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RESEARCH ARTICLE

Evolution of *T. simplex*, Jenkins from the Middle Miocene to the Early Pliocene and its Chances of Becoming a Distinct Subspecies

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Abstract

The presence of Turritellidae fossils in rocks is very important, because they are index fossils at the levels of mollusk biostratigraphy in Indonesia. However, its use is not yet optimal, due to one of the reasons being different names for the same specimen or conversely giving the same species name to different forms. One example is Turritella simplex. This research is intended to re-identify Turritella simplex originating from two populations that have different shapes and sizes. The goal is to find out whether the two populations are the same or different species. The method used is the analysis of the similarity of the identification parameters and the similarity test of the biometric patterns. The results showed that the two populations from Cilanang and Meningten showed similar morphological identification parameters, but differen in biometric aspects. The recommendation from this research is to divide it into two different subspecies, and can be represented at different biostratigraphic levels. Both populations show an evolutionary process in terms of biometry and morphology.

Keywords: *Turritella*, evolution, biostratigraphy, mollusk, biometry

1. Introduction

Turritellidae fossils are a group of mollusks that can be used for biostratigraphic and paleoecological analysis (Allmon, 2011; Anderson & Allmon, 2017, 2018). The existence of Turritellidae fossils in Indonesia has also been used as index fossils for biostratigraphic levels, especially on the island of Java (Pandita et al., 2013). Research on these fossils was preceded by discoveries Jenkins (1863) which identified several new species. The number of discoveries of Turritellidae foail species has increased since Martin, (1881) carry out investigations on samples resulting from geological exploration. Martin (1919) then succeeded in constructing the first mollusk biostratigraphic unit on the island of Java using the Lyellian method. Oostingh (1839 in Pandita et al., 2013) then developed a biostratigraphic method using index fossils from the Turritellidae family. Research on Turritellidae was then carried out again by Shuto, (1974) who tried to revise a number of naming from Martin's samples collected at the Leiden Museum. After Shuto (1974) study, there was not much field research to discover new species.

Field investigations again at a number of type locations found a number of fossils with slightly different physical forms that received the same name (Pandita et al., 2013). One of them is Turritella simplex Jenkins, which is found in the Meningten and Cilanang rivers.

2. Objectives

The purpose of this study was to carry out detailed identification of two T. simplex jenkins populations, with the aim of knowing whether the two populations were the same or different species. The next goal is to know the meaning of the evolution of the two populations.

3. Materials

The research sample is a collection stored in the ITNY Paleontology Laboratory with a total of 35 samples. The samples came from two locations in Meningten Valley (MNT) and Cilanng’s river (CLN). The location of the Meningten valley is at the coordinates 06°53’56,3”S and 108°42’12,5”E. The Cilanang River is located in the southwest of the city of Bandung, with coordinates 07°00’07,7”S dan 107°19’39”E (Figure 1).

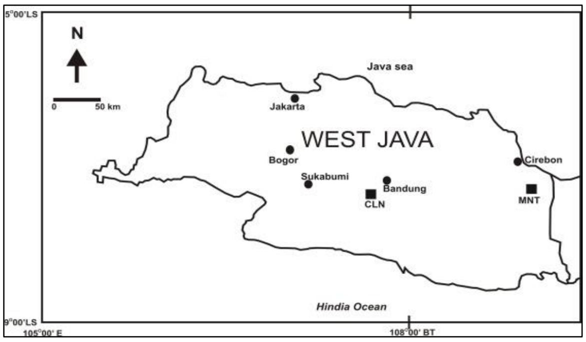

Fig 1. The sampling locations were from the Meningten (MNT) and the Cilanang river (CLN) in West Java Province

4. Methods

Research methods include field research, laboratory investigations and statistical analysis. Investigations in the field were carried out in the form of fossil excavations, rock observations, and stratigraphy for locations in Cilanang and Meningten.

Laboratory investigations in the form of identification of the two populations that have been stored in the Paleontology Laboratory of the Institut Teknologi Nasional Yogyakarta. Parameter identification of Turritella was carried out using a qualitative morphological and biometric approach. In the morphological aspect using parameters proposed by several previous researchers (Allmon, 2011; Kotaka, 1959; Marwick, 1957; Merriam, 1941; Shuto, 1974). In this study, a biometric study was carried out using a statistical approach to determine the correlation of several biometric parameters. The biometric parameters used are the width of the suture of the last chamber (Wsut), the width of the corner of the last chamber (Wang), and the length of the shell (L). (Figure 2). These biometric parameters were proposed by (Pandita et al., 2013).

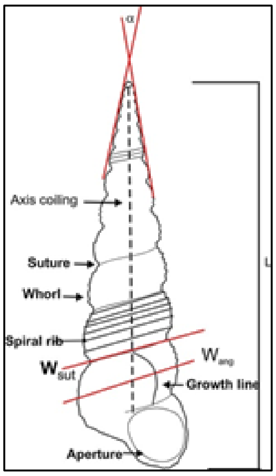

Fig 2. The parameter identification of Turritella

Statistical analysis used a similarity test both in terms of species-determining morphological characteristics, as well as from the biometric aspect. From the morphological aspect, the approach is carried out by the similarity of physical characteristics that determine the species in Turritella. Biometric aspects were tested using two methods, namely linear regression and similarity test (T-Test). (Hasan, 2004).

$$t = \frac{x_1 - x_2}{s\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \qquad 1)$$

Where: t = value of acceptance if $-t_{(1-1/2\square)} < t < t_{(1-1/2\square)}$

x1 & x2 = mean values

n1 & n2 = number of population

S = is the average standard deviation

The formula for the average standard deviation of the two populations:

$$S^2 = \frac{(n_1 - 1)\, S_1^{\,2} + (n_2 - 1)\, S_2^{\,2}}{n_1 + n_2 - 2} \qquad 2)$$

Where: S1 & S2 = standard deviation value of each tested population.

5. Geological Setting

5.1. Physiography

Regionally, the location of Meningten Valley is included in the physiographic boundary between the Bogor Zone and the North Serayu Mountains (van Bemmelen, 1949). t is a series of structural hills that extend west-east then curve to the southeast in the east. To the west it borders the Bogor zone. Meanwhile, to the east it borders the Java Depression. To the south it borders the Java depression zone, and to the north it borders the Java North Coast zone. The morphology consists of river valleys and river plains.

The location on the Cilanang River is included in the border between the Bandung Zone which is on the north side, and the Southern Mountains of West Java on the south side. The location is in a river valley, with strong wavy evidence morphology.

5.2. Stratigraphy

The location in the Meningten Valley is the upper part of the Kalibiuk Formation, in the form of gray silt. The age of the Kalibiuk Formation is estimated to be in the Early Pliocene based on the fossil content of planktonic foraminifera (Silitonga et al., 1996). Oostingh (1938) based on mollusk fossil included the rocks in the Meningten Valley area into the Cheribonian Stage which is equivalent to the Late Miocene-Early Pliocene.

The location on the Cilanang river is the lower part of the Cimandiri Formation (Koesmono et al., 1996). The age of this formation is based on the mollusk fossil content, estimated to be in the Middle Miocene. There has been no age determination from other methods carried out at this location.

6. Systematic Description

6.1. *T. simplex* Jenkins (Cilanang specimens)

Specimens of Turritella simplex Jenkins, obtained from the S. Cilanang location which is located in the Gunung Halu area, Bandung Regency. The number of specimens whose biometrics were observed and measured was 17, with the sample collection located at the ITNY Paleontology Laboratory.

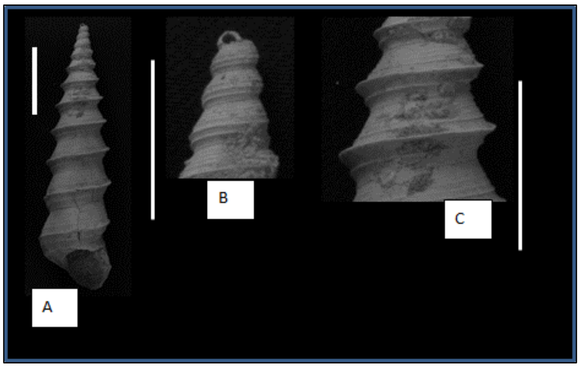

Fig 3. *Turritella simplex* (CLN): A) overall shape, B) channelized suture shape in early rounds, C) sub carinate suture shape in adult chamber rounds. White line scale 1 cm.

Turritella simplex is characterized by a rapidly growing shell, early forms tend to be multicostate with convex chamber edges. There are 5 smooth main spirals that form from the initial room. The suture is initially channelized then turns subcarinate in the mature turn (Figure 3). A sharp keel is formed from round the 4th or 5th chamber to the final chamber (Fig. 3), which is formed by the 2nd main spiral from the anterior suture. The keel position occupies one third of the chamber from the anterior. Antispiral low curved growth line with sinuses. The aperture is circular in shape.

A total of 17 specimens from field collection were measured to determine the biometric aspects of Turritella simplex. The measurement results show that the shell size is less than 60 mm, based on the Turritellidae body size classification from Kotaka, (1959), body size between 20 mm and 60 mm is included in the medium category. The measurement data shows that the standard deviation of the Wsut:Wang ratio is below 10%, while the Wsut:L ratio is above 10%. Based on the standard deviation value, Turritella simplex has a uniform ratio of suture width (Wsut) to maximum width (Wang) between specimens. However, the ratio of shell length to final suture width varies more, because the standard deviation value is greater than 10% (Table 1).

Table 1. Biometrics of Turritella simplex.

No.Spec	$L_{(mm)}$	W_{ang}	W_{sut}	a (°)	Jml Kmr	W_{ang}:L	W_{sut}:L	W_{sut}:W_{ang}
01A/1B	40,40	15,00	10,95	21,00	9,0	0,3713	0,2710	0,7300
01A/2B	41,80	16,30	11,80	21,00	9,0	0,3900	0,2823	0,7239
01A/3B	30,55	14,95	10,30	21,00	8,0	0,4894	0,3372	0,6890
01A/1Y	50,25	14,85	11,20	19,00	12,0	0,2955	0,2229	0,7542
01A/2Y	38,50	16,00	10,50	20,50	8,0	0,4156	0,2727	0,6563
01A/3Y	53,80	17,60	12,00	19,50	11,0	0,3271	0,2230	0,6818
01A/4Y	27,70	13,40	9,70	21,50	8,0	0,4838	0,3502	0,7239
01A/5Y	37,80	13,70	11,00	20,00	10,0	0,3624	0,2910	0,8029
01A/6Y	37,40	15,75	11,30	22,00	10,0	0,4211	0,3021	0,7175
01A-2	46,60	15,70	12,00	21,50	9,0	0,3369	0,2575	0,7643
01A-3	54,05	17,35	13,90	21,00	10,0	0,3210	0,2572	0,8012
01A-5	42,95	16,75	12,70	21,00	8,5	0,3900	0,2957	0,7582
01A-7	35,50	13,90	10,10	21,00	9,0	0,3915	0,2845	0,7266
01A-9	39,00	12,50	9,55	18,00	9,5	0,3205	0,2449	0,7640
01A/7Y	39,35	16,15	10,85	20,00	8,0	0,4104	0,2757	0,6718
01A/8Y	31,45	15,05	10,55	21,00	8,0	0,4785	0,3355	0,7010
01A/9Y	41,55	16,25	11,85	21,00	8,5	0,3911	0,2852	0,7292
Mean	41,16	15,27	11,21	20,57		0,3797	0,2780	0,7353
Std. Dev		1,51	1,20	1,09		0,0590	0,0371	0,0424

Table 2. Biometrics of *Turritella simplex*. from location MNT-13

No.Spec	$L_{(mm)}$	W_{ang}	W_{sut}	a (°)	n Whorl	W_{ang}:L	W_{sut}:L	W_{sut}:W_{ang}
1B	68,80	25,00	15,85	12,50	12,0	0,3634	0,2304	0,6340
2B	73,30	28,80	16,60	11,00	12,0	0,3929	0,2265	0,5764
3B	63,85	20,45	15,00	12,50	12,5	0,3203	0,2349	0,7335
4B	71,90	29,40	16,80	15,00	12,5	0,4089	0,2337	0,5714
5B	72,60	28,55	16,45	14,00	12,0	0,3933	0,2266	0,5762
6B	90,90	26,75	18,30	11,00	13,0	0,2943	0,2013	0,6841
1Y	95,70	28,30	21,50	15,00	13,0	0,2957	0,2247	0,7597
2Y	85,30	32,50	19,10	13,00	13,0	0,3810	0,2239	0,5877
3Y	97,20	30,30	20,10	13,50	12,0	0,3117	0,2068	0,6634
4Y	64,70	22,60	15,40	12,50	10,0	0,3493	0,2380	0,6814
5Y	89,00	27,40	18,30	12,50	14,0	0,3079	0,2056	0,6679
6Y	63,90	22,80	16,20	15,00	12,0	0,3568	0,2535	0,7105
7Y	82,40	27,60	18,50	13,00	13,0	0,3350	0,2245	0,6703
8Y	77,00	31,50	18,30	14,00	13,0	0,4091	0,2377	0,5810
9Y	98,50	30,55	20,25	15,00	13,5	0,3102	0,2056	0,6628
10Y	72,10	28,80	18,50	15,00	12,5	0,3994	0,2566	0,6424
11Y	89,95	26,80	17,80	11,00	12,5	0,2979	0,1979	0,6642
12Y	96,80	28,40	19,75	15,00	13,5	0,2934	0,2040	0,6954
Mean	80,77	27,58	17,93	13,36		0,3456	0,2240	0,6535
Std. Dev	11,74	3,48	1,87	1,32		0,0433	0,0174	0,0563

6.2. T. simplex Jenkins (Meningten specimens)

The turritellidae found at the Meningten site is Turritella simplex (Martin, 1883). The shell that appears is large. The entire sample lacks a protoconch, but the beginning of a teleconch is observable. At the beginning of its growth, the periphery is somewhat multicostate in structure. The number of main spiral ribs is 5. In adults the peripheral pattern changes to monocarinate which is composed of spiral rib number 2 from the anterior suture. The growth line grows antispirally by forming a single sinus, whereas at the bottom the sinus does not form.

A total of 18 specimens from MNT13 were measured to determine the biometric aspects of Turritella sp. The measurement results show that the shell length of this group is longer than 60 mm, based on the classification of body size of Turritellidae from Kotaka (1959), body size longer than 60 mm is large. The measurement data shows that the standard deviation for the Wsut:Wang ratio has a standard deviation value below 10%, while Wsut:L shows a value below 10% (Table 2). Based on the standard deviation value, Turritella sp. has uniform Wsut:L and Wsut:Wang ratios between specimens. So this population can be said to be the same species.

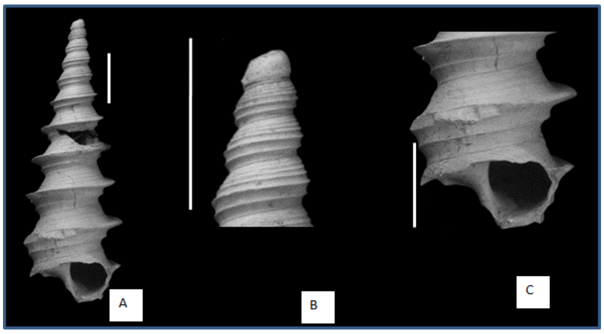

Figure 4. *Turritella simplex*. of MNT: A) overall shape, B) shape of channelized sutures in early rounds, C) shape of subcarinate sutures in mature chamber rounds. Black line scale 2 cm.

7. Result

In terms of geology, the two populations or species are different. T. simplex originates from the Cilanang Formation which is thought to have formed in the Middle – Upper Miocene (Pandita et al., 2013). Meanwhile, Turritella sp. comes from the Kalibiuk Formation (MNT) where the formation is estimated to be Early Pliocene (Hita Pandita, 2014)

The two populations had differences in the keel pattern, where the specimen from MNT. had a very strong keel (Figure 4) while T. simplex keel expressed strongly (Figure 3). Another difference is in terms of biometry, where Turritella sp. longer than T. simplex. Seeing these conditions, it is necessary to test whether the two are indeed worthy of being separated as different species or whether they can be made into one species.

The number of spiral ribs of the two populations is relatively the same, which is 5 pieces. There is a difference in the pattern, where specimens from Cilanang tend to be smooth, whereas specimens from Meningten are clearly visible.

Some aspects of the morphological characteristics of the two populations can be said to be almost the same. The same aspects include that the peripheral pattern at the beginning of growth is multicostate and changes to monocarinate in the late chambers. The suture pattern of the two populations is the same as sub carinate.

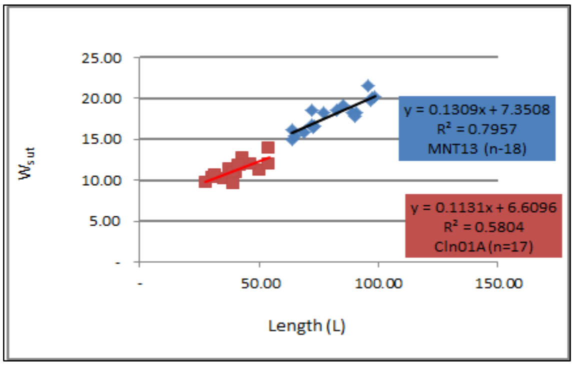

Fig 5. Linear regression pattern of the Wsut: L ratio parameter in *T. simplex* (CLN01A) with *Turritella simplex*. (MNT13).

The first study carried out a linear regression pattern analysis to see whether there was a relationship between the two species. The two parameters tested, namely the ratio Wsut:L and Wang:Wsut, are biometric parameters proposed by (Pandita et al., 2013). The Wsut:L ratio shows that the two species have parallel but not coincident linear directions (Figure 5). Meanwhile, the Wsut:Wang ratio shows intersecting linear regression (Figure 6). Based on this, the two populations have different growth patterns, this confirms that the two are indeed different species.

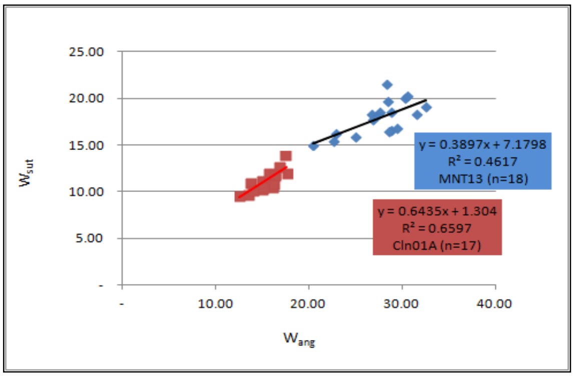

Fig 6. Linear regression pattern of the Wsut:Wang ratio parameter in *T. simplex* (CLN01A) with *T. simplex* (MNT13).

The second study was analyzed using a two-way different test known as the T-Test. Data processing uses the excel program, because the number of the test population is not large. The acceptance level used is a number commonly used in the T-Test. So the acceptance limit with the total number of samples for both populations is -2.034 < t_0 < 2.034 obtained from the t distribution table (Riduwan, 2018). Based on the results of the T-Test test, it was shown that both parameters yielded a value of t_0=--6.052572 for the Wsut:L ratio and t_0= -4.491925 for the W_{sut}:W_{ang} ratio (Table 3). These two values are not included in the acceptance range, so the two populations can be considered to have different patterns.

8. Discussion

The two populations show a number of similarities in terms of morphological characteristics. Referring to the identification parameters from Kotaka (1959) and Merriam (1941) the two populations can be said to be the same species. The differences were not significant as a species differentiator.

However, there are significant differences in the biometric aspect. From both the linear regression pattern and the T-Test, the two populations show a strong difference. Biometric aspects can be used by several researchers to determine subspecies (Imbrie, 1956; Pandita & Apriani, 2021). Seeing these differences, the two populations can be said to be different subspecies.

Table 3. The results of the T-test on the two parameter ratios Wsut:L and Wsut:Wang from two populations of the species *T. simplex*., (MNT) and *T. simplex* (CLN).

No. Sample	Spesies	n samples	t_0 a=0.05	W_{sut}:L	W_{sut}:W_{ang}	T-test (W_{sut}:L)		T-test (W_{sut}:W_{ang})	
						s	t	s	t
MNT13 CLN01A	Turritella sp T. simplex	18 17	2,034	0,224007 0,281683	0,653459 0,729164	0,0282	-6,052572	0,0498	-4,49192516

A species can be separated into several subspecies that must fulfill several categories. Apart from physical aspects, there are differences, so to differentiate sub-species in fossils they must meet the criteria for different geological aspects (Mayr & Ashlock, 1991). The two populations represent two geological aspects in the form of different ages, namely the Middle Miocene for the population from Cilanang and the Upper Miocene-Early Pliocene for the population from Meningten.

Based on the various approaches above, there is a proposal to differentiate the two populations as different subspecies. The population originating from Cilanang is a paratype of Turritella simplex Jenkins which was first discovered around Mount Halu (Jenkins, 1863), so it still gets the name Turritella simplex simplex. Meanwhile, the population from the Meningten Valley was first discovered by Martin (1881) and identified as Turritella simplex, proposed to be a subspecies of Turritella simplex meningtenensis n.ssp.

Looking at the geological age, *T. simplex simplex* is a marker for the Middle Miocene age. Meanwhile, T. simplex meningtenensis is a marker for the Late Miocene-Early Pliocene age.

9. Conclusion

Detailed studies both in terms of morphological and biometric characteristics can clearly provide a clear picture of the differences in a fossil population. If this difference is strengthened by a significant difference in geology, it can separate two populations that were previously one species without being differentiated into sub-species, and finally it can be proposed to turn into sub-species. The results of this study succeeded in proposing the separation of Turritella simplex, Jenkins into two different sub-species.

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