Discriminating conodont recording bias: a case from the Nanzhang-Yuan´an Lagerstätte (#95703)

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Discriminating conodont recording bias: a case from the Nanzhang-Yuan′an Lagerstätte

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Abstract

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Keywords: Conodont; Lagerstätte; Bias; Size; Lower Triassic

1. Introduction

As nektonic marine organisms, conodont animals originated in the Cambrian and disappeared near the Triassic-Jurassic boundary (Clark, 1983; Goudemand et al., 2011; Sansom et al., 1992). The conodont animal consists of a head with feeding apparatus and eyes, a trunk and a caudal fin (Briggs et al., 1983; Aldridge et al., 1993) and its whole length may reach up to centimeters or tens of centimeters, while the length of a single conodont element is in the millimeter/submillimeter range (e.g. Gabbott et al., 1995; Takahashi et al., 2019). Owing to the absence of mineralized skeleton, conodont elements were usually the only preserved parts of conodont animals. Different conodont elements of an apparatus might exhibit completely different evolution rates, and fast evolving elements were more concerned and utilized for bio-stratigraphic correlations (Orchard, 2007; Chen et al., 2016). Partly because of their huge quantities in the strata even after the dissolution method, conodont elements still have played important and excellent roles in defining the geologic timescale (e.g. Shen et al., 2023).

To obtain sufficient conodont elements, the solution-dissolving method has been utilized by tremendous studies (e.g. Jiang et al., 2007; Sun et al., 2012), including a recent report about acquiring conodont elements from chert with NaOH solution (Rigo et al., 2023). Nevertheless, we have know since the last century that the fossil record of conodonts can be fundamentally biased owing to taphonomic processes and laboratory procedures. What's more, preservations of conodont elements in the strata were also influenced by their morphology, which leads to biased fossilization of different anatomical units (Orchard, 2007). Hence, owing to the limitations of their size, morphology, preservation condition and laboratory process, few apparatuses or clusters have been found directly on the rock surface (e.g. Gabbott et al., 1995; Goudemand et al., 2011), while wonderful collections of dispersed conodont elements have been reported through the most commonly used acid-dissolving method.

As a basic biological trait, the size of the conodont element is not only related to ecological change (Chen et al., 2013) but also influences taxonomic identification (Chen et al., 2016). Differential destruction of elements during laboratory processing by the acid-dissolving method may influence the conodont data (Ziegler et al., 1971; von Bitter, 1972; Jeppson et al., 1985; von Bitter and Purnell, 2005). Taphonomic and laboratory processes can affect the number, dimensions and ratio of the different elements. Associations of conodonts on the bedding planes are the most reliable archive because they were not affected by laboratory treatment. In order to evaluate differences in composition, size and ratio of different elements, the material from the Jianglingjian Formation offers the possibility to examine conodont faunas both from the bedding planes and from the residues after the acid-dissolving method.

【Figure 1 can be putted here】

Figure 1. Early Triassic paleogeographic re-construction and the location of the Zhangjiawan section, Hubei Province, South China (after Benton et al., 2013)

2. Geological setting

During the Early Triassic, the South China block was located near the equator at the eastern part of the Tethys Ocean, while a vast of shallow-marine deposits were recorded in the North Marginal Basin of the Yangtze Platform (Benton et al., 2013). Up to now, abundant fishes have been reported from the Lower Triassic of the North Marginal Basin of Yangtze Platform, and two distinctive marine reptile faunas (the Nanzhang-Yuan′an fauna and the Chaohu fauna) have also been found from this region (Benton et al., 2013). As a representative section of the Nanzhang-Yuan′an fauna, the Zhangjiawan section is located in the west of Hubei Province of south-central China (Fig. 1; Wu et al., 2023). This section is about 25 km to the north of Yuan′an County and ~120 m in thickness, which is well-exposed along a road and a quarry (Wu et al., 2023). The Zhangjiawan section outcrops vermicular limestone, limestone, dolomite, brecciated dolomite, laminar limestone, volcanic tuffs and sandy mudstone, suggesting that it belongs to the restricted platform facies. Reported marine reptiles were all from the laminar limestone which is about 36 m in thickness. A 0.5-meter-thick, wedge-like or lenticular-like strata which consist of centimeter-sized thin beds appear in the middle part of the laminar limestone (Fig. 2A), suggesting the deepest depositional environment with the least hydrodynamic effect in this section.

【Figure 2 can be putted here】

Figure 2. Conodont elements recovered from Zhangjiawan section, Yuan′an County, Hubei Province, South China. (A) Dark-colored laminated limestone of the uppermost Jialingjiang Formation. The dashed line indicates the thinnest beds where the clusters were found. (B) Recovered conodont cluster after acetic acid dissolution. (C) Founded isolated conodont element from the bedding plane. (D, E and F) Founded conodont natural assemblage from the bedding plane. (G-N)Founded different isolated elements and clusters. (Also see the supplementary material of Wu et al., 2023)

3. Materials and method

Bulk samples (each weighing *ca.* 5 kg) were formerly systematically collected from the Zhangjiawan section (Wu et al., 2023). Then these samples were crushed into 3*3 cm in size (sometimes bigger than this size) and processed with diluted acetic acid. Amazingly, a conodont cluster was obtained from residues after the acetic acid dissolving and sieve-separating procedures (Fig. 2B), indicating that well-preserved clusters may have been preserved on the bedding planes which were millimeters in thickness. Hence, we collected cracked rocks and observed them under the binocular microscope directly. To make a better comparison, a sample weighing about 20 kg from where the cluster was found was collected. The sample was composed of limestones which were millimeters in thickness. Considering that crushing might destroy conodont elements, those limestone laminates were processed directly with diluted acetic acid (10%) to obtain conodont elements without crushing. The sample was kept in the diluted acetic acid for about 24 hours until only minor or no buddle could be seen. Then the supernatant liquor was poured out and the diluted acetic acid was added again. Every 5 days later, the undissolved residues were sieved by sieves which were 20 and 160 meshes. The undissolved rocks were left to be processed until they were all dissolved. After drying in the oven at 30°C, the residues were checked under a binocular stereo-microscope to obtain conodont elements.

Lengths of conodont elements from the bedding planes and the acetic acid dissolving method were measured and values of log microns were used for statistical analysis. Owing to their outstanding cusp and the presence of the third process, elements of Ellisonidae have more variable morphology than other Early Triassic conodonts (Orchard, 2007). For M elements, the distance from the tip of the cusp to the distal end of the longer process was measured (Fig. 2C). For P and S elements which have only one process, the distance between the two distal ends was measured (Fig. 2D-G, I-L). For those elements which bear three processes, the two longer processes were chosen and the two distal ends were measured (Fig. 2H, M). For those broken conodont elements, they were also measured in length but it refers to the maximum linear dimension (Fig. 2C-D, M, N). According to the anatomical standard and morphological aspect, conodont elements were classified into three types, including P, M, and S elements (Purnell et al., 2000; Sun et al., 2020). Restricted information of elements of Ellisonidae can be discerned when they were preserved on the rock surfaces, hence the further recognization of P (P_{1-2}) and S (S_{0-4}) elements was not considered in this study.

【Figure 3 can be putted here】

Figure 3. Length distributions of different conodont elements. (A) Length percentile plot of conodont P, M, S elements from bedding plane and dissolving residues. Note the gap between the Bedding-S elements and the others even after the logarithm of length. (B) Distributions of length for conodont P, M, S elements from bedding plane and residues after acid-dissolving.

4. Results

Owing to the low yielding of conodonts from the upper Lower Triassic, especially when samples were from the Jialingjiang Formation of South China, 167 and 71 conodont elements are acquired from the bedding planes and the residues after acid-dissolving, respectively (Table 1). Conodonts from the bedding planes include 25 P elements (14.9%), 21 M elements (12.5%) and 121 S elements (72.4%), while 17 P elements (23.9%), 17 M elements (23.9%) and 37 S elements (52.1%) are acquired from residues after acid-dissolving, indicating that the latter method resulted in fewer acquisitions of S elements. According to these materials, some differences can still be reflected. The average lengths of the two groups are 998.4 μm and 700.7 μm, which shows that conodont elements from bedding planes are overall larger. Preserving on the bedding planes, the length of P elements ranges from 450 μm to 1550 μm with an average of 868.4 μm, the length of M elements ranges from 240 μm to 1600 μm with an average of 747.4 μm, the length of S elements ranges from 290 μm to 2810 μm with an average of 999.9 μm. Acquiring from residues after acid-dissolving, the length of P elements ranges from 447 μm to 1226 μm with an average of 753.8 μm, the length of M elements ranges from 341 μm to 1345 μm with an average of 680.8 μm, the length of S element ranges from 356 μm to 1373 μm with an average of 685.5 μm. The two-sample t-test shows that P and M elements from different methods are not highly significant (p=0.51 and 0.21, respectively) although those from bedding planes are averagely larger than those from residues, while S elements from the two groups are highly significant ($p < 0.01$). Given all the elements of different types of each group, they have also highly different distribution of lengths. Percentile plot indicates that bedding plane S elements have outstanding larger individuals while the others have similar percentages of length distributions (Fig. 3 A and B). In general, conodont elements acquired from bedding planes have larger sizes and a greater percentage of S elements.

Table 1. Number, ratio, length range, length average of conodont elements and their differences.

【Table 1 can be putted here】

5. Discussion

Conodont elements are phosphatic and self-repairable micro-fossils (millimeter to sub-millimeter), which belong to extinct marine crown vertebrates, and may be easily damaged after the death of conodont animals and when trying to acquire them from the rock (Donoghue and Purnell, 1999; von Bitter and Purnell, 2005; Goudemand et al., 2012). Furthermore, post-mortem conditions, such as sediment compaction and diagenesis, may bias the preservations of elements with a different position in the apparatus (von Bitter and Purnell, 2005; Purnell and Donoghue, 2005).

The studied conodont elements are acquired from the Zhangjiawan section, which has been reported as a representative section for the Lower Triassic Nanzhang-Yuan′an Fauna (Yan et al., 2021). In this section, dark-colored lamellar limestones with abundant microbial-induced sediment structures and marine reptile fossils are sandwiched by massive dolomites and sandstones. The acquired conodont materials are from the middle part of the dark-colored lamellar limestone, which is also the thinnest bed of the Zhangjiawan section, suggesting that those conodont materials were deposited in a low-energy environment where sorting and selective destruction had just a slight influence on their preservations. However, the co-existence of conodont natural assemblages as well as isolated conodont elements on the bedding planes also reflects that conodont animals experienced limited but non-negligible disturbances after their death.

The ratios of different types of conodont elements from the bedding planes and the residues after acid-dissolving indicate that those elements have been affected by both natural and artificial processes (Table 1). On one hand, elements show different resistances to post-mortem sorting, sediment compaction and diagenesis. As a special Early Triassic group, the conodont apparatus of Ellisonidae consists of 15 elements, with four P elements, two M elements and nine S elements (Koike, 2016; Sun et al., 2020), while conodont elements of this study on bedding planes exhibit enrichments of M and S elements or shortage of P elements. This suggests that conodont elements are biasedly preserved even under near-still water, or that they have been differently affected by lithification (Cooper et al., 2006; Sessa et al., 2009). For example, clusters of the earliest Triassic conodont *Hindeodus* indicated that their P_2 elements were more difficult to access or preserve even in a deep-water environment (see Zhang et al., 2017 and their comments by Agematsu et al., 2018). On the other hand, in our material, elements show different resistances to sorting during the laboratory process of the acid-dissolving method. Compared with the conodont elements acquired from acid-dissolving, the ratio of S elements shows a significant decrease, while the ratio of M elements shows a slight or negligible decrease. It suggests that S elements have been affected by the acid-dissolving method. Through isolated conodont elements after the acid-dissolving method, Koike (2016) proposed the apparatus compositions of five species of Ellisonidae, and his materials also showed that their M and S elements were prone to be preserved better than P elements.

Length distributions of the conodont element from the two methods also suggest that their preservations are affected by multiple factors (Table 1 and Fig. 3). Before being affected by processes of acid-dissolving, M elements are averagely smaller than P and S elements, while S elements are the largest among them. This is different from some reported well-preserved assemblages of Ellisonidae, which showed that P elements are smaller than M elements and that S elements are the largest (Sun et al., 2020), suggesting that M elements of Ellisonidae are more fragile than P elements. In addition, research about the genus of *Idiognathodus* shows that their S and M elements were usually larger than their P elements (see Fig. 4 in Purnell, 1993), which is consistent with Ellisonidae. As stated by Orchard (2005), conodont elements exhibited a higher representative of pectiniform elements (which were usually P elements) when they were acquired from relatively nearshore, and/or high-energy deposits where bias arising from post-morterm sorting and selective destruction cannot be ignored. This might be explained by element heterogeneity mineralization. Or, this might have been caused by their morphologies, as M elements are breviform digyrate and bear two inclined downward processes, while P elements are crescent-shaped angulate (Sun et al., 2020). S elements are averagely smaller than P and M elements in the materials acquired from the acid-dissolving method, and the other types also show reductions in size by eliminating larger individuals (Fig. 3B). This suggests that conodont elements are influenced by the process of this method, even for the less vulnerable P elements. What is noticeable is that elements in the same position of different conodont species have variant endurances. For example, a Middle Triassic multi-element research of *Nicoraella germanica* indicated that P and M elements are over-represented (Table 1 in Chen et al., 2019).

Previous studies have shown that the size of the conodont element was an ideal proxy for ecological changes (Balter et al., 2008; Luo et al., 2008; Chen et al., 2013; Leu et al., 2019; Wu et al., 2019; Zhang et al., 2020). For example, diametrical or harmonious size-changing curves of conodont elements have been connected to transient or long-term ecological changes (Chen et al., 2013; Zhang et al., 2020). However, conodont elements may exhibit different size variation trends during the same interval (Leu et al., 2019). This might have been the result of their different responding mechanisms which are further connected to their different habitats (Joachimski et al., 2012; Sun et al., 2012; Leu et al., 2019; Chen et al., 2021). Although the size of the conodont element can be controlled by ecological factors, and bias coming from laboratory processes have a limited impact on their conclusions during the conodont apparatus reconstructions (Chen et al., 2016), it is still worth noticing that different degrees of influences may occur when data are used for different aims (Jeppsson, 2005). In this study, results showed that conodont elements might have experienced different degrees of artificial damage during the laboratory processes. Hence, attention must be paid when trying to decipher the conodont data for taxonomy, ecology, and so on, especially when conodont species have variant morphology of multi-elements.

6. Conclusions

Conodont elements (including clusters) (Ellisonidae) from the bedding planes of the Early Triassic Nanzhang-Yuan′an Lagerstätte as well as conodont elements acquired from the corresponding bed through the acid-dissolving method provide insight into the bias which have to be taken in account when trying to decipher the conodont materials. Conodont elements from the two methods all exhibit different kinds of bias, especially those from the acid-dissolving method. Owing to their different tolerances caused by different morphologies, conodont elements of Ellisonidae in different positions exhibit selective preservation or different degrees of destruction even before laboratory processes. The widely used acid-dissolving method increases the bias by selectively destroying the M and S elements. Large individuals of all three different elements are prone to be broken during laboratory processing, while the S elements are affected the most. This study indicates that biases of conodonts’ size and morphology caused by natural and artificial laboratory processes must be taken into account when deciphering these data.

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Conflict of interest The authors declare that they have no conflict of interest.

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Figure 1

Early Triassic paleogeographic re-construction and the location of the Zhangjiawan section, Hubei Province, South China (after Benton et al., 2013)

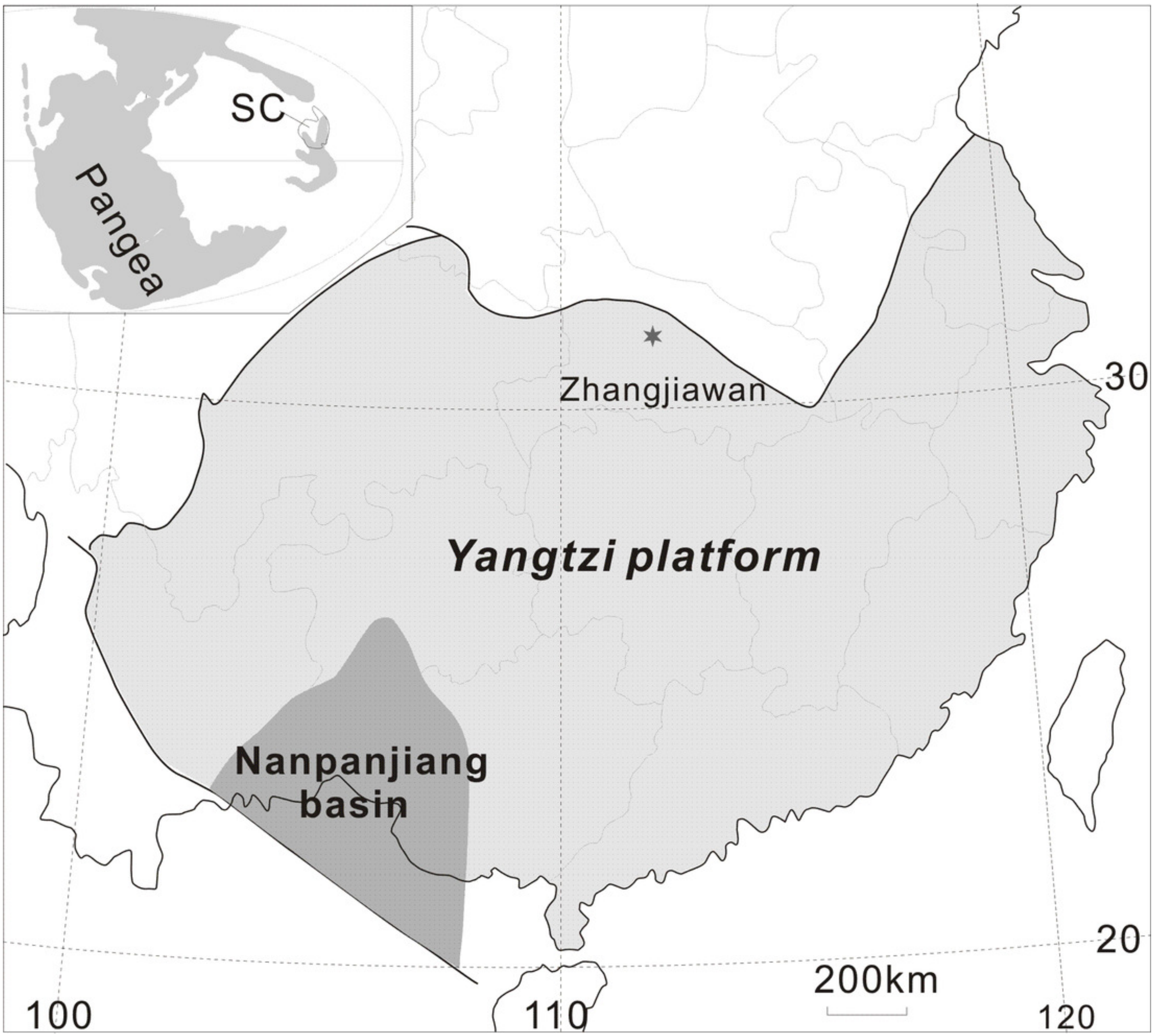

Figure 2

Conodont elements recovered from Zhangjiawan section, Yuan′an County, Hubei Province, South China.

(A) Dark-colored laminated limestone of the uppermost Jialingjiang Formation. The dashed line indicates the thinnest beds where the clusters were found. (B) Recovered conodont cluster after acetic acid dissolution. (C) Founded isolated conodont element from the bedding plane. (D, E and F) Founded conodont natural assemblage from the bedding plane. (G-N)Founded different isolated elements and clusters. (Also see the supplementary material of Wu et al., 2023)

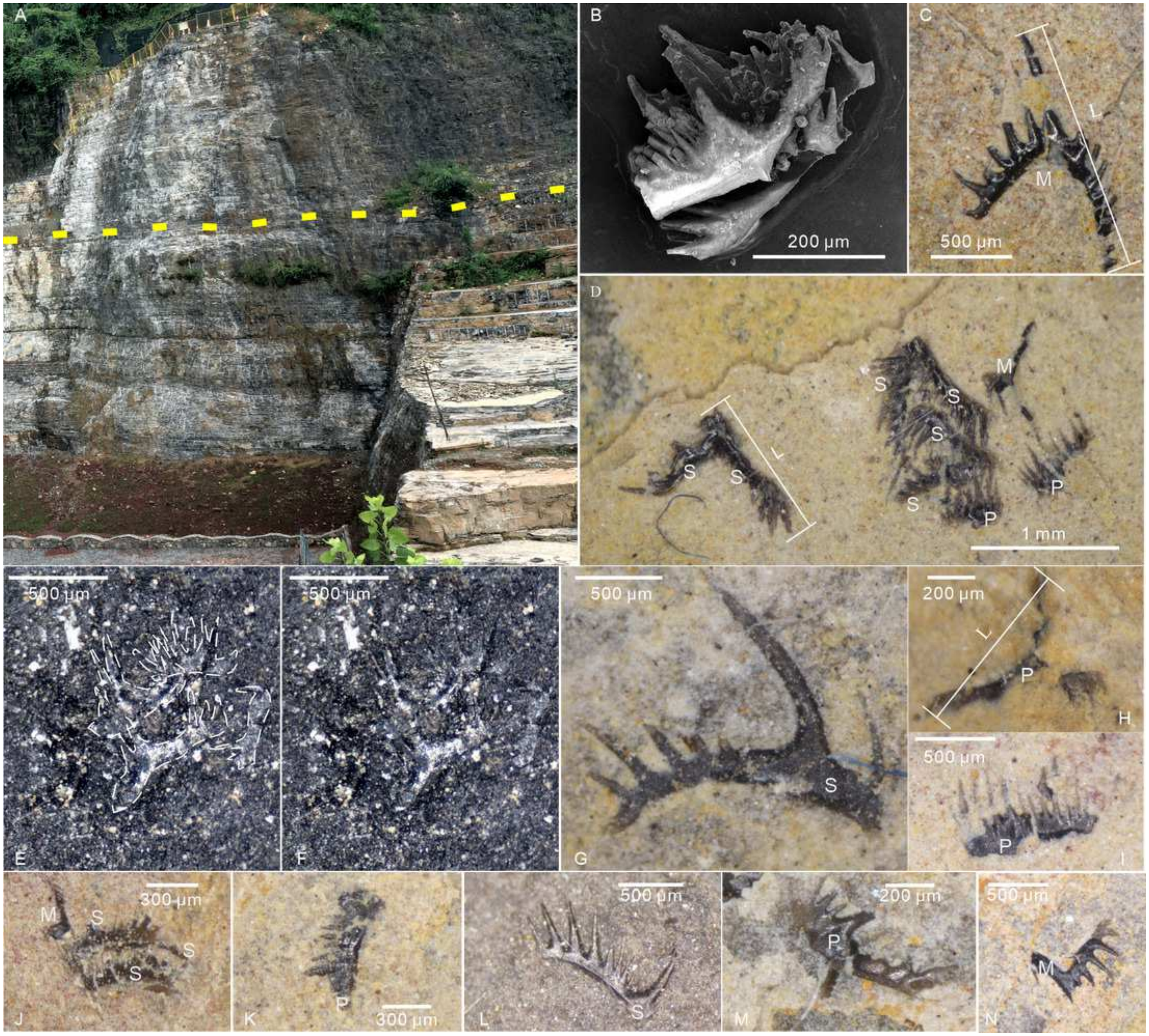
A
B
200 µm
C
L
M
500 µm
D
S
M
S
S
L
S
S
P
S
P
1 mm
500 µm
500 µm
500 µm
200 µm
L
P
H
E
F
S
G
500 µm
P
I
M
S
300 µm
S
S
J
P
300 µm
K
500 µm
S
L
200 µm
P
M
500 µm
M
N

Figure 3

Length distributions of different conodont elements.

(A) Length percentile plot of conodont P, M, S elements from bedding plane and dissolving residues. Note the gap between the Bedding-S elements and the others even after the logarithm of length. (B) Distributions of length for conodont P, M, S elements from bedding plane and residues after acid-dissolving.

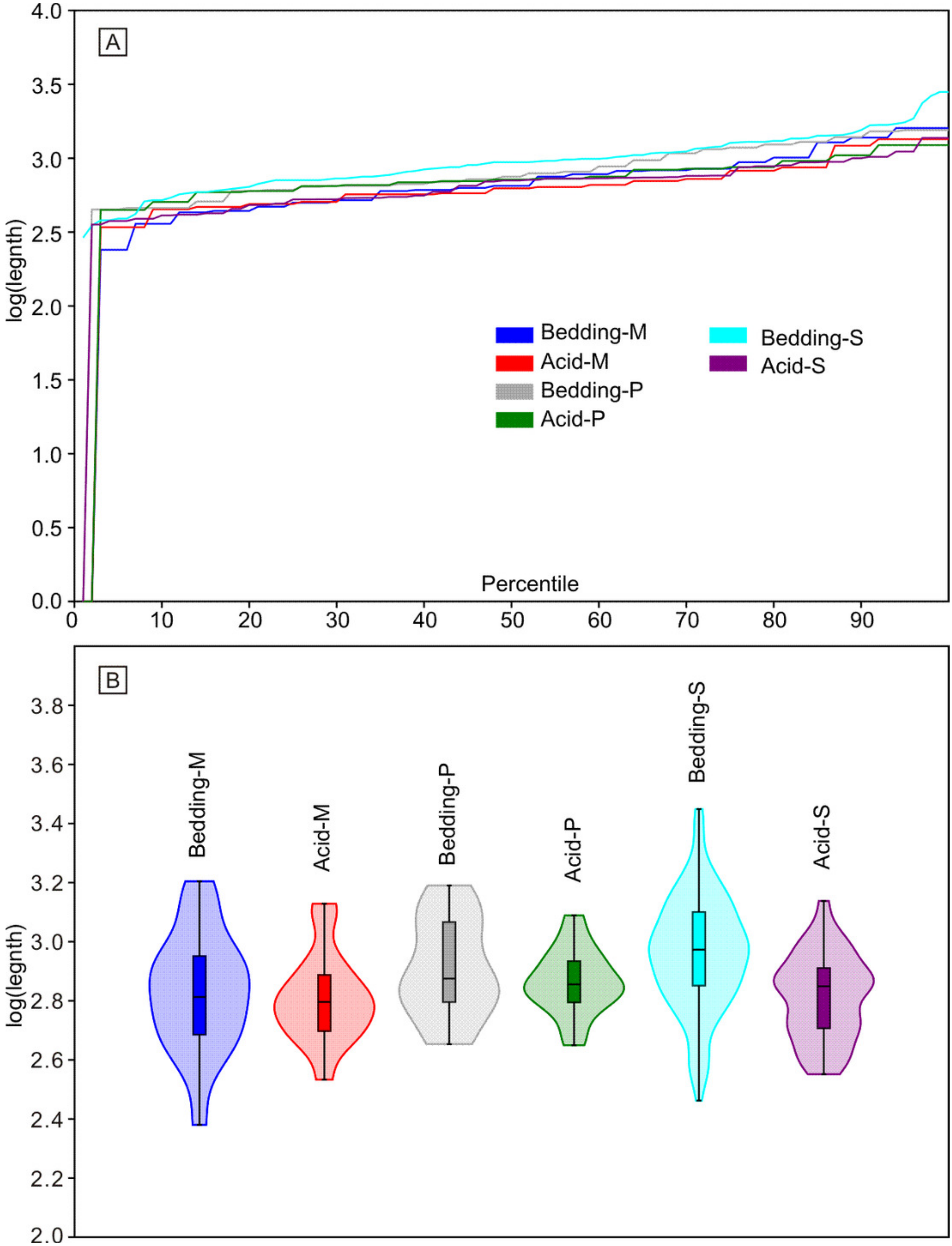
A
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
log(legnth)
Bedding-M
Acid-M
Bedding-P
Acid-P
Bedding-S
Acid-S
Percentile
0
10
20
30
40
50
60
70
80
90
B
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
log(legnth)
Bedding-M
Acid-M
Bedding-P
Acid-P
Bedding-S
Acid-S

Table 1(on next page)

Number, ratio, length range, length average of conodont elements and their differences.

1 Table 1. Number, ratio, length range, length average of conodont elements and their differences.

Acquiring way	Position/type	N	P	Ratio (P:M:S)	R (μm)	A (μm)	A* (μm)	*p*	*p**
Bedding Planes	P	25	14.90%	1:1.2:5.8	450 to 1550	868.4	948.4	0.21	<0.01
	M	21	12.50%		240 to 1600	747.1		0.51	
	S	121	72.40%		290 to 2810	999.9		<0.01	
Acid-dissolving	P	17	23.90%	1:1:2.2	447 to 1226	753.8	700.7	0.21	<0.01
	M	17	23.90%		341 to 1345	680.8		0.51	
	S	37	52.10%		356 to 1373	685.5		<0.01	

Note: P−Percentage; R−Range of length; A—Average of length; A*—Average of length (all elements); *p*—*p*-Value (contrast with the same type); *p**—*p*-Value (contrast with all elements)