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中国东南沿海硅藻常见的形态畸变特征及其  
与环境因子的关系研究

Common Teratological Forms of Marine Diatoms from  
Southeast China Sea: Morphology and Environmental  
Influence

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## 摘要

硅藻的细胞壁由上下两个硅质壳面形成,具有种间特异性的花纹,是硅藻分类学的重要依据。硅质壳的外形及花纹通常具有规则性的轮廓及排列方式,但在某些情况下,硅藻的硅质壳会发生一些形态上的改变,称之为硅藻的形态畸变或变形(deformation)。畸变可以表现在壳面的整体轮廓改变,也可能发生在壳面的孔纹、壳缝及各种附属结构上。导致硅质壳畸变的原因有多种,但硅质壳畸变的过程和机理尚不很清楚。

国外有关硅藻硅质壳形态畸变的相关研究大多集中在淡水硅藻方面,而我国这方面的研究报道几乎空白。基于此,本文依托国家自然科学基金项目“海洋硅藻硅质壳变形的特征与生态学机制”开展了初步的研究,取得了以下主要结果:

1.通过对在我国东南沿海采集的硅藻样品的观察以及对历史资料的整理分析,本文总结了自然环境下发生形态畸变的硅藻共15属27种以及3个未定种(含曾经有文献记录的种类8种),并对所有畸变种类进行了形态描述和图示。结果表明,自然海区中形态畸变的硅藻大多分布于近岸水体,提示畸变硅藻的出现可能与水体的污染有关。

2.整理了人工培养条件下产生形态畸变的硅藻共12属,20种,38个株系,对其进行了形态学描述和图示(其中包括曾经有文献记录的25个株系)。人工培养条件下,硅藻的畸变形式可分成三个大类:第一类畸变形式为单一型畸变,即仅发生壳面轮廓、壳面孔纹、壳缝、拟壳缝、壳面突起物等某一种畸变;第二类畸变形式则表现为混合型畸变;第三类为细胞群体组成方式的改变。人工培养条件下的硅藻形态畸变常表现为混合型。

3.修订了卡式缝舟藻(*Rhaphoneis castracanei*)及双角缝舟藻四角形变种(*Rhaphoneis ampiceros* var. *tetragona*)因形态畸变而被定义成新变种、新变型的分类学问题;

4.发现一个硅藻新纪录种 *Haslea ostrearia*,并对其正常形态与畸变的壳面形态进行了描述和图示。

5.在室内培养条件下探索了盐度、营养盐水平及 Cd 胁迫条件与几种硅藻的

硅质壳畸变的关系。研究结果表明，N、P、Si 营养盐限制均与奇异棍形藻和 *H. ostrearia* 畸变硅质壳的比例升高有相关性，高浓度的 Cd(大于 50 $\mu$ g/L)胁迫条件也会导致 *H. ostrearia* 畸变率的升高（10.02%~10.14%）。虽然本论文探讨了培养基中盐度对 *H. ostrearia* 生长的影响，但未发现盐度与畸变率有相关性。

6.比较了 4 种拟菱形藻同种不同地理株系形态畸变的差异。尽管多列拟菱形藻 (*Pseudonitzschia multiseriis*)、尖刺拟菱形藻 (*P. pungens*)、巴西拟菱形藻 (*P. brasiliiana*) 均表现出不同地理株系之间细胞形态畸变的部分差异，但规律性不明显。比较了三种硅藻（多列拟菱形藻、尖刺拟菱形藻、奇异棍形藻 (*Bacillaria paradoxa*)）在自然环境下与人工培养条件下细胞形态畸变的差异，发现人工培养条件导致的细胞畸变程度更为严重，形态更为复杂。

7.本文整理出了国内首个自然环境及人工培养条件下存在形态畸变的硅藻种类名录，为这些种类的正确形态分类提供了参考依据；同时初步分析了其产生畸变的潜在原因，为本领域的进一步研究奠定了基础。

**关键词：**硅藻，形态畸变，环境因子，东南沿海

## Abstract

Diatom cell wall is formed by the epitheca and hypotheca, the species-specific shape and ornamentation of the silicon cell wall is an important basis of diatom taxonomy. The outline of the shape and pattern of the striation have typical rules, but if exposed to different kinds of stress during reproductive processes, the diatom cell outline and striation pattern can change in different ways, producing teratological forms. Most frequently, diatoms present abnormal valve outline, distorted raphe system or abnormal striation pattern. The reason that cause teratological forms are more, but little is known about their mechanism.

Research about diatom deformities has been carried out, but mostly about freshwater diatoms. Study on diatoms deformities with marine diatoms from China has not been reported. Based on this consideration, the paper is a preliminary study on the deformed diatoms in China as a part of a research project relies supported by the National Natural Science Foundation of China (41076079).

1. Morphological observation of deformed diatoms was made with the samples collected in the southeast coast of China. Combined with the investigation of historical data and references, the article is aimed to summarize the teratological forms from natural environment. A total of 15 diatom genera, 27 species and 3 unidentified species of diatoms with teratological forms were reported in this paper (8 species were from reported references). The description of the deformity types was made for all of the taxa. It is shown that deformed diatom is usually distributed in the water close to land, which implies that water pollution may be correlated to the deformity.

2. Artificial culture can result in high rate of distortion of diatoms. In this paper, totally 12 genera, 20 species, 38 strains of diatoms with teratological forms were investigated (25 strains were based on reported references). Morphological description of teratological form of each taxon was made with LM and EM photographs and illustrated pictures. Diatoms distorted form can be divided into three categories, the first type of distortion in the form of a single type of distortion that only happen to the valve outline, or raphe system, or striation; the second type of distortion show mixed deformities; the third category is the composition of the cell chain changes. Generally diatom tends to have mixed type of distortion under artificial culture conditions.

3. The deformed frustles of *Rhaphoneis castracanei* and *Rhaphoneis amphiceros* var. *tetragona* used to be defined as a new variety and new form. In this study, we have corrected the taxonomic error based on the comparison of regular valves and deformed valves.

4. *Haslea ostrearia* is described in this paper as a new diatom record for China. The normal morphology and distortion morphology of the species was described.

5. Indoor culture experiment was designed to study the influence of water salinity, nutrient level and Cd stress conditions on diatoms and their potential relationship with teratological forms of several species of diatom. The study shows that the N, P, Si nutrient limitation has a correlation with the deformation rate of *Bacillaria paradoxa* and *H. ostrearia*; high concentrations of Cd stress (>50 µg/L) can lead to the increase of deformation rate in *H. ostrearia* (10.02%~10.14%). It is

indicated that high salinity can affected the growth of algal species, but does not reflect the correlation with the rate of deformation.

6. Morphological differences among different geographic strains of 4 species of *Pseudo-nitzschia* were compared. Although some distortion differences in morphology among different geographic strains of the 3 species of *Pseudonitzschia* (*P. multiseriata*, *P. pungens* and *P. brasiliensis*) have shown, the regularity is not manifest. There is a more serious and more complex deformation of 3 species of diatom(*P. multiseriata*, *P. pungens* and *Bacillaria paradoxa*) in artificial conditions compared with that in the natural environment.

7. This study is the first try in China about the deformation of diatoms. In this paper a list is given to summarize the domestic abnormal diatoms including morphological description and ecological distribution as well as photographs. As a basic research, this study suggests the fundamental information of diatom deformation foundation for further study in diatom taxonomy, morphology and ecological importance.

**Key words:** Diatom, Teratological forms, Environmental factors, Southeast China Sea

## 缩略词

LM:Light Microscopy 光学显微镜

SEM: Scanning electron microscopy 扫描电子显微镜

TEM: Transmission electron microscopy 透射电子显微镜

UV: Ultraviolet 紫外线

SCS:South China Sea 南中国海

ICP-MS: 电感耦合等离子质谱

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