue; columella leviter arcuata, angusta. Long. 78, maj. diam. 22 mm."

Sample No. 26241

Description:

Shell large, with slightly convex conical spire; spire high, apical angle 15°, pleural angle 11°. J-type whorl profile in adolescent stage, JC-type in body whorl; sutural furrow broad. In the early stages C_1 and C_2 are conspicuous and sharp; on the adolescent whorls r_3 and r_4 appear; on the adult whorls r_5 appears on the distal part. The body whorl has the spiral rib formula; $J(r_{01}C_1 \cdot C_2 \cdot r_3r_4r_5)$. On the adult and adolescent whorls C_1 C_2 and r_3 become rounded and C_1 and C_2 are prominent even on the penultimate whorl and the body whorl. Outer lip thin. Base evenly convex. The growth-line is characterized by its large inclination angle. (β: 19–22°); the sinus is inclined in distally.

Variation: The primary spiral themselves are constant, but their thickness is variable. The appearance of the secondary spirals is variable. The surface of the shell is often defaced and the features of the ornamentation and growth-line become obscure.

Distribution: Nemuro, Hokkaido (Type locality, Recent); Japan Sea (Recent).

Comparison:

T. nipponica differs from the present species by the size of the spire, the value of β, and the shape of the growth-line.

Turritella fortilirata tibana Nomura, 1940

pl. 5, Fig. 8.

1940 *Turritella (Haustator) tibana,* Nomura, Rec. Oceanographic Warks Jap., Vol. XII, No. I, p. 105, Pl. 1, Fig. 12.

Orginal Description:

"Shell resembling Turritella (Haustator) nipponica Yokoyama from the Pliocene and Pleistocene of Kwanto region but the ribs are less prominent and bipartite upon aged whorl. The whorls are proportionally narrower, or in other wards they are more slowly enlarging. The ribs are five in each lower whorl, the upper two close to upper suture and smaller than the others."

Turritella huziokai, n. n.

Pl. 4, Fig. 2, 3, 4

1951 *Turritella fortilirata multilirata,* Kotaka, Short Papers Inst. Geol. Pal. Tohoku Univ., No. 3, pp. 71–80. pl. II, figs. 3, 4.

Turritella fortilirata multilirata is preoccupied by ADAMS & REEVE, 1849. Moll. Voyage of Samarang. *Turretella multilirata,* fig. 54.

Holotype: G. S. J. Palaeont. No. KI-2624-10. Off the coast of Erimo-zaki, Hokkaido. (Recent)

Description:

Shell large, thick and heavy; apical angle large. Whorl high, flat in the middle, with four main spirals and indistinct interstitial threads: $HJ[C_1 \cdot C_2C_3 \cdot C_4r_{45}]$ Ribs spaced broadly, not prominent, roundish. Growth-line double-arched with fairly small inclination angle; sinus moderately deep, with maximum point generally somewhat above C_3. Colour of shell light brown. Operculum dark brown in colour, round, concentric, with thin multispiral ornamentation.

Comparison :

Differs from *T. fortilirata* in the large apical angle, the low spiral ribs, and the small inclination angle of the growth-line.

Variation : The paratypes (10 individuals) show the following variations : the variation of the apical angle and height of whorl is described elsewhere in this paper. The thickness of the outer lip is variable ; the whorl profile varies from HJ to JD, and the secondary ribs, r_2r_{23} and r_{34}, rarely appear.

Turritella oyasio, n. sp.

Pl. 7, Fig. 6

Holotype : Kyōto Univ. Geol. Coll. No. TK 303-JC 512065. Mokugahara, Nishi-tonami-gun, Toyama Pref. (Otokawa Group, upper Miocene, F_3G)

Description : Shell large, high, sharp subconical ; whorl profile C-type, moderately convex ; sutures deep. The adolescent whorls have the rib formula : $C(C_1C_2C_3C_4)$, and the angular ribs, C_1 C_2 and C_3 are prominent and heavy ; the rib formula for the adult whorls is $C(\cdot C_1 \cdot C_2 \cdot C_3C_4)$; the interspaces between the main spiral ribs are broader than the thickness of the ribs except for C_3 and C_4 which are close together. Growth-line of double-arched type, with sinus of moderate depth ; inclination angle 10°–12° (mean 11.5°), skewed distally.

Comparison : Differs from *T. fortilirata* in the large inclination angle of the growth-line trace, and the rounded whorl profile.

Distribution : Fujiwara form. Nara Pref. (upper Miocene)

Turritella ikebei Kotaka, 1951

Pl. 3, Figs. 5, 6, 8 ; Pl. 7, Fig. 3.

1938 *Turritella (Haustator)* sp., Otuka, Venus, Vol. VIII, No. 1, p. 39, p. 43, fig. 3.

1951 *Turritella ikebei*, Kotaka, Short Papers I.G.P.S., No. 3, p. 86, Pl. 11, Figs. 12, 13 ; Pl. 12, Figs. 11, 12.

Sample : No. KI–221129–3.

Loc. : Tambara, Makuda-mura, Kimitsu-gun, Chiba Pref. Reg. No. 521. 288 Loc. 1.

Fossil Zone : The 3rd Jizodō Fossil Zone. (according to Sakakura, 1935)

Description : Shell of medium size ; spire conical ; pleural angle small and approximately equal to apical angle (θ : ca. 14°). Whorl high ; whorl profile convex. The third whorl has a faint carina in the middle ; the next whorl has a rib in the proximal part, and two weak ribs are visible near both sutures ; the adult whorls have five flat cords similar in character ; the interspaces between the cords are wider than the breadth of the cords. Growth-line of double-arched type, with deep sinus ; inclination angle is 5°—6°.

Comparison : All forms of *T. nipponica* Yokoyama, except the subspecies *T.*

nipponica chikagawaensis Hat. & Kot., differ from this form in having a large apical angle, strong cords and an angulated whorl profile. Also the early sculpture of *T. nipponica* differs in that the 2nd and 3rd spiral ribs are on the distal side of the primary rib; this character influences the whorl profiles. The growthline inclination of *T. fortilirata* is about 20 degrees, which is larger than that of the present species.

Distribution: Ōyatsu, Nishiyatsu and Sasage, Chiba Pref. (Miura Group, lower Pleistocene). Nobaguchi, Yokohama City (Nakazato formation Miura Group, Plio-pleistocene, I). Kakio (Point M), Kanagawa Pref. (Kakio formation, Miura Group, Plio-pleistocene, I).

Turritella tokunagai Yokoyama, 1924

1924 *Turritella tokunagai* Yokoyama. Jour. Coll. Sci. Imp. Univ. Tokyo, Vol. XLV, Art. 3, p. 10, pl. 1, figs. 8, 9, 10.

1934 *Turritella tokunagai* Makiyama. Mem. Coll. Sci. Kyoto Imp. Univ., Ser. B, Vol. 10, 2, 6, p. 160.

Original Description:

"The shell is medium sized and many whorled. The whorls number a little over ten in number, are convex and spirally ridged. The ridges are five in number, of which the uppermost and the lowest are situated close to their respectice sutures. Of the three remaining ridges, the middle is the strongest and greatest. These ridges are in some specimens sharp and much narrower than their interstics, while in the others more flattened and broader, a character probably due to weathering. The apical angle is about 20 degree."

Description: Shell small, conical; profile of adult whorl is C-type with strong broadly spaced cords. The spiral rib formula is C [$C_1\,C_2\,r_{23}\,C_3\,C_4$].

Growth-line of double-arched type, with sinus of moderate depth; the spirally directed sinus is not exposed on the outer whorl surface; inclination angle small.

Distribution: Jōban Coal Field (Asagai formation, Lower Miocene, E) Ishikari, Hokkaido (Poronai formation, Lower Miocene, E) Karafuto.

Turritella chichibuensis, n. sp.

Pl. 2, fig. 6; Pl. 5, fig. 1.

Holotype: G.S.J. Paleont. No. KI-95. River cliff of Arakawa at Tatsugase, Yorii-machi, Saitama Pref. (Miocene)

Description: Shell small, concave conical; whorl profile C-type, moderately convex. The younger whorls have two ribs in the middle part, C ($C_1\,C_2$); adolescent whorls have the rib fomula, C ($C_1\,C_2\,C_3\,C_4$); in the adult whorls distinct secondary spiral ribs are developed, and the primary ribs are strong and flattened: C ($r_{01}\,C_1\,r_{12}\,C_2\,r_{23}\,C_3\,C_4$). Growth-line of double arched type with small inclination angle; the maximum of the spirally directed sinus in the proximal part is not exposed on the outer whorl surface.

Variation: Secondary spiral ribs appear on the adolescent and the adult whorls. The interstitial spaces are usually broader than the ribs, but occasionally their width is about the same.

Comparison: Differs from *T. nipponica* in its small apical angls, high spire, and the presence of secondary spirals. *T. tokunagai* resembles this species in having four strong ribs, but it does not have the prominent secondary spirals, and the apical angle is considerably greater than that of the present species. The rib formula of *T. chichibuensis*, C [r C_1 r C_2 r C_3 C_4], differs from that of *T. kadonosawaensis*, J [C_1 C_2 r_3 r_4 r_5].

Distribution: Nenokami, Takinoue, Yoshida-machi, Chichibu-gun, Saitama Pref. (Akahira formation, lower Miocene.)

Moriya, Nagano Pref. (Moriya formation, lower Miocene)

Species group of T. tanaguraensis Kot.

The growth line is of the double-arched type, and has a moderate inclination ($\beta=10^\circ\pm$); the whorl profile in the younger stage is V-type; at this stage, the whorl has a pair of strong primary ribs which are close to each other in the middle part of the whorl; V (C_1C_2). On the adolescent whorls, several interstitial secondary ribs begin to appear, and the primary pair moves toward the anterior part of the whorl. MERRIAM called this ontogenetic process "bicostate".

The members of this group and their geological ranges are:

T. tanaguraensis Kotaka	(Miocene)
T. kadonosawaensis Otuka	(Miocene)
T. kadonosawaensis yosidai Kotaka	(Miocene)
T. kadonosawaensis tsudai n. subsp.	(Miocene)
T. s-hataii Nomura	(Miocene)

Turritella kadonosawaensis Otuka, 1934

1934 *Turritella kadonosawaensis* Otuka. Earthq. Res. Inst., Vol. XII, Part 3, Pl. LI, Fig. 104.

1937 *Turritella fortilirata kadonosawaensis* Otuka. Jour. Geol., Vol. 44, p. 163.

Original Description:

"The upper half of the surface sculpture of a whorl in the specimens collected from the Kadonosawa series is flat and slopes steeply, with 3 (or 4) narrow spiral threads; the lower half is ventricosa, with 2 strong flat topped spirals the interspace of which are ornamented with fine spirals."

The type specimen of this species (Tokyo Univ., No. 1533) is deformed, but has the following general rib formula: J [C C r r r]. The formulae for several whorls are:

(C·C·r r·)
(C·C·r r·)
(C·C r r r·)
(·C·C r r r·)

Distribution: Kadonosawa Nidatori, Iwate Pref. (upper Kadonosawa Group, middle Miocene, F_2), Togari, Akiyo-mura, Toki-gun, Gifu Pref. (Mizunami Group, middle Miocene, F_2). Senjyōjiki, Hamada, Shimane Pref. (middle Miocene, F_2).

Turritella kadonosawaensis yoshidai Kotaka, 1951

Pl. 4, Fig. 8.

1951 *Turritella yoshidai* Kotaka, Short Papers Inst. Geol. Pal. Tohoku Univ., No. 3, p. 87, pl. 12, fig. 10.

Description: Shell thin, moderate in size, with conical; apical angle small; whorl profile JC-type; upper half of whorls is flat; suture shallow. In the younger whorls, 2 strong ribs apper on the proximal part; on the distal part of the adolescent whorls two faint ribs appear: JC [$C_1 C_2 r_3 r_4$]; on the adult whorls interstitial and closely spaced ribs apper. Growth-line of the double-arched type; the maximum point of the antispirally directed sinus is at the point of C_2; curvature small.

Variation: The variation in the rib ornamentation is as follows:

(·C·C·r r··)	frequency 17%
(·C·C·r r·)	75%
(·C·C r r·)	8%

In general the spiral ribs are rounded, but often they become angular or flattened.

Distribution: South Toyama (Yatsuo Group middle Miocene F_2) (see Fig. 19, Table 2)

Turritella kadonosawaensis tsudai, n. subsp.

Pl. 2, Fig. 7; Pl. 4, Fig. 7.

Holotype: G.S.J. palaeont. No. KI-24511. Futamata, Asakawa-mura, Kahoku-gun, Ishikawa Pref. (Reg. No. 521. 43, Loc. 51). Sunagozaka formation, Yokawa Group, (Ikebe, 1948), Miocene.

Description:

Shell moderate in size, with concave conical spire, and with more than ten whorls; the diameter of the whorls increases gradually in the early stages and the apical angle is less than the pleural angle. Sutures abutting, comparatively deep. The early whorls have two prominent cords in the proximal area and four weak ribs in the distal area; the profile of adolescent whorls is inflated, but not angular, and there are two interstitial threads; on the adult whorls, the eight cords are equally developed, and the interstitial spaces are very narrow. Base flat. Growth-line of double arched type; inclination angle about 10 degrees.

Variation: Accoding to the writer's observation of 35 paratypes, the ornamentation shows very little variation. In some specimens the proximal half of the whorl is swollen, even in the adult whorls. The apical angle is fairly constant.

Turritella tanaguraensis Kotaka, 1951

Pl. 2, Figs. 4, 5, Pl. 5, Fig. 4.

1931 *Turritella* sp. Yokoyama. Jour. Fac. Sci. Imp. Univ. Tokyo, Sec. II, Vol. 3, Pt. 4, p. 201, Pl. 12, fig. 4.

1936 *Turritella kadonosawaensis* Nomura & Hatai. Saito Ho-Onkai Mus. Res. Bull. No. 10, p. 143, Pl. XVI, figs. 1, 2.

1938 *Turritella kadonosawaensis* Oinomikado. Trans. Palaeont. Soc. Jap., No. 69, p. 88.

1950 *Turritella yokoyamai* Ida (MS) K. Huzita & S. Ogose, Jour. Geol. Soc. Jap., Vol. LVI, No. 662, p. 489.

1951 *Turritella tanaguraensis* Kotaka. Saito Ho-Onkai Mus. Res. Bull., No. 21, p. 10, pl. 1, Figs. 16, 17.

Description:

Shell moderate in size, with conical spire, and flat base; the apical angle is small, and equal to the pleural angle. In the early whorls, a strong carina is developed in the middle of the whorl, and another carina appears distal to it; the adult whorls have faint striae in the proximal part, one in the middle, and four in the distal area. The whorl profile is angular in the middle and concave distally. Growth-line of double arched type, with a fairly deep sinus; the point of inflextion at the distal end cannot be seen; the growth line inclination is moderate.

Distribution: Tanagura, Higashi-shirakawa-gun, Fukushima Pref. (Tanagura Group, Miocene). The river bed of Usui-gawa, Annaka-machi, Gumma Pref. (Annaka formation, Usui Group, Miocene) Matsuyama, Saitama Pref. (Miocene). Togari, Akiyo-mura, Toki-gun, Gifu Pref. (Mizunami Group, Miocene).

Variation: Specimens of *T. tanaguraensis* from Matsuyama have a conspicuous substural band.

Comparison:

T. kadonosawaensis Otuka resembles *T. tanaguraensis,* but the distal secondary spiral ribs are strong and a few threads are developed, *T.* (*Eichwaldiella*) *bicarinata* Eich., a European species, is a bicarinate form, but it has a large apical angle, and the sinus is shallower than that of the present species.

Turritella s-hataii Nomura, 1935

1934 *Turritella matsumotoi* Makiyama (MS), Ikebe, Globe Vol. XXII, No. 2, p. 110.

1935 *Turritella s-hatai* Nomura, Saito Ho-Onkai Mus. Res. Bull., No. 6, p. 231, pl. XVII (II), figs. 19–21.

1938 *Turritella* (*Haustator*) *s-hataii* Nomura, Otuka, Venus, VIII, No. 1, p. 41, pl. 21.

Holotype: Tohoku Univ. No. 2551. NE Higashi-shiogama, Miyagi Pref. (Shiogama formation Miocene).

Original description:

"Shell moderate in size, high-turrete, slender consisting of about twelve (or more?) whorls which are nearly flat or a little convex around the middle. Surface sculpture consists of five, more or less prominent, rather rounded spiral cord which are nearly equal in size upon the whorl, and unequal upon the lower ones; in the latter case the middle three are larger than the other and the lowest borders the suture, the next one above it forms a feeble angle of whorl; each interspace of the lower whorls provided with a single (rarely two) interstitial thread; entire surface also sculptured with rather coarse lines of growth, espertialy more distinct in the interspace than on the top of cords. Aperture unknown."

Samples from Togari, Gifu Pref. have the following features: Spire conical, whorl profile in adolescent whorl is J–type; the ribs C_1 C_2 are flattened; in the early stage the rib formula is J $(\cdot C_1 \cdot C_2 \cdot r_3 r_4 r_5)$. On the later adolescent whorls, the whorl profile changes into J C–type:

$$JC\,(r_{01}\,C_1\,r_{12}\,C_2\,r_{23}\,r_3\,r_4\,r_5\,r_6)$$

The tops of the ribs are sharp and the interstitial spaces are narrow. The adult whorls have tertiary spirals and divergent main ribs:

$$C\,(\cdot\cdot r \cdot \ddot{C} \cdot r \cdot \ddot{C} \cdot r \cdot r \cdot r \cdot r \cdot);\quad C\,(\cdot r \cdot \ddot{C} \cdot r \cdot C \cdot r \cdot r \cdot r\, r).$$

Growth-line of double arched type; inclination angle is 14°; the depth of the antispirally directed sinus is moderate, and the spirally directed sinus is on the proximal suture.

Variation:

The spiral ribs are constant in the early stages, but remarkable variations appear on the adult whorls in the form of the tertiary spiral ribs, the divergence of the main ribs, and the degree of development of the main ribs.

Distribution: Iwaizawa, Yokote, Akita Pref. (Sugoda formation, Miocene). Togari, Gifu Pref. (Mizunami Group, Miocene). Isshi, Mie Pref. (Awa Group, Miocene). Okuyamada, Kyoto Pref. (Tsuzuki Group, Miocene) Mizushina, Kusano-mura, Fukushima Pref. (Hon'ya formation, Miocene) Amakata, Shizuoka Pref. (Kurami formation, Miocene) Ishikari and Teshio, Hokkaido (Miocene)

Comparison: The rib formulae for this and related species are:

kadonosawaensis	J [C C r r r]
kad. yoshidai	J C [C C·r r·]
kad. tsudai	C [r C r C C C r r]
s-hataii	J C [r C r C r r r r]

These four forms are somewhat similar, but the following differences are notable: The whorl profile of the younger whorls of *s-hataii* is J-type, and in the adult whorls it is JC-type, but in *tsudai* is always C-type. The spire of *kadonosawa-*

ensis (s.l.) is concave conical and is small or moderate in size, whereas *s-hataii* has a large conical spire. The ornamentation of *s-hataii* is strongly differentiated and it has secondary or tertiary ribs even on the adolescent whorls; the main ribs diverge on the adult whorls which develop six main ribs: (C C r r r r).

Turritella omurai Kanehara, 1937

1937 *Turritella omurai* Kanehara, Bull. Imp. Geol. Surv., Vol. XXVII, No. 1, p. 9, pl. IV, figs. 5, 6, 7.

Original description:

"Shell rather large for the genus, high turreted, with many whorls (six preserved on some paratypes), apical angle 15 degree and more. Whorls moderately rounted separated by distinct, linear and depressed suture. Periphery continuous and rounded. Sculpture consist of nine unequal principal cords and four or more finer alternating ones. Of the principal cords, the fourth, fifth, seventh and ninth from top the strongest; the first, second, third sixth and eighth of medium strength. Finer superimposed on the broad sculptures. Basal disk well defined by sutural (ninth) cords; on it, near its margin, is low but wide cord. Growth-line close and fine and Haustator like."

"Turritella" importuna Yokoyama

Pl. 5, Figs. 2, 3.

1924 *Turritella importuna* Yokoyama. Jour. Coll. Imp. Univ. Tokyo, Vol. XLV, Art. 3, p. 10, pl. 1, figs. 6, 7.

The writer found an interesting specimen from the Jōban Coal Field (No. 126; Loc. 4007, Koyamada, Okumura, Futaba-gun, Fukushima Pref.).

Description: Four whorls are preserved; apical angle large (ca. 25°); h/d extremely small; five flattened spiral ribs with narrow interstitial spaces: J C (r C C C r). Growth line of single arched type, with shallow sinus, not skewed. The aperture is ovate, and the axis is not like that of *Turritella*.

This specimen is similar to one of the cotypes, and the writer therefore thinks that the cotypes may include a different species, in spite of the fact that the growth-line described by J. Makiyama is of the double-arched type.

Turritella iwakiensis Kotaka, 1951

1951 *Turritella iwakiensis* Kotaka. Saito Ho-on Kai Mus. Res. Bull., No. 21, p. 11, Pl. 1, Figs. 19-21.

Original description:

"Shell moderate in size, turretted consisting of about twelve whorls (nine preserved in plastoholotype). Whorl profile evenly and shallowly convex, the maximum convexity at lower part of whorl. Surface with five flat-topped spiral cords and three fine interstital striae, lowest supersutural and very fine except on body whorl. Five spiral cords occur on early stages of juvenile spire, first round topped and subequal in breadth, and broader than spiral cords as shell grows. Fine striae begin to occur in interspaces of adolescent grows stage between second and third cords from top, upper suture and top cord, and top and second cord in turn. Interspaces between fourth and fifth cords is broadest of all and deeply excavated, and others subequal in breadth. Growth line indistinct but sinus Aperture not preserved."

Family Mathildidae
Genus *Mathilda* Semper, 1865
Type: *Mathilda quadricarinata* (Brocchi)

Mathilda totomiensis (Makiyama), 1927

Pl. 3, Fig. 8.

1927 *Turritella totomiensis* Makiyama. Mem. Coll. Sci. Kyoto Imp. Univ. Ser. B., Vol. III, No. 1, p. 69, pl. III, fig. 9.

Topotype No. KI–251019

Differs from *Turritella* in having no sinus and in the existence of axial notches in the interstitial spaces. The growth line, inclined from the shell axis, is linear.

Distribution: Dainichi, Ugari-mura, Suchi-gun, Shizuoka Pref. (Dainichi formation, Kakegawa Group, lower Pliocene, H_1)

Submitted June 25, 1952

本邦産キリガヒダマシ属の研究*

伊　田　一　善

要　旨

日本の新生代殊に新第三系以降の地層に産するキリガヒダマシ属について分類を行う上に重視すべき殻の構成要素を比較検討した。

そのうち頂角，螺塔の比高は一部の形式のものについてのみ分類の基準となる。たゞしこれらが幼殻と成殻とで変る変り方は1つの要素としてとつてよい。螺脈は最も変異の現れ易い要素である。その扱い方如何で分類の混乱が生ずる危険がある。螺層の比高はかなり有効である。幼層の螺脈の発達形式は大区分に適している事は言うまでもない。生長線が單弧状であるか複弧状であるかは亜属の差を示すものと見る。生長線の傾き，深さ，歪み螺脈と螺層の傾きは小区分の分類に有効である。

これらにもとづいて日本産のキリガヒダマシ属の 30 余の種・亜種を3亜属・1種群にまとめた。

次に現生種に関する生態学的知識を導入し化石キリガヒダマシの分布を検討した。日本の新生界においてこゝに述べた種・亜種は中新世を3分し鮮新世を2分する程度の單位区分について生物層序学的示準となりうる。また地方的にはこれを利用してさらに小さい区分も試みた。

*本研究にあたつて昭和23年度文部省自然科学研究費の補助を受けた（No. 3040）

和　名　一　覧　表

PLATES

AND

EXPLANATIONS

PLATE 1

Fig. 1. *Turritella (Turritella) terebra* (Linné), No. 346 "Ryukyu", Recent. (×1)

Fig. 2. *Turritella (Turritella) perterebra* Yokoyama, Topotype No. 164, Dainichi, Shizuoka Pref.; Dainichi sand, lower Pliocene (H_1) (×1)

Fig. 3. *Turritella (Turritella) perterebra* Yokoyama, ditto. No. 172. (×3)

Fig. 4. *Turritella kiiensis* Yokoyama, No. 26231. Iwakishin, Osawano-mura, Kaminiikawa-gun, Toyama Pref. (Yatsuo Group) Miocene. (×1)

Fig. 5. *Turritella (Kurosioia) filiora* Yokoyama. No. 24521-2, Tombe, Shizuoka Pref.; (Nango form. Kakegawa Group.) ($H_2 I_1$) (×3)

Fig. 6. *Turritella (Kurosioia) filiora* Yokoyama. No. 93: Kaigarazaka, Totsuka, Yokohama; (Naganuma form.) Pleistocene. (×3)

Fig. 7. *Turritella (Kurosioia) kurosio* n. sp. No. 2421804, Kiba, Shima-gun, Mie Pref. Pleistocene (×3)

Fig. 8., 9. *Turritella neiensis* n. sp. Holotype, No. 149; Shimizu, Unohana-mura, Nei-gun Toyama Pref. (Yatsuo Group) Miocene. (×4)

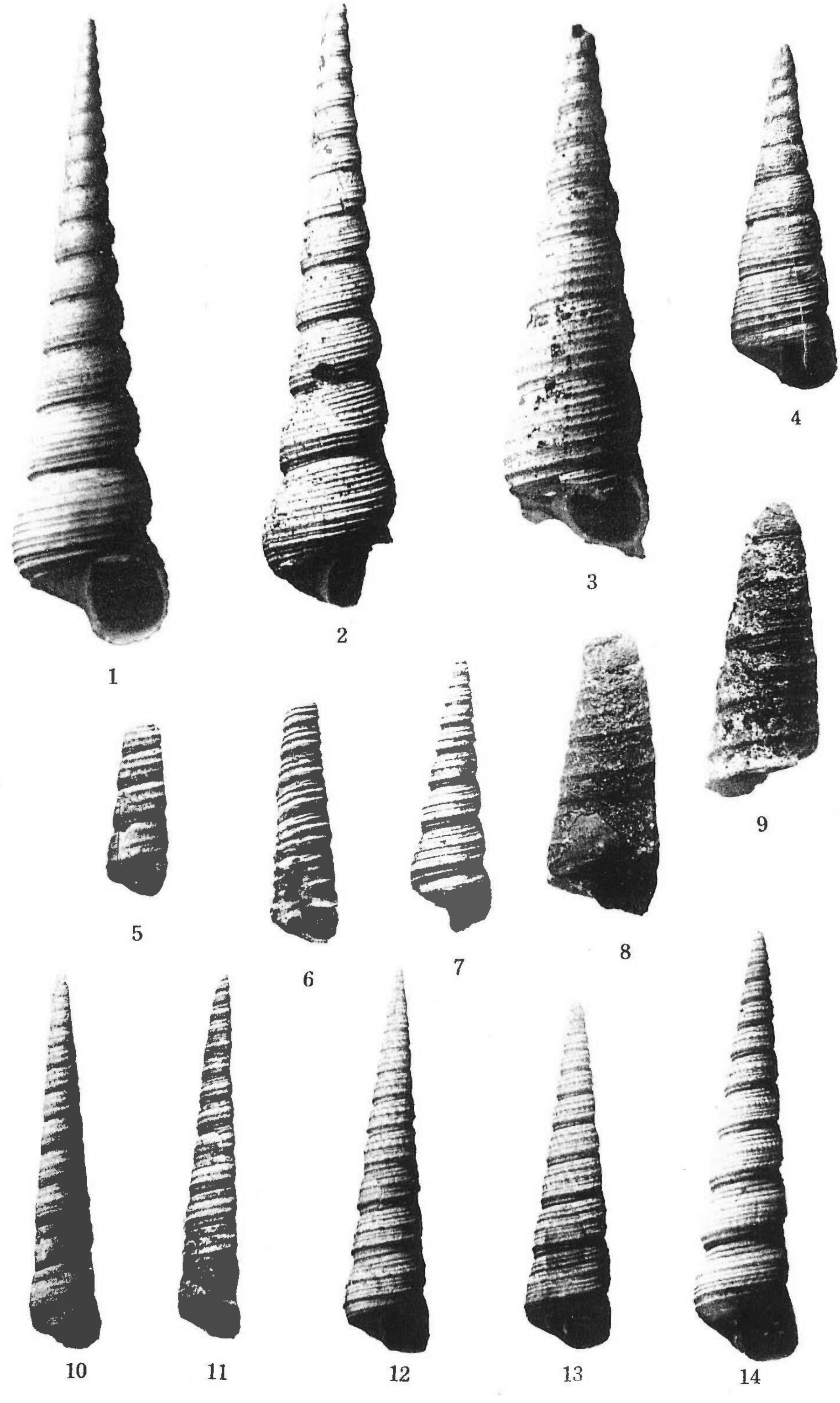
Fig. 10. *Turritella (Kurosioia) fascialis gracillima* Gould, No. 24519-2, Kamakura, Kanagawa Pref. Recent. (×3)

Fig. 11. *Turritella (Kurosioia) fascialis fascialis* Menke, No. 26222, Suiken, Wakayama, Recent. (×3)

Fig. 12. *Turritella (Kurosioia) kurosio* n. sp. No. 2421701; Akugawa, Wakayama Pref. Pleistocene. (×3)

Fig. 13. *Turritella (Kurosioia) kurosio* n. sp. Paratype No. 2412712, Natural gas well Shizuoka Tennen Gas Co. R. 15 Iida-mura, Ihara-gun, Shizuoka Pref. Pleistocene. (×2.5)

Fig. 14. *Turritella (Kurosioia) kurosio* n. sp. Paratype No. 2412714, ditto. (×3)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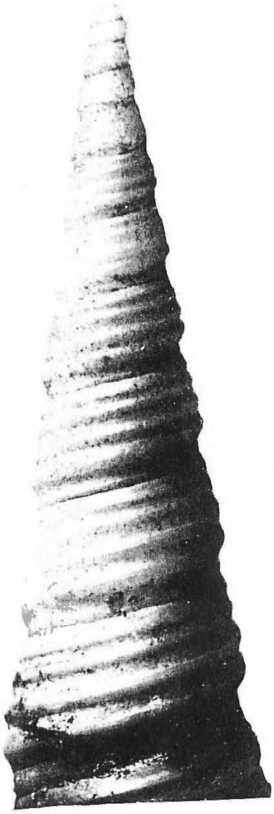

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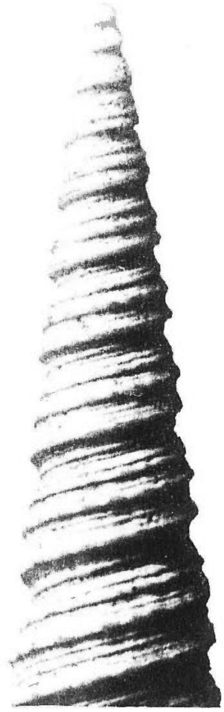

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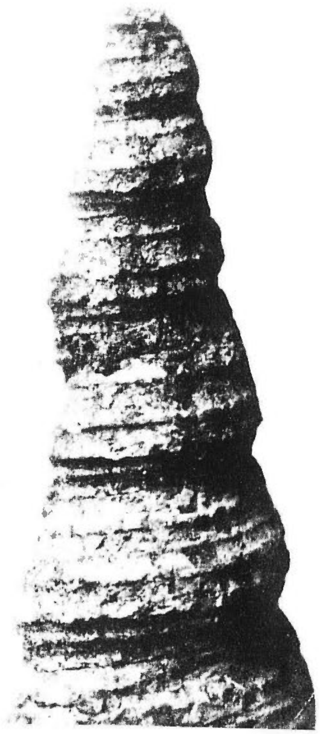

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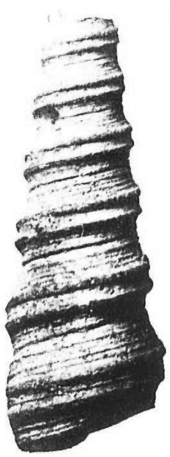

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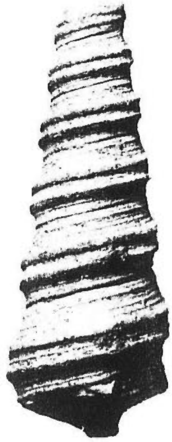

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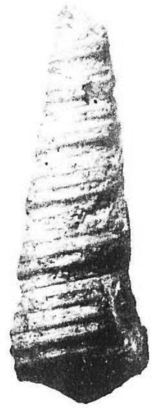

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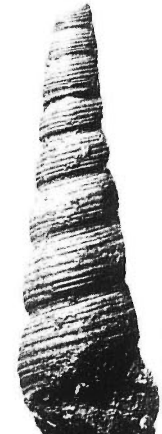

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PLATE 2

Fig. 1. *Turritella (Neohaustator) nipponica miyata* n. subsp. No. 221022–1, Holotype ; Kamimiyata, Kanagawa Pref. (Miyata formation) Pliocene. ($H_2 I_1$) ; Nuclear whorls. (×6.5)

Fig. 2. *Turritella (Kurosioia) kurosio* n. sp. No. 2421701 ; Akugawa Pleistocene ; Nuclear whorls. (×7)

Fig. 3. *Turritella kiiensis* Yokoyama. No. 135 ; Iwaya, Toyama Pref. Miocene ; Nuclear whorls. (×10)

Fig. 4., 5. *Turritella tanaguraensis* Kotaka No. 120 ; the river-bed of Usui-gawa, Annaka-machi, Gumma Pref. Miocene (collected by Y. Ishiwada) (×3)

Fig. 6. *Turritella chichibuensis* n. sp. No. 95 ; Holotype ; Tatsugase, Yorii-machi Saitama Pref. (coll. by K. Watanabe.) (×3)

Fig. 7. *Turritella kadonosawaensis tsudai* n. subsp. Paratype; No. 24511–8; Futamata, Asakawa-mura, Kohoku-gun, Ishikawa Pref. (Miocene), (×2)

PLATE 3

Fig. 1. *Turritella (Neohaustator) nipponica miyata* n. subsp. No. 221022-1, Holotype, Kamimiyata Kanagawa Pref. (Miyata form.) ($H_2 I_1$) (×2)

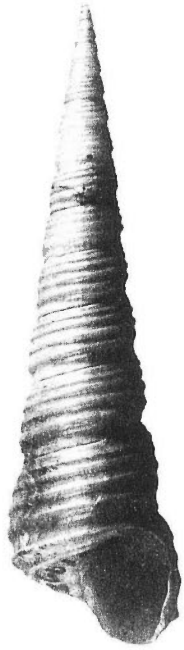
Fig. 2. *Turritella (Neohaustator) nipponica nojimaensis* n. subsp. No. 24102002, Paratype; Muronoki, Kanagawa Pref. (Nojima form.) ($H_2 I_1$) (×2)

Fig. 3., 4. *Turritella (Neohaustator) nipponica nojimaensis* n. subsp. No. 24102001, Holotype: ditto. (×2)

Fig. 5., 6. *Turritella (Neohaustator) ikibei* Kotaka No. 221129-3, Tambara, Chiba Pref. (Jizōdō the third fossil bed.) ($I_2 J$) (×2)

Fig. 7. *Turritella (Neohaustator) nipponica* Yokoyama. No. 2625, Hokkaido, Recent. (×3)

Fig. 8. *Turritella ikebei* Kotaka, No. 221129-4, Tambara, Makuda-mura Kimitsu-gun, Chiba Pref. Pleistocene. (×2)



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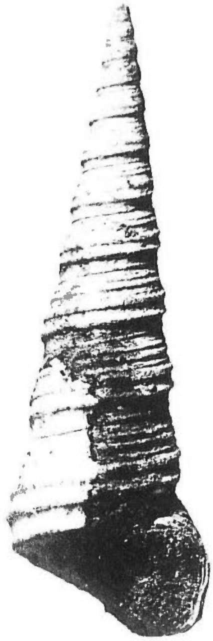

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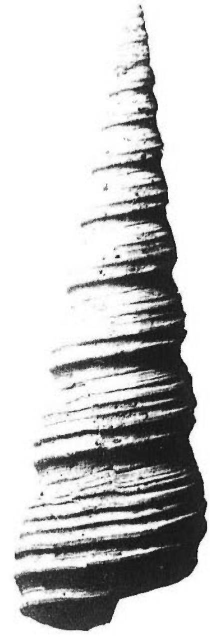

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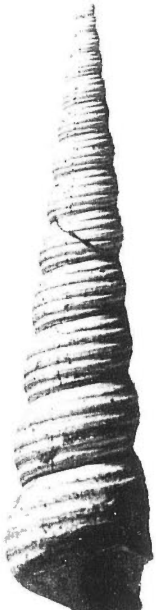

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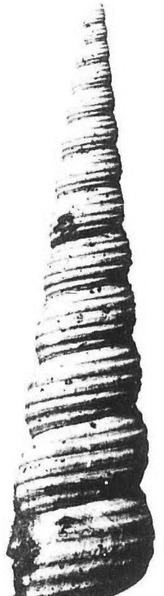

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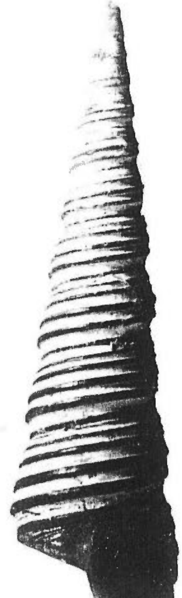

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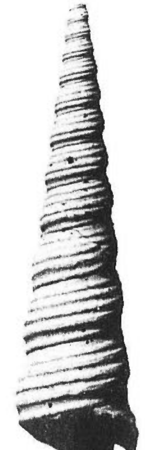

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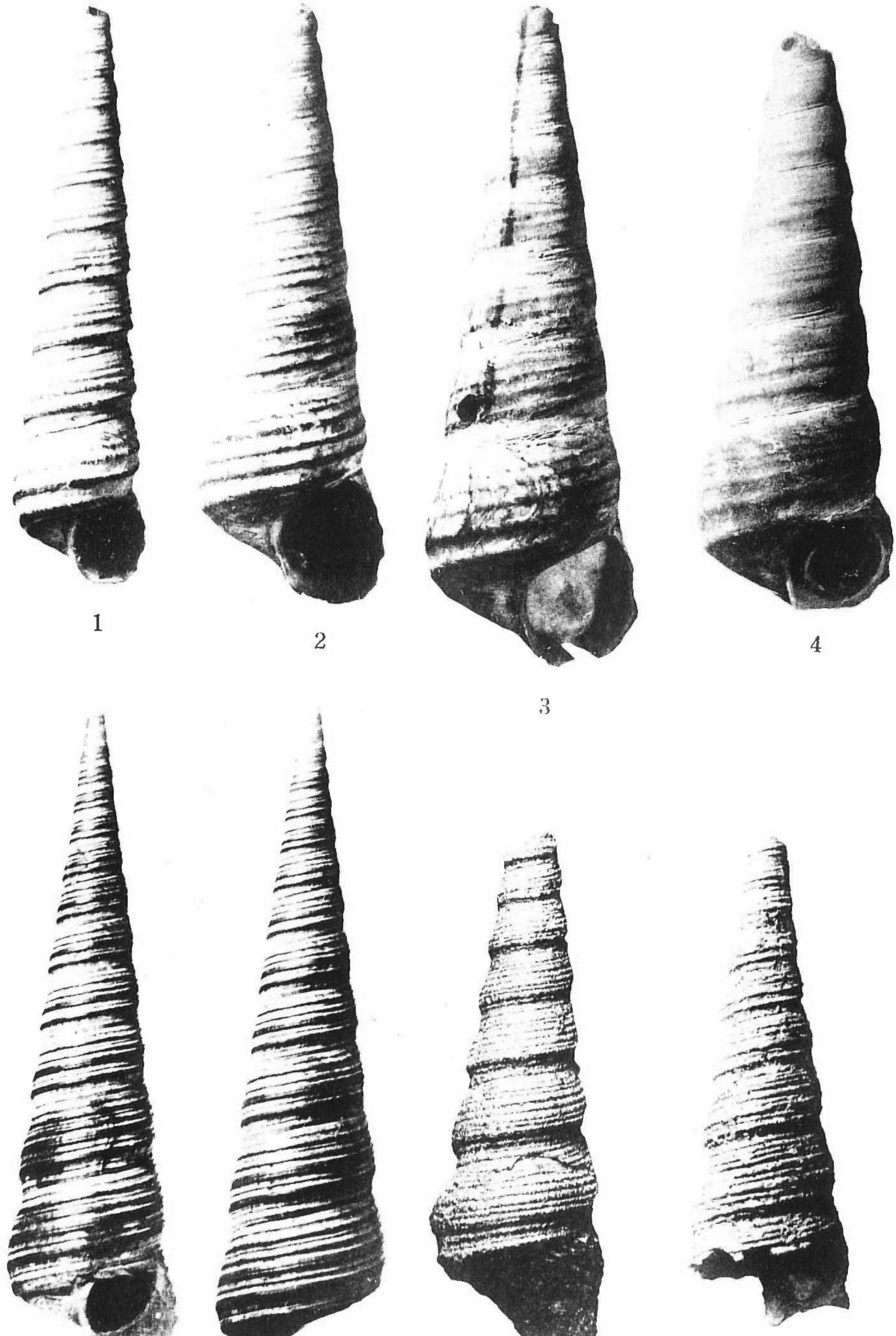

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PLATE 4

Fig. 1. *Turritella* (*Neohaustator*) *fortilirata* Sowerby No. 26241, (Recent) (×1)

Fig. 2–4. *Turritella* (*Neohaustator*) *huziokai* n. n. (Recent), Erimo-zaki, Hokkaido (Fig. 2 No. 2624-7 ; Fig. 3, No. 2624-10 ; Fig. 4 No. 2624-11) (×1)

Fig. 5., 6. *Turritella binaestriata* Kuroda (MS) No. 2475 Loc. Off the Coast of Tango. (Recent) (×2)

Fig. 7. *Turritella kadonosawaensis tsudai* n. subsp. Holotype, No. 24511-11 Futamata, Asakawa-mura, Kahoku-gun, Ishikawa Pref. ; (Miocene) (×3)

Fig. 8. *Turritella kadonosawaensis yoshidai* Kotaka Ikuridani, Nei-gun, Toyama Pref. (Miocene) No. 23103-4 (×3)

PLATE 5

Fig. 1. *Turritella chichibuensis* n. sp. No. 23618-1 ; chorotype ; Takinoue Yoshida-machi, Chichibu-gun, Saitama Pref. (Akahira form.) lower Miocene (×1.5)

Fig. 2., 3. "*Turritella*" *importuna* Yokoyama. No. 126 ; (Loc. 4007, by H. Matsui) Koyamada, Oku-mura Futaba-gun, Fukushima Pref. (×3)

Fig. 4. *Turritella tanaguraensis* Kotaka No. 108A ; Doshio, Fukuda-mura, Hiki-gun, Saitama Pref. (×1.5)

Fig. 5. *Turritella* (*Neohaustator*) *nipponica miyata* n. subsp. Paratype No. 221022-4, Kamimiyata, Minamishimoura-mura, Miura-gun, Kanagawa Pref. (Miyata form.) Pliocene ($H_2 I_1$) (×2)

Fig. 6. *Turritella* (*Neohaustator*) *nippanica nojimaensis* n. subsp. Paratype No. 24102029 Muronoki, Yokohama. (Nojima Form, Miura Group) Pliocene. (×2)

Fig. 7. *Turritella* sp. No. 312, Togakusoi Coal Mine, Nagano Pref. (Ogikubo form.) Lower Pliocene. (×2)

Fig. 8. *Turritella fortilirata tibana* Nomura No. 327 ; Tayazawa, Wakimoto-mura, Minamiakita-gun, Akita Pref. ($H_2 I_I$) (Shibikawa form.) (×1)

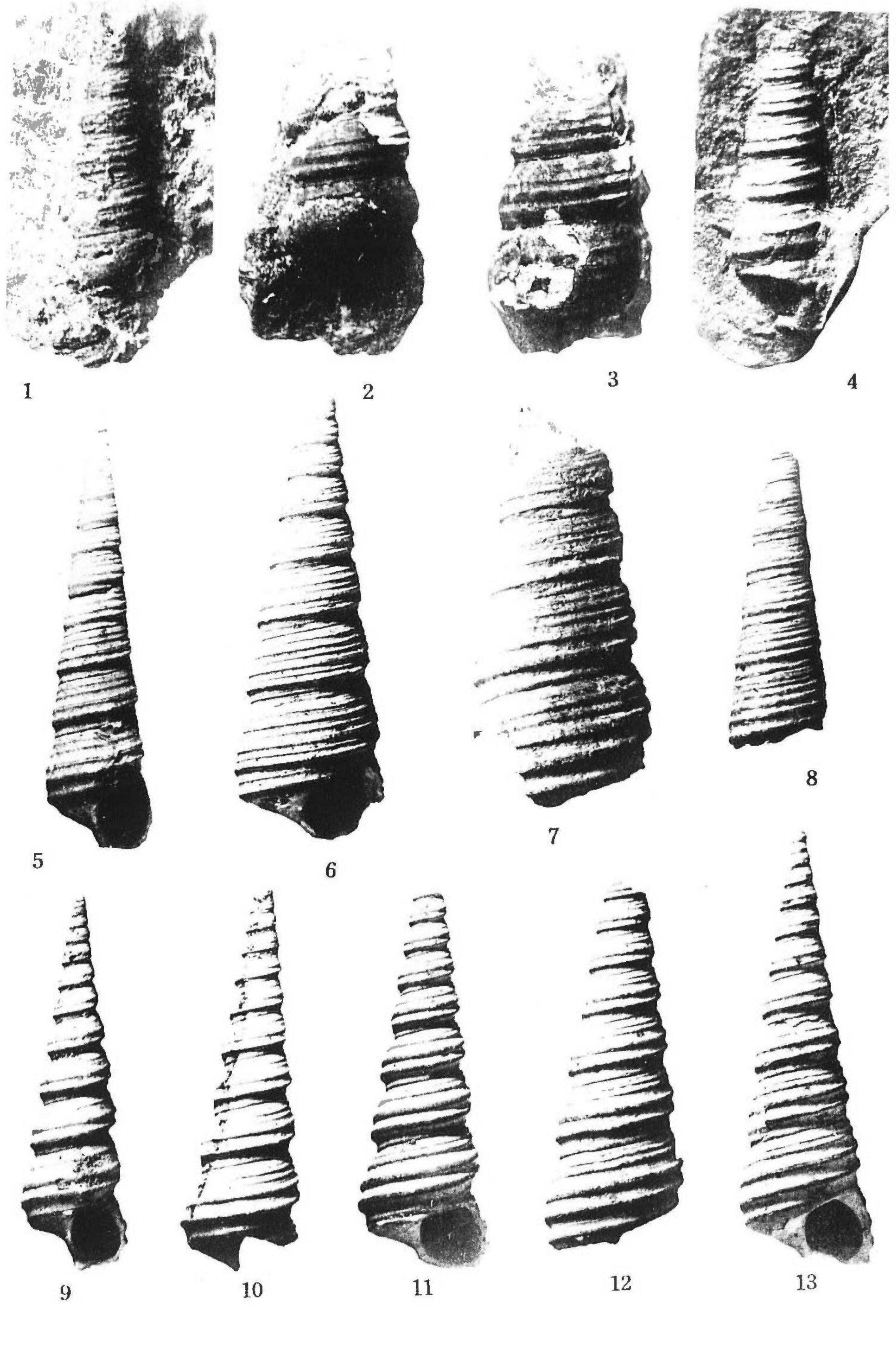
Fig. 9. *T.* (*Neohaustator*) *nipponica* Yok. ? No. 221208-3, Osabanai Kasuge-mura, Akita Pref. Pliocene, (×2.5)

Fig. 10. *Turritella* (*Neohaustator*) *nipponica* Yokoyama No. 353, ditto. (×2.5)

Fig. 11. *Turritella* (*Neohaustator*) *nipponica nipponica* Yokoyama No. 350, ditto. (×2.5)

Fig. 12. *Turritella* (*Neohaustator*) *nipponica nipponica* Yokoyama; No. 527. 367-2; The north-east cliff of Shiba, Yokohama (Koshiba form. Miura Group) Pliocene (×2)

Fig. 13. *Turritella* (*Neohustator*) *nipponica nipponica* Yokoyama, No. 527. 367. -1, ditto. (×3)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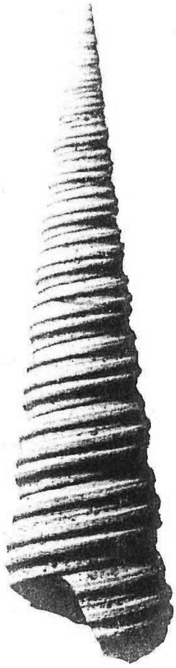
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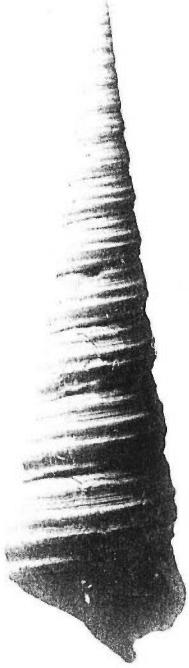
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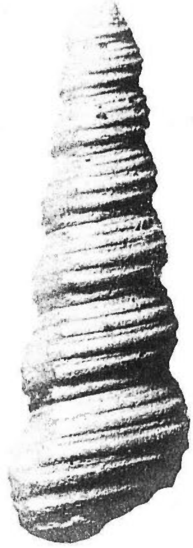
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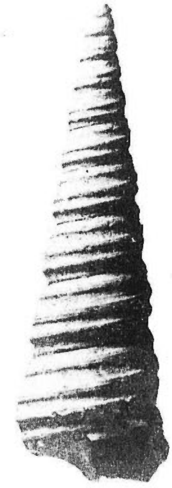
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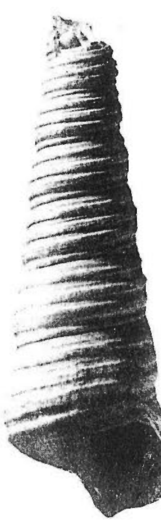
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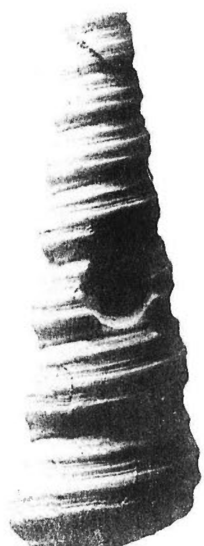
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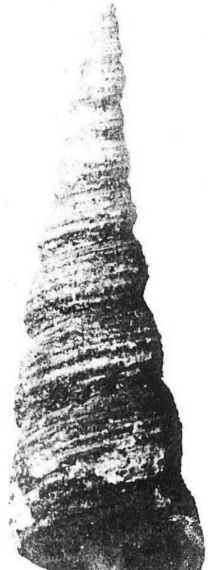
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PLATE 6

Fig. 1. *T.* (*Neohaustator*) *saishuensis* Yok. No. 366, Manganji, Akita Pref.; Pliocene (×1.3)

Fig. 2. *T.* (*Neohaustator*) *saishuensis etigoensis* Ikebe, No. 25092, Ogi, Niigata Pref. (Funabashi sand) up. Plioc. (×2) (type)

Fig. 3. *T.* (*Neohaustator*) ***nipponica mitsunashii*** n. subsp. No. 5161216 Seki, Kimitsu-gun, Chiba Pref. (Holotype) Pliocene (×2)

Fig. 4. *T.* (*Neohaustator*) *saishuensis* Yok. No. 368, Manganji, Akita Pref.; Pliocene (×3); Nuclear ornamentation.

Fig. 5. *Mathilda totomiensis* (Makiyama) No. KI. 251019, Topotype; Dainichi Loc. 611, (Dainichi sand, Kakegawa group) (H_1). (×3)

Fig. 6. *T.* (*Neohaustator*) *saishuensis* Yok. No. 231023-1, Anrakuji, Toyama Pref.; Pliocene (×1.3); growth line.

Fig. 7. *T.* (*Neohaustator*) *saishuensis etigoensis* Ikebe, No. 3, Ogi, Nishikoshi-mura, Santo-gun, Niigata Pref. (Funabashi sand) (×2); growth line.

Fig. 8. *Turritella kiiensis* Yokoyama, No. 135, Iwaya, Kurosedani-mura, Nei-gun, Toyama Pref. (Yatsuo Group) Miocene. (×2.5)

PLATE 7

Fig. 1. An Otsuka's spiral of *T. ikebei* Kotaka, No. 521. 28-11A (×1.2)

Fig. 2. *Turritella (Turritella) perterebra* Yok. Topotype No. 163 low. Pliocene; growth line; (×2)

Fig. 3. *T. (Neohaustator) ikebei* Kotaka No. 221129-7, Tambara Makuda-mura Chiba Pref.; Pleistocene; Nuclear ornamentation. (×18)

Fig. 4. *T. (Neohaustator) saishuensis etigoensis* Ikebe No. 25092, Ogi, Niigata Pref.; Nuclear ornamentation. (×12)

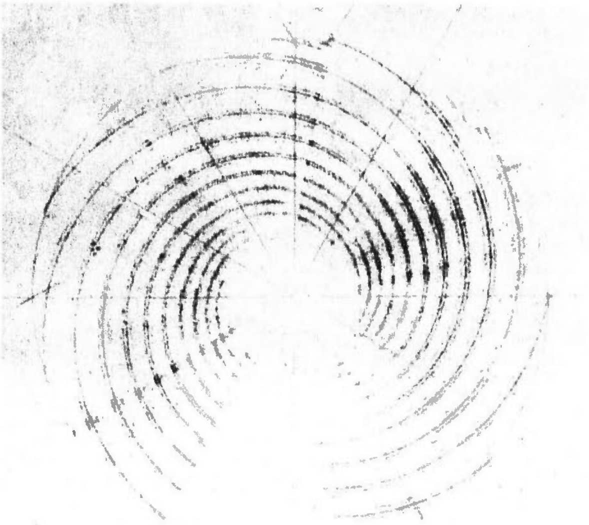
Fig. 5. *T. saishuensis* Yok. (*etigoensis* Ikebe?) No. 231023-8 Anrakuji, Toyama Pref.; growthline. (×2)

Fig. 6. *Turritella oyasio* n. sp. Kyoto Univ. No. TK 303, JC 512065 Holotype; Mokugahara, Higashi-tonami-gun, Toyama Pref. upper Miocene (F_3 G) (×1)

Fig. 7. *Turritella (Kurosioia) filiora* Yokoyama No. 263281; Nishihigasa, Akimoto-mura, Kimitsu-gun, Chiba Pref. Pliocene. (×5)

Fig. 8. *Turritella kiiensis* Yokoyama, No. 133; Growth-line. (×2)

Fig. 9. *T. (Neohaustator) nipponica mitsunashii* n. subsp. Paratype No. 5161220 Seki, Tamaki-mura, Kimitsu-gun, Chiba Pref. Pliocene. (×2)



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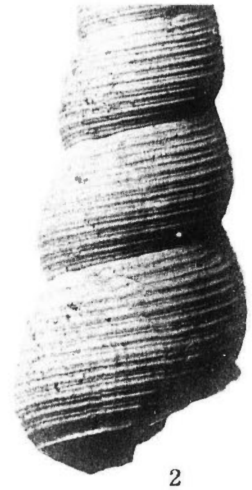

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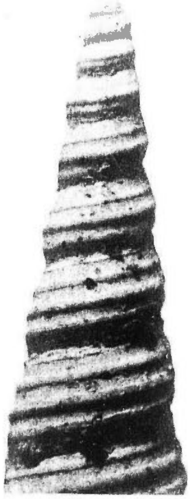

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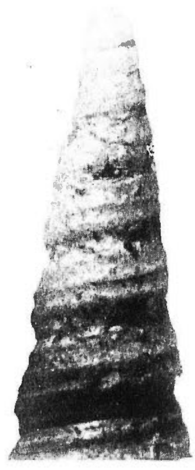

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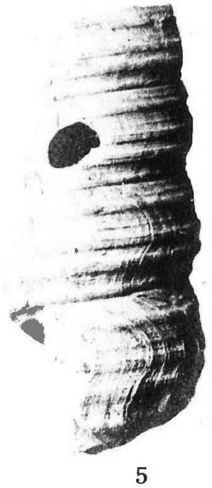

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The Geological Survey of Japan has published in the past several kinds of reports such as the Memoirs, the Bulletin, and the Reports of the Geological Survey.

Hereafter all reports will be published exclusively in the Reports of the Geological Survey of Japan. The Report will be consecutive to the numbers of the Report of the Imperial Geological Survey of Japan hitherto published. As a general rule, each issue of the Report will have one number, and for convenience sake, the following classification according to the field of interest will be indicated in each Report.

A. Geology & allied sciences
- a. Geology.
- b. Petrology and Mineralogy.
- c. Palaeontology.
- d. Volcanology and Hotspring.
- e. Geophysics.
- f. Geochemistry.

B. Applied geology
- a. Ore deposits.
- b. Coal.
- c. Petroleum and Natural Gas.
- d. Underground water.
- e. Agricultural geology. Engineering geology.
- f. Physical prospecting. Chemical prospecting & Boring.

C. Miscellaneous

D. Annual Report of Progress

Note: In addition to the regularly printed Reports, the Geological Survey is newly going to circulate "Bulletin of the Geological Survey of Japan" which will be published monthly commencing in July 1950

本所刊行の報文類の種目には從來地質要報，地質調査所報告等があつたが今後はすべて刊行する報文は地質調査所報告に改めることとし，その番號は從來の地質調査所報告を追つて附けることにする。そして報告は一報文につき報告1册を原則とし，その分類の便宜のために次の如くアルファベットによる略號を附けることにする。

A 地質およびその基礎科學に關するもの
- a. 地 質
- b. 岩石・鉱物
- c. 古生物
- d. 火山・溫泉
- e. 地球物理
- f. 地球化學

B 應用地質に關するもの
- a. 鉱 床
- b. 石 炭
- c. 石油・天然瓦斯
- d. 地下水
- e. 農林地質・土木地質
- f. 物理探鑛・化學探鉱および試錐

C その他

D 事業報告

なお刊行する報文以外に當分の間報文を謄寫して配布したものに地下資源調査所速報があつたが今後は地質調査所月報として第1号より刊行する。

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