

A new perspective of the central structure and the alignment of neogene discoasters

Rui O P Xa Gama

Shell International Exploration and Production Inc, USA; Rui.Da-Gama@shell.com

Osman Varol

Varol Research_USA, 5212 Sagesquare Street, Houston, TX77056, USA; osman@varol.com

ABSTRACT: With few exceptions, Neogene star-like Discoasters exhibit diamond shaped distal depressions (concavities) on radial elements. The concavities and the sutures they form appear to be primary morphological features observed on the distal side of the Discoaster. The concavities, sutures and the inner end of rays, bend and extend outwards to form processes (distal bosses). On the proximal side, the boss (when present), results from the inward merging of proximal ridges. Bosses are an integral part of the individual ray element and thus are not often observed in isolation within the sedimentary record. Herein we discuss the relationship between proximal and distal features observed on the centre of star-like Discoasters and speculate these may have been joined on 'male/female' structures comprising two or more Discoasters; on these structures the Discoasters rays are not aligned and seem offset or rotated. This offsetting suggests a mechanism that facilitates the interlocking and possibly the movement between proximal and distal structures.

Key Words: Nannofossils, Neogene, Discoaster, Structure

Introduction

Discoasters are the most important single group of Cenozoic nannoliths, ranging from the Paleocene to the Pliocene. The first illustrations of this *incertae sedis* group were made by Ehrenberg, 1854. In 1927 Tan introduced the term Discoaster for stellate or star-shaped nannoliths. Tan also proved the organic nature of these structures. The origin and the structure of Discoasters remains not fully understood as they are mostly recorded isolated in both SEM and LM preparations. Various authors have proposed reclassification or splitting of the genus *Discoaster*, e.g. Ehrenberg, 1854; Tan, 1927; Deflandre, 1954; Loeblich & Tappan, 1963; Prins, 1971; Theodoridis, 1984). Loeblich & Tappan (1963) validated the genus *Discoaster* by designating *Discoaster pentaradiatus* as the type species. Bramlette & Riedel (1954) paved the basis for exist-

ing taxonomy. Although there have been many publications discussing taxonomic aspects of the group little has been added to our understanding of their structure. Their concavo-convex curvature suggests disposition around a spherical organism but we cannot be certain whether they were intracellular or extracellular (Aubry, 1984). Stradner & Papp (1961) is an insightful work that explains the structure of Discoasters with illustrations but lacks in depth discussions and supportive evidence from real images.

The group includes a variety of morphologies with two main characteristics: radial symmetry in plan view and no birefringence on the polarising light microscope (with very few exceptions e.g. *D. pentaradiatus* and *D. quintatus*). Many Neogene Discoasters have concave and convex faces designated proximal and distal (Farinacci,

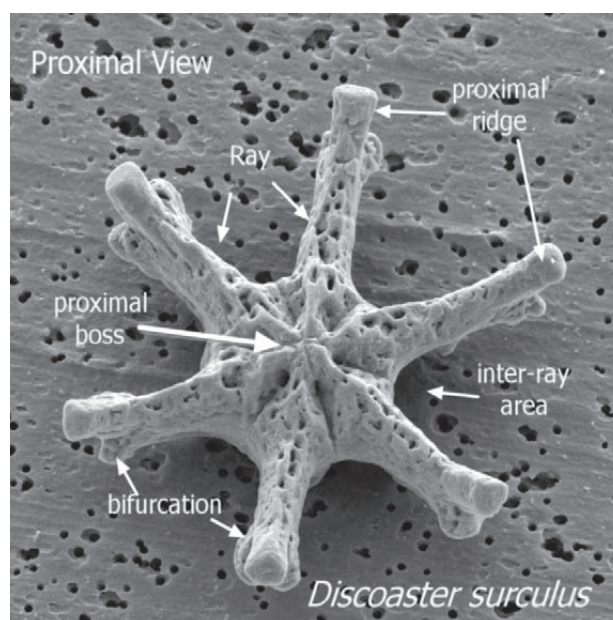
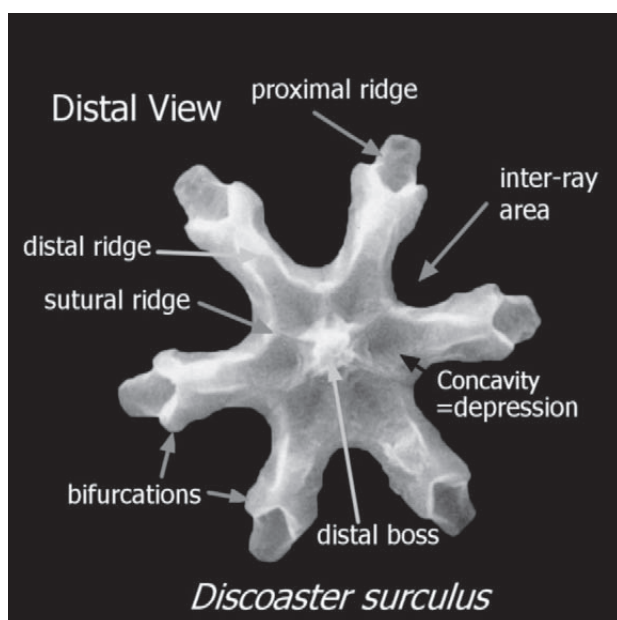


Fig. 1 & 2 Discoaster terminology herein. (Proximal view - picture courtesy of Dr. Jeremy Young). Note: In the natural settling position, the C axis of Neogene Discoasters (with the exception of *D. pentaradiatus* and *D. quintatus*) is nearly vertical to the microscope stage and appears non-birefringent.

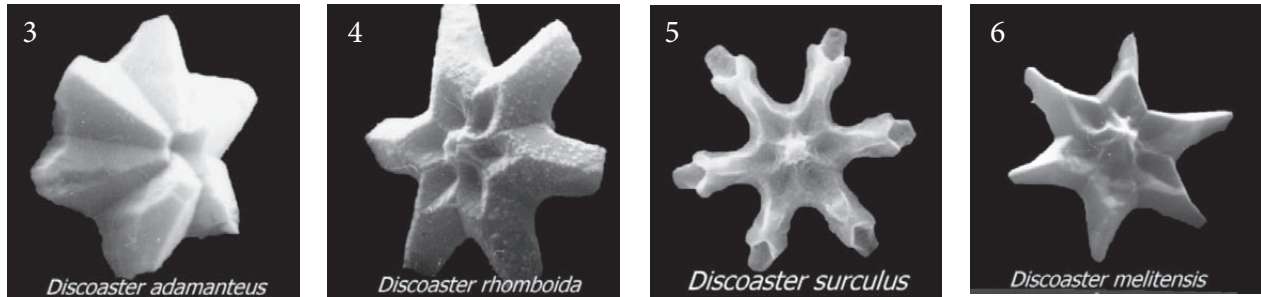


Fig. 3 Scanning Electron Microscope (SEM) image displaying the absence of concavity; Fig. 4-6 SEM images showing how concavity, sutures and boss are related and control the morphology of the central area in the distal side.

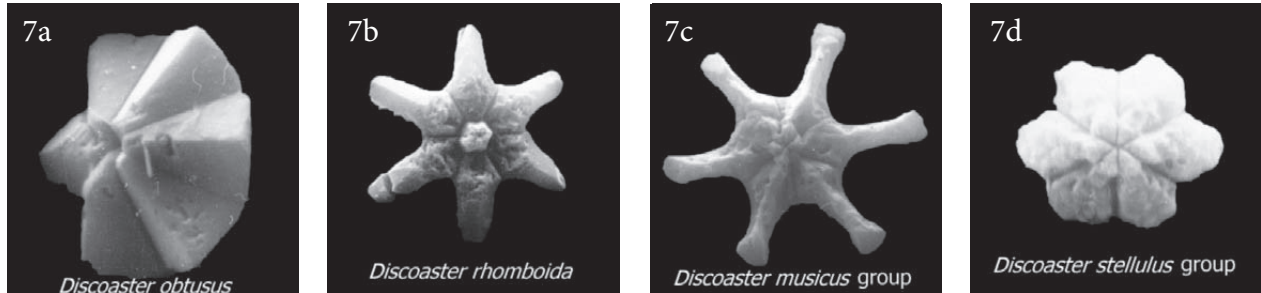


Fig. 7 (a-d): SEM images displaying the construction of central area.

1989). Their star-like structure is composed of wedge-shaped radially arranged elements or rays (Fig. 1) that converge to the centre of the Discoaster (Stradner and Papp, 1961; Aubry, 1984).

The number, shape and relation of these elements determine the overall outline of species. In addition, Neogene star-like Discoasters are classified using other structural elements as shown in Fig. 1 & 2, including: a) sutural ridges (sutures) on the distal side; b) the form of ray terminations; c) appendages protruding beyond the ray tips reflecting the extension of proximal ridges (visible from the distal side); d) ridges along the extension of the ray and a more or less prominent boss with a knob or star shape in the centre in both proximal and distal sides.

Discussion

Distal Side

With few exceptions (Fig. 3 & Fig. 7a) the centre of Neogene star-like Discoasters exhibit concavities (diamond shaped distal depressions) in the inner end of radial elements. The concavities are a consistent feature of the distal side and appear to control the overall shape of the cen-

tral area of most Neogene star-like Discoasters. The depth of the concavities determines how pronounced the sutural ridges are (Figs. 4-6; Fig. 9a-d). The concavities are a primary morphological feature for speciation frequently observed on the distal side. The sutural ridges converge towards the centre of the Discoaster where they meet and extend outward to form the central boss (Figs. 4-6 and Fig. 9a-d). The shape and size of the resultant boss (Fig. 9a-d) is a primary morphological feature for speciation.

Light microscopic images of single ray elements in side view Fig. 8 (a-e) show continuation or extension of the ray to form distal and proximal bosses. Although this idea is not new, no clear evidence from LM and SEM images and discussions were presented to support it. Herein we show that ray elements and bosses are part of a single unit rather than separate structures. In addition, SEM images (Fig. 7 (a-d)) show the continuation or extension of sutures through to the central process and confirm these are not separate structures but an integral part of the ray element. Isolated (broken off) bosses are very rarely observed, which provides further evidence for structural integrity. The evidence above supports structural observations by Stradner (in Stradner & Papp, 1961) and The-



Fig. 8 (a-e): LM images showing single ray elements containing both proximal and distal bosses indicating these are integral part of the ray. The bosses form at the inner end of the ray. On the side view of broken rays of Discoasters the C axis is not vertical to the microscope stage and thus the ray element are birefringent. With a gypsum plate, the c-axis is parallel to the gypsum slow ray and appears yellow (tangential c-axis).

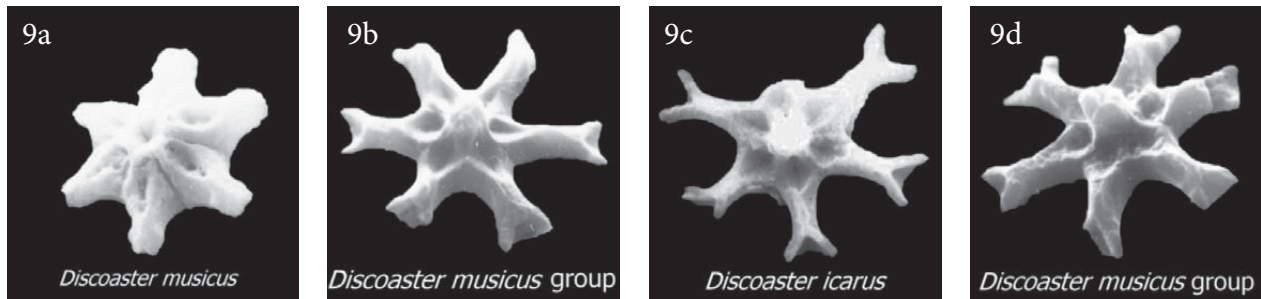


Fig. 9 (a-d): SEM images of the distal side with examples of deep concavities and distinct bosses.

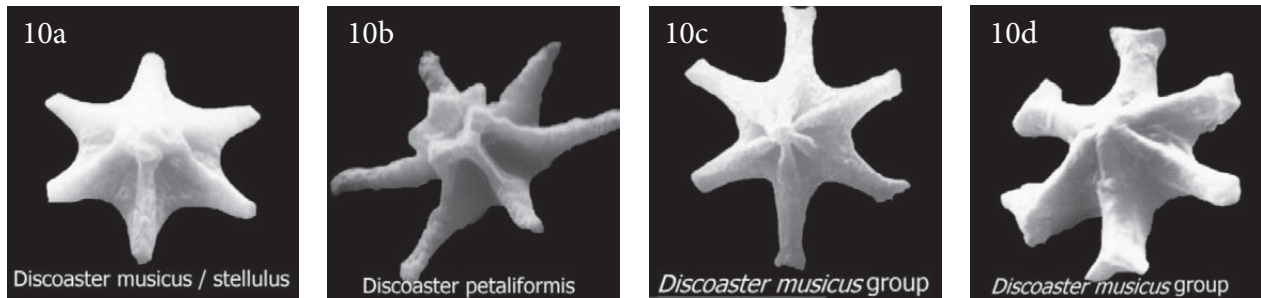


Fig.10(a-d): SEM images showing examples of proximal bosses and ridges

odoridis (1984). However, due to preservation factors, the extension of sutural ridges into the central boss is not always visible. Central boss structures vary considerably and may assume several shapes: flaring, stellate, slender or robust Fig. 9 (a-d), Fig.10 (a-e). The distal ridges are positioned between the outer end of the ray and the concavity and thus are often considerably shorter than the proximal ridges Fig. 9 (a-d).

Proximal side

The proximal side is characterised by the absence of concavities and the presence of more or less prominent ridges and a central boss. The proximal boss is formed via merging and thickening of proximal ridges (Fig.10 & Fig.11b).

Stack arrangement

On rare occasions, star-like Discoasters appear to be joined by their bosses to form chains or stacks of two or more Discoasters (Fig.12 a-c, Plate 1). Within these structures a preferential arrangement is inferred with the

proximal face of one Discoaster interlocking with the distal face of the adjoining Discoaster. The proximal, distal and sutural ridges together with concavities seem to facilitate interlocking, with a slightly offset or rotated junction necessary in order to lock adjacent structures. The proposed locking mechanism is supported by the disposition of structures on proximal and distal sides and by the offset rotation of the individual Discoasters in the chain structures observed in Fig. 12 (a, b, c) and in Plate 1. This mechanism possibly allowed some flexibility of movement within the chain arrangement.

The bosses appear to be structurally weak and preferential surfaces for splitting, and thus chains/stacks are rarely preserved. It is possible that Discoasters were crystallographically joined by the bosses through a weak 'calcite bridge' or more likely by an organic 'adhesive' possibly made of soft tissue.

Several nannofossil specialists occasionally indicate observing these structures in well preserved nannofossil rich samples, however, they prefer to overlook

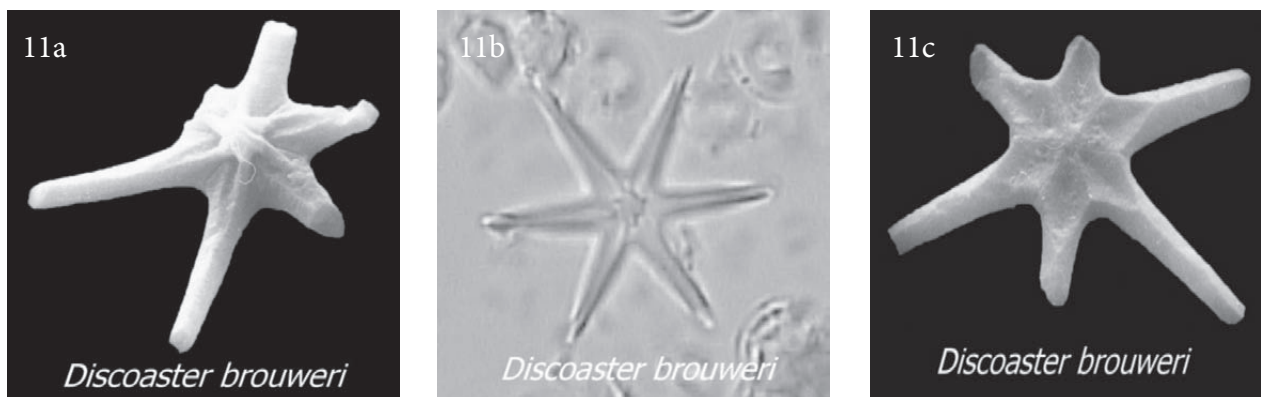
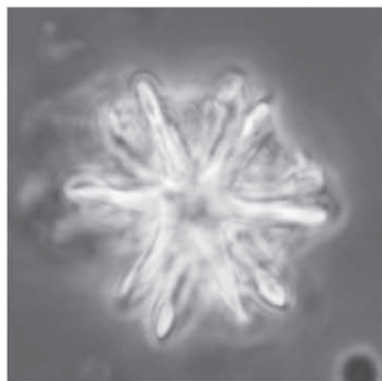


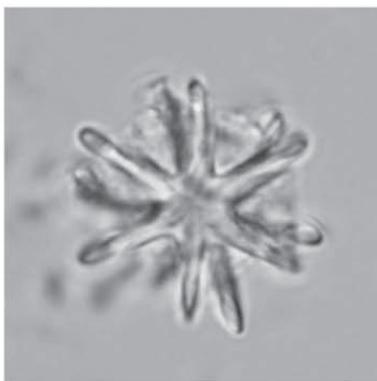
Fig.11(a-c) SEM & LM image showing *D. brouweri* displaying off-centre ridges.

Plate 1

Discoaster brouweri



1



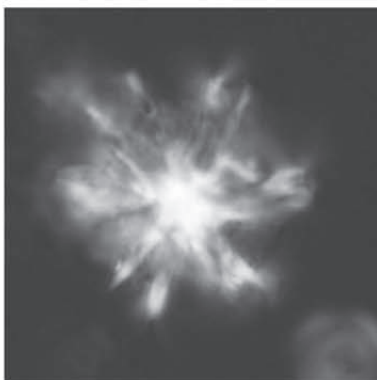
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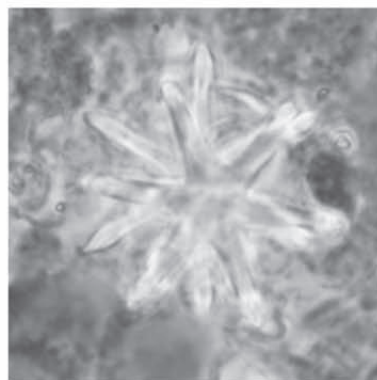
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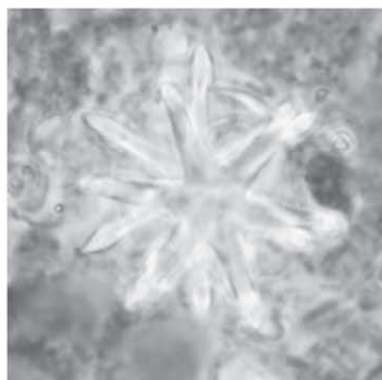
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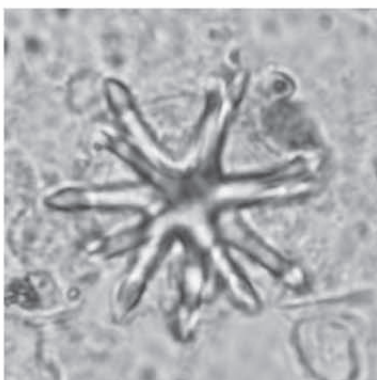
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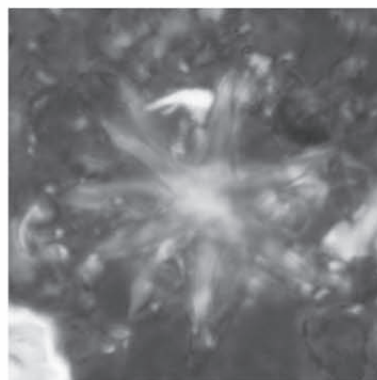
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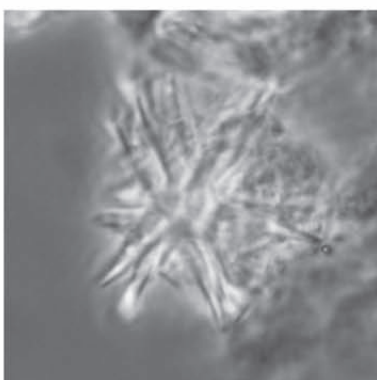
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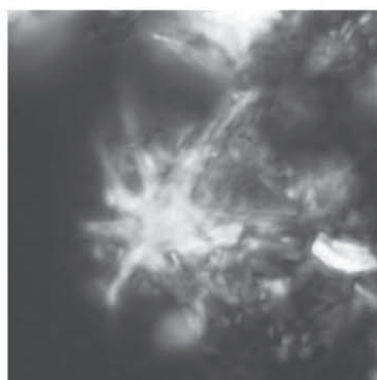
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10



11



12

10µm

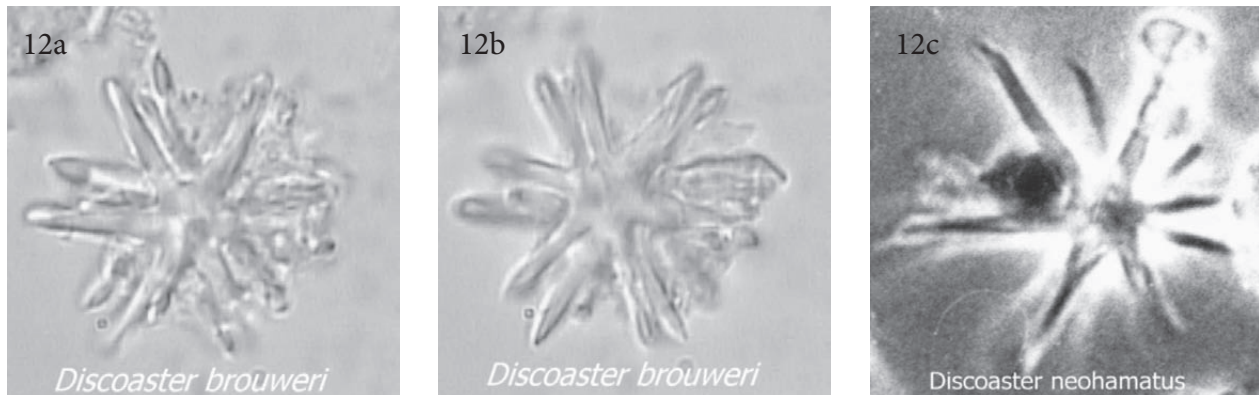


Fig.12(a-c) LM image showing chain arrangement of Discoasters.

(non age diagnostic) and consider them a random agglomeration of Discoasters. Further research will allow a better understanding of the mechanisms associated with the alignment of Discoasters.

Conclusions

We have shown that with few exceptions Neogene star-like Discoasters exhibit concavities (or depressions) in the inner ends of their ray elements. The concavities and the sutural ridges in between are primary morphological features for speciation and appear to control the overall shape of the central area on the distal side of most Neogene star-like Discoasters.

The central structure is formed via merging of individual ray elements and is not a crystallographically separate structure. This is confirmed by LM images of individual ray elements showing vestiges of proximal and distal bosses to be an integral part of the ray unit, and by SEM images showing the extension of the sutures through to the central process.

We demonstrated that star-like Discoasters are occasionally joined by their bosses (proximal surface against distal surface) in structures with two or more Discoasters. The Discoasters in these structures are not aligned and seem to show an offset rotation possibly reflecting the mechanism that facilitates interlocking and a certain flexibility to the structure. The bosses appear to be structurally weak and preferential surfaces for splitting, and consequently these structures are rarely preserved.

We aim to raise the awareness of these type of structures and possibly at fomenting further research in order to better understand the organism that produced the Discoaster.

Acknowledgements

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Recommendations

Due to rare observations of Discoasters in stack arrangements, we recommend, when possible, to record their occurrences and to post into a centralised database (e.g. Nannotax website).

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