Marine geology and geophysics

Silicoflagellates from Ocean Drilling Program leg 113: New fossil evidence of their variability

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The silicoflagellate species concept is problematic. Modern silicoflagellate populations commonly exhibit considerable skeletal variability, and biologists have emphasized this variability with taxonomies that have relatively few genera and species. Paleontologists, on the other hand, tend to emphasize the importance of relatively minor morphologic differences, which are commonly seen as representing distinct taxa. This has produced lengthy floral listings that may not show true biological relationships.

Silicoflagellate paleontologists split the taxonomy primarily because the skeletons can possess considerable morphological differences even though they are biologically the same (as is found in modern populations). Because there often can be no intermediates, such as between a five- and six-sided basal ring, such differences are sometimes seen in the fossil record as representing distinct species. Unfortunately, little is known of silicoflagellate variability in relation to specific natural environments and such ecophenotypic variability is difficult to assess in fossil assemblages.

Recent deep-sea drilling in the Weddell Sea by the Ocean Drilling Program has provided two unusual fossil examples of silicoflagellate variability. The first of these is a lower Pliocene assemblage of highly variable skeletons conspecific with *Distephanus speculum speculum* (Ehrenberg). These skeletons, however, possess a variety of bridged apical structures instead of the usual apical ring. The second assemblage, consisting of three species, is even more unusual and may represent the oldest silicoflagellates ever found; it might include the progenitors of all other silicoflagellates. One of these taxa is characterized by exceptional variability and is described in McCartney and others (in press) as a new genus, *Variramus*. The two examples are discussed below.

The pseudofibula plexus. In the lower Pliocene of Ocean Drilling Program (ODP) 113 sites 689B, 690B, 693A, 695A, 696A, 696B, and 697B is found an unusual assemblage of six-sided *Distephanus* lacking apical rings. The basal ring usually has six sides, but five- and seven- or more-sided forms also occur. The size of the skeleton itself, as well as the relative size and position of the basal spines, pikes, and struts, indicates a very close kinship with *Distephanus speculum speculum* (Ehrenberg) that occur above, below, and often within the *pseudofibula* interval. We consider them to be conspecific.

The apical structure of members of the *pseudofibula* plexus has exceptional variability. The assemblage is dominated by three morphologies (figure 1) in approximately equal abundance. The *pseudofibula* form (figure 1a) has a multi-element bridge that divides the skeleton into two similar halves. The *varians* form (figure 1b; 2a) is characterized by three skeletal elements that intersect to form a triple junction above the center of the basal ring. The *notabilis* form (figure 1c) has a semicircular multi-element bridge that is asymetrical with respect to the rest of the skeleton. In addition to these three morphologies, there are also the *pseudocrux* form, which has an apical ring of fewer elements than the basal ring, and the *pseudopentagonus* form with five basal sides. The latter two morphologies are relatively rare.

Members of the *pseudofibula* plexus have been illustrated numerous times in the silicoflagellate literature (see McCartney and Wise in press, for a review), but the relationships between them have not been studied in any detail. Both the abundance of the morphologies and the geographical spread of the ODP 113 sites indicate that these morphologies may be useful paleoenvironmental indicators. The morphologies have also been found in arctic waters of similar age and elsewhere in the geological record (see Locker and Martini 1987).

Variramus. A rich array of unusual silicoflagellates was found in Lower (Albian?) Cretaceous sediments of ODP holes 693A and 693B. Their morphologies show considerable variability and consist of hollow branching skeletal elements without apical or basal rings. The assemblage occurs in a greenish-gray, radiolarian diatomite (core 113-693A-44R) or diatom claystone

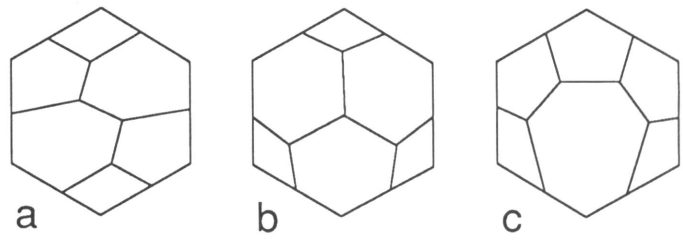

Figure 1. Line drawings showing three common skeletal morphologies of *Distephanus speculum speculum* found in the *pseudofibula* plexus: (a) forma *pseudofibula*, (b) forma *varians*, and (c) forma *notabilis*.

(core 113-693B-19X) that conformably overlies a thick sequence of organic-rich Lower Cretaceous mudstones (Aptian-Albian). Except for rare seven-sided *Vallacerta*, no other silicoflagellates occur in these units.

The taxon in question is characterized by extraordinary variability: The skeleton generally has a morphology similar to the apical ring of a four- or five-sided *Dictyocha*, although simpler and more complex morphologies also occur. Two specimens are illustrated in figure 2 (c and d) (an additional seven plates showing the range of variability are included in McCartney et al. in press). Despite their unusual morphologies and early age, there is little question that these are silicoflagellates, since they are of similar size and have spines, pikes, hollow elements, and simple configurations of triple junctions that are typical silicoflagellate traits (see McCartney 1988).

These silicoflagellates are similar in both their morphology and variability to specimens described by Deflandre (1950) as *Cornua aculeifera*. However, the original description of *Cornua* (Schulz 1982) is for trigonal morphologies of much less variability. The predominance of non-trigonal morphologies, the exceptional variability, and the early age have led McCartney et al. to place these forms into a new genus.

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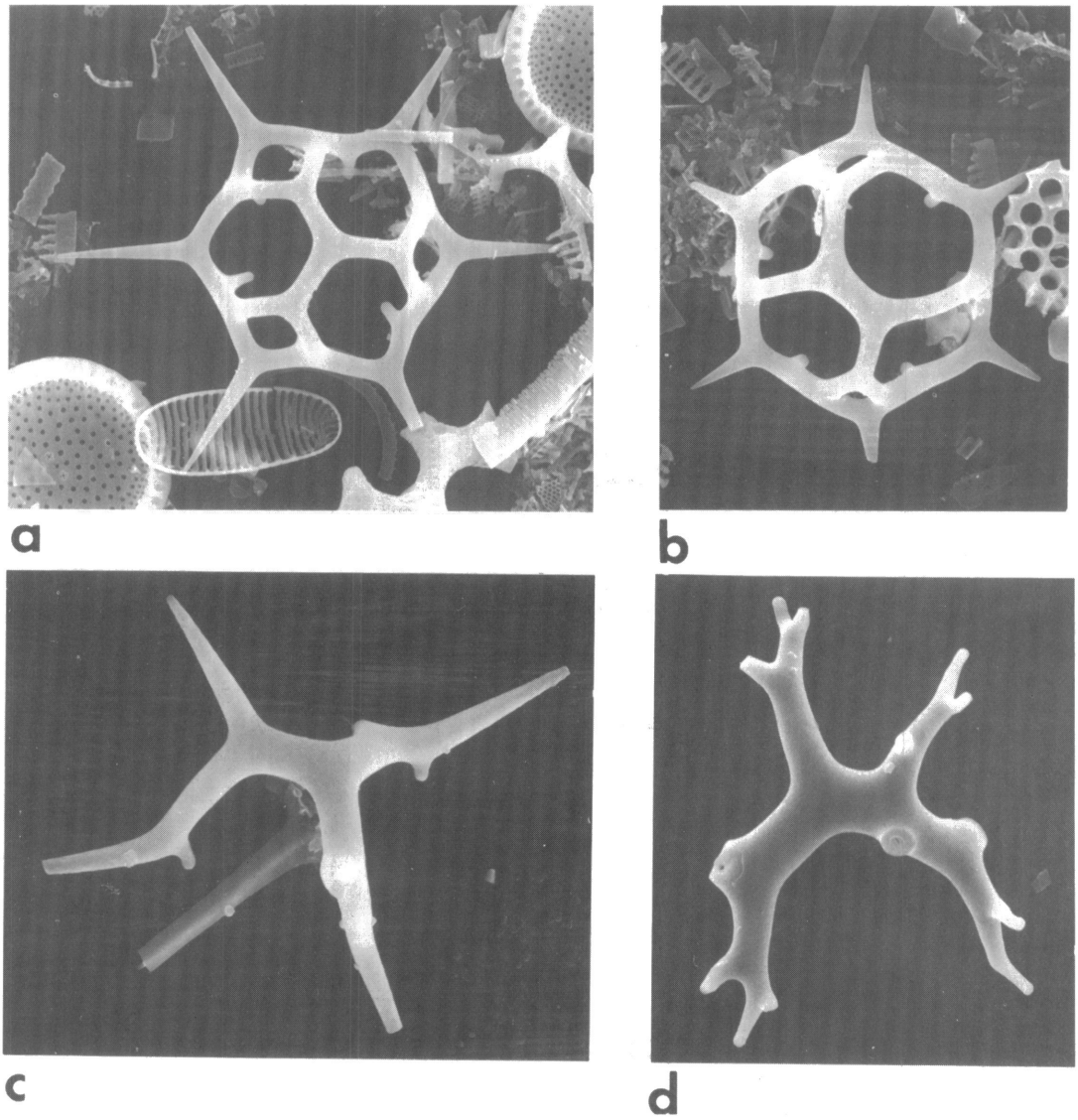

Figure 2. Scanning electron micrographs of unusual silicoflagellate morphologies (magnification 1,100×): (a) *Distephanus speculum speculum* forma *varians*, (b) *Distephanus speculum speculum* forma *pseudofibula*, (c and d) *Variramus aculeifera* (Deflandre).

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Onset of continental glaciation on East Antarctica as dated by nanoplankton

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The continental glaciation on East Antarctica is important, because it controls the world's climate and affects global sea levels. Before Ocean Drilling Program (ODP) leg 119, there was no unequivocal evidence for the beginning of continental glaciation on East Antarctica prior to the middle Miocene. The lower Oligocene glacial sediments recovered from the Ross Sea were tentatively believed to be the result of local glaciation; because the Ross Sea lies between East and West Antarctica, mountain glaciers from the Transantarctic Mountains could have reached it (Barrett, Hambrey, and Robinson in press). ODP leg 119 drilling in Prydz Bay has avoided this complication because Prydz Bay is unambigously East Antarctica, and it drains 22 percent of the east antarctic ice sheet.

About 500 meters of sediments were drilled at ODP site 739 in Prydz Bay (67°28.52'S, 75°76.59'E), and a sequence of glaciogenic sediments (figure) was recognized for the material recovered from top to bottom of the hole (ODP Leg 119 Shipboard Scientific Party 1988). Nanoplankton were rare or absent in most of the core-catcher samples examined on board; however, a well-preserved and diverse assemblage of calcareous nanofossils and three species of silicoflagellates were found in sample 119-639C-30R-1, 108–109 centimeters from 222 meters below sea floor. Calcareous nanofossils present in the sample include rare *Chiasmolithus altus, Reticulofenestra umbilica,* few *Chiasmolithus oamaruensis, Reticulofenestra hillae, Isthmolithus recurvus,* and abundant *Reticulofenestra daviesii.* Silicoflagellates found include rare *Corbisema triacantha triacantha, Dictyocha medusa,* and *Dictyocha fibula. Isthmolithus recurvus* has previously been used as a zonal marker in the zonations of Martini (1971), Okada and Bukry (1980), and Wise (1983). It ranges from late Eocene to early Oligocene (34.9–37.8 million years old in the time scale of Berggren et al. 1985). The ranges of other calcareous nanofossils are: *Chiasmolithus altus,* middle Eocene/Oligocene; *Chiasmolithus oamaruensis,* late Eocene/early Oligocene; *Reticulofenestra daviesii,* middle Eocene/Oligocene; *Reticulofenestra hillae,* middle Eocene/early Oligocene; *Reticulofenestra umbilica,* middle Eocene/early Oligocene (Perch-Nielsen 1985a). The ranges of the three silicoflagellate species found are not well known but they have been reported from Eocene/Oligocene sediments (Perch-Nielsen 1985b). All the nanoplankton (both calcareous and siliceous) present are well preserved and dispersed on different slides made from this sample. Special attention was paid to detect any reworking in the sample and no apparent evidence was found. Therefore, this sample can be assigned an age of late Eocene/early Oligocene (34.9–37.8 million years old). Underlying this sample are over 200 meters of glaciogenic sediments, which must be older than 34.9 million years. From the sedimentary characteristics, we can infer that ice was grounding near the site for most of the time as represented by the lower 200-meter sequence. From the fact that the drilled site is 170 kilometers from the present ice sheet front, we know that an ice sheet much larger than the present one existed in the earliest Oligocene and possibly earlier. Such a large ice sheet could not be local. Together with the glacial evidence observed in the Ross Sea and the early Oligocene ice-rafted debris found in the southern Indian Ocean (Barron, Larsen, et al. in press; Breza et al. 1988), we can conclude that major continental glaciation in East Antarctica had occurred by the earliest Oligocene.

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