

## **4 Morphological variability and adaptability in Egyptian Eocene ostracod species *Paracosta mokattamensis* (Bassiouni)**

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### **4.1 Abstract**

Microscopic observations as well as geometric morphometric analyses of specimens belonging to three previously identified species of the genus *Paracosta* Siddiqui (*P. mokattamensis*, *P. humboldti* and *P. ducassae*), from the middle Eocene of Egypt, led to conclude that these three species should be considered as three morphs of one species (*Paracosta mokattamensis* (Bassiouni)). The results reveal that the use of quantitative shape analyses is the most powerful tool for differentiating forms within the species exhibiting shape polymorphism in their life cycles. Nonetheless, the microscopic observations of the different characteristics of the organisms should be a helpful tool in identifying the ornamental polymorphism. The study of the environmental and geographical distribution of *Paracosta mokattamensis* MTA and its two related morphs (MTB, MTC) could interpret the lack of economic phosphate deposits in the Paleogene of Egypt, the Middle East and North Africa. This study exemplifies adaptability as a parallel way to migration for organisms to survive.

**Keywords:** Adaptability, polymorphism, geometric morphometrics, *Paracosta mokattamensis*, Eocene, Egypt.

### **4.2 Introduction**

The relationship between *Paracosta mokattamensis* (Bassiouni) and *Paracosta humboldti* (Bassiouni) and its related form: *Paracosta ducassae* (Bassiouni et al.) was unknown for a long time since 1969 until Boukhary

et al. (1993) tried to find out a clear relationship between the last two forms. These authors, in their study on the middle Eocene ostracods of Mingar El Rayan in Fayoum, arrived at the conclusion that *P. ducassae* is nothing more than a morph of *P. humboldti*. However, for no reason, they mentioned their specimens as a subspecies of *P. humboldti* ( e.g. *P. humboldti ducassae*) in their explanation of the photographed specimens. In 2002, Elewa stated that *P. ducassae* (see Bassiouni et al. 1984 for the systematic description) is a synonym of *P. mokattamensis* and the later species together with *P. humboldti* are two morphs of the same species. He attributed this type of polymorphism to the ornamental polymorphism of Reyment (1988) in which the irregularly ornamented morph (*P. humboldti*; MTB in the present study) possesses a more bluntly rounded posterior end than the other morph (*P. mokattamensis*; MTA in the present study). It is worth mentioning that *P. mokattamensis* was recognized from the Nile Valley, however the other two forms were from Fayoum. In general, all the above mentioned studies did not spot the light on the quantitative shape differences of the forms under scope of the present work.

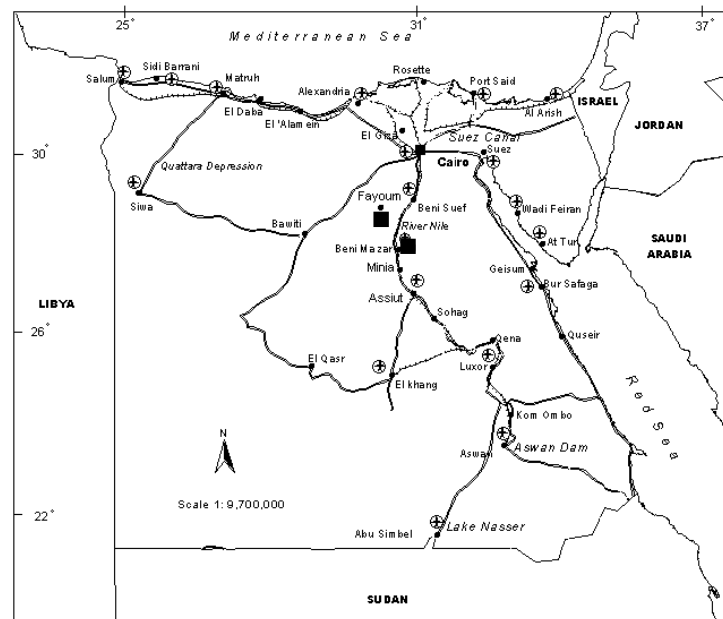
The aim of the present study is to differentiate between shapes of these related forms by means of geometric morphometrics to establish whether there is an adequate shape variation between these forms leading to separate them into three different species, as it was believed earlier, or there is a type of polymorphism that leads to assign the studied forms to one species with different morphs. Moreover, the environmental and geographical distribution of these forms will be discussed hereafter.

To achieve the aim of this study the thin plate spline and relative warps analyses were applied. The thin plate spline method is based on analogy of a 2D morphological object to a thin homogenous deformable metallic plate (Bookstein 1989, 1991); thus one specimen is fit to another by its stretching, and the numerical estimate of degree of such a smooth deformation is the *bending energy* coefficient.

The shape variation encompasses two components, an affine (uniform) part and non affine (non uniform) part (Bookstein 1991). In the affine change, the orthogonality of principal axes is preserved, and parallel lines remain parallel, like the deformation of a square into a parallelogram or a circle into an ellipse. The non affine change is represented by the residual of size-free change that remains after the difference due to any affine change has been subtracted from the total change in shape, for example, when an initially flat object is twisted or warped. For some examples on the method I refer the reader to Reyment (1993, 1995a, b and 1997), Reyment and Bookstein (1993) and Reyment and Elewa (2002).

### 4.3 Material and measures

The studied material was collected by the author from two different areas (Fig. 1): one section opposite to Beni Mazar city on the eastern side of the Nile Valley, about 60 km north of Minia city (for *P. mokattamensis*); and two sections from Wadi El Rayan, about 100 km south of Fayoum in the Western Desert (for *P. humboldti* and *P. ducassae*). Table 1 shows the lithology of the three sections from which the studied material was collected.

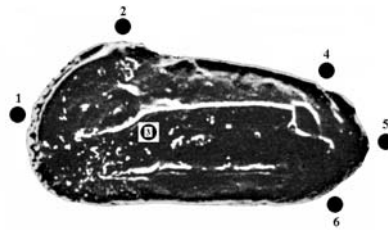


**Fig. 1.** Location map of the studied forms. Big black squares show the locations from which the author collected the studied forms

Eighteen well-preserved, adult specimens from the studied ostracod species (10 males and 8 females; 10 specimens of *Paracosta mokattamensis*; 4 specimens of *P. humboldti*; and 4 specimens of *P. ducassae*) were selected for the morphometric analyses. Six landmarks were selected on the left views of carapaces, or otherwise the right views of carapaces were rotated by 180 degree to be compatible with the left views of carapaces, for the thin plate spline and relative warps analyses (Fig. 2): the mid-point along the anterior margin (no. 1), the location of the eye tubercle (no. 2), the location of the adductor area (no. 3), the contact

**Table 1.** The lithology of the three sections from which the studied material was collected

Morph	Age	Section and lithology
MTA ( <i>Paracosta mokattamensis</i> )	Middle Eocene (Lutetian)	El Sheikh Fadl section, on the eastern bank of the Nile Valley, opposite to Beni Mazar city, about 60 km north of Minia city; chalk-marl complex
MTB ( <i>Paracosta humboldti</i> )	Middle Eocene (Lutetian)	Two sections at Wadi El Rayan, about 100 km south of Fayoum, Western Desert; sandy marl to sandy shale facies
MTC ( <i>Paracosta humboldti ducassae</i> )	Middle Eocene (Lutetian)	Two sections at Wadi El Rayan, about 100 km south of Fayoum, Western Desert; sandy marl to sandy shale facies

**Fig. 2.** Sketch showing the locations of the six landmarks used in the present study. Figure is based on MTC (photomicrograph after Boukhary et al. 1993)

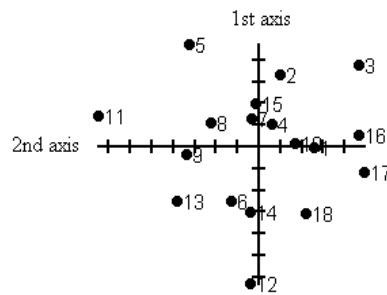
#### 4.4 Geometric morphometry

##### 4.4.1 The relative warps analysis

The program of the relative warps analysis was written by F. J. Rohlf (1998b), version 1.2.

### Non affine shape differentiation in the three forms

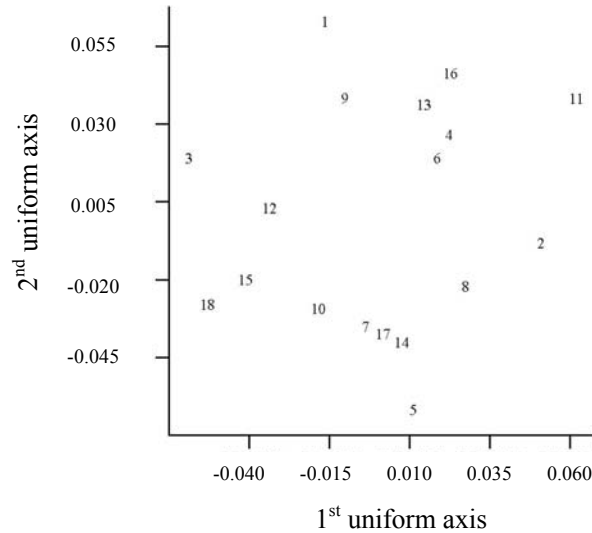
The ordination for the 1<sup>st</sup> and 2<sup>nd</sup> warps (Fig. 3) is the representation of the non affine (= non uniform) shape variation. The first singular value for these data constitutes 39.60% of the variance, the second one comprises 28.13% of the variance, thus, more than 67% of the variance is included within the first two relative warps which are sufficient for interpreting the shape variation within the studied data. Figure 4 indicates that the 1<sup>st</sup> relative warp has a tendency to separate most specimens with subrectangular shape (at the upper section; like 2, 3, 5, 15) from those with ovate shape (at the lower section; like 6, 12, 13, 14, 18). On the other hand, the 2<sup>nd</sup> relative warp separates most specimens with symmetrical anterior margin (at the left; like 5, 8, 9, 11, 13) from those with asymmetrical anterior margin (at the right; like 3, 16, 17). It seems that the 2<sup>nd</sup> relative warp exhibits a polymorphic character in the studied forms.



**Fig. 3.** Ordination by the non-affine shape components for the three studied forms. 1-10: *Paracosta mokattamensis*, 11-16: *P. humboldti*, 17-18: *P. humboldti ducassae*

### Affine shape differentiation in the three forms

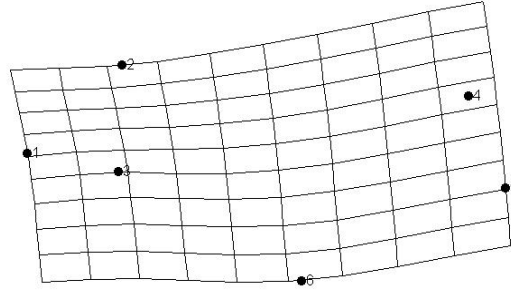
Figure 4 shows the plot of the 1<sup>st</sup> vs. 2<sup>nd</sup> uniform axes. From this figure, It is clear that the 1<sup>st</sup> uniform axis could separate between the forms exhibiting acutely triangular posterior margin (at the left; like 3, 12 15, 18) from the forms with obtusely triangular posterior margin (at the right; like 2, 4, 8, 11, 16). The 2<sup>nd</sup> uniform axis differentiates most females (at the upper section; like 1, 3, 6, 9, 11, 13, 16) from most males (at the lower section; like 2, 5, 7, 8, 10, 12, 14, 15, 17, 18). As it was expected, the affine projection could provide additional information about the relationship between the studied forms.



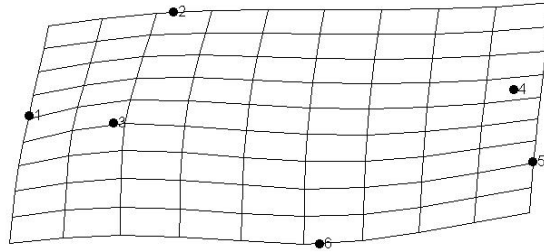
**Fig. 4.** Ordination by the affine shape components for the three studied forms. Numbers are same like Fig. 3

#### 4.4.2 The thin plate spline analysis

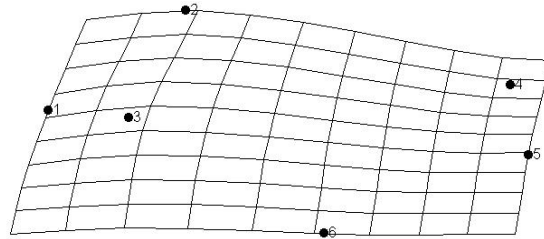
The program used for the thin plate spline analysis is that of F. J. Rohlf (1997), version 2.13. This technique is a graphical representation of mapping from one shape to another. Left views of three males of *P. mokattamensis*, *P. humboldti* and *P. ducassae* (one specimen for each) were considered as typical (reference) specimens for the analysis. Figure 5 portrays the mapping of the non affine case of *Paracosta mokattamensis* (MTA in the present study) into *P. humboldti* (MTB in the present study). The deformation is not so strong and the bending energy is 0.04684. Both the dorsal and ventral zones are affected. Figure 6 displays the warp of MTA into *P. ducassae* (MTC in the present study). The bending energy is weaker than the previous case and equals 0.03706. The figure shows that the ventral margin is more affected than other sides. From Fig. 7, showing the warp of MTB into MTC, it can be noticed that the deformation is weaker than the previous two cases with bending energy equal 0.01625. The dorsal zone is more affected than other sides.



**Fig. 5.** The non affine deformation for the comparison between MTA and MTB



**Fig. 6.** The non affine deformation for the comparison between MTA and MTC



**Fig. 7.** The non affine deformation for the comparison between MTB and MTC

The three comparisons indicate that the similarity of MTB to MTC is stronger than that of MTA to MTC. In the mean time, the similarity of MTA to MTC is stronger than that of MTA to MTB. In other words, MTC could be a transitional form between MTA and MTB.

#### 4.5 Discussion and conclusions

The genus *Paracosta* was introduced to science by Siddiqui (1971) from the Eocene of West Pakistan to represent those forms with normally developed four longitudinal ridges and reticulation on the lateral surface of the carapace. This genus is perhaps the most characteristic taxon of the epicontinental seas of the southern Tethys (Keen et al. 1994). The importance of this genus in Egypt is due to its occurrence from the Maastrichtian to middle Eocene representing some distinct phylogenetic trends, and the short stratigraphical ranges of some of its species, hence, they could be used as zonal markers. For detailed discussion on the biostratigraphical, paleogeographical and evolutionary significances of this genus, see Elewa (2002).

For the present work, the author examined several specimens of the studied forms of this genus, using the microscopic observations as well as the morphometric analyses, and could separate these forms into three different forms within a single species that is *Paracosta mokattamensis* (the first recognized form by Bassiouni 1969b from Gebel Mokattam, at the east of Cairo).

According to the microscopic observations (Fig. 8), MTA is ovate to subrectangular in outline, however, MTB is subrectangular. The median rib in MTB is branching and gives rise to a small riblet, but in MTA it ends at the muscle node. However, in some specimens of MTB the median rib is stopped at the muscle node indicating a transitional form between these two forms. Moreover, MTB has a curved eye rib connecting the eye tubercle to the median rib while it is absent in MTA. On the other hand, the median rib in MTB possesses a depression at the anterior end which is lacking in MTA and MTC. Also, the surface is smooth in MTA and MTC, but it shows transverse riblets in MTB. It is clear that the microscopic observations could successfully define the ornamental polymorphism of Reyment (1988) in the studied forms.

In the mean time, the geometric morphometry led to some important results:

- \* The 1<sup>st</sup> non affine relative warp axis could separate most specimens with subrectangular shape from those with ovate shape. In fact, not all specimens of MTA show an ovate outline but some show subrectangular outline like MTB. This leads to a somewhat overlap between the two morphs.

- \* The 2<sup>nd</sup> relative warp axis separates most specimens with symmetrical anterior margin from those with asymmetrical anterior margin. This could be attributed to the shape polymorphism (type 1) of Reyment (1985) in



which the swung rounded anterior is opposed to the regularly rounded anterior margin.

**MTA**



**MTB**



**MTC**



**Fig. 8.** Photomicrographs of the three studied forms (after Bassiouni 1969b for MTA and MTB; after Boukhary et al. 1993 for MTC)

\* The 1<sup>st</sup> uniform axis could separate between the forms showing acutely triangular posterior margin from the forms with obtusely triangular posterior margin.

\* The 2<sup>nd</sup> uniform axis could differentiate most females from most males, or in other words it could detect the sexual dimorphism within the studied forms.

\* The thin plate spline analysis led to the conclusion that the similarity of MTB to MTC is stronger than that of MTA to MTC. Meanwhile, the similarity of MTA to MTC is stronger than that of MTA to MTB. In conclusion, MTC is presumed in the present study to be a transitional form between MTA and MTB.

Paleoenvironmentally, as I mentioned above, *P. mokattamensis* was recognized from the Nile Valley, however the other two forms were from Fayoum. By tracing the environmental conditions under which these forms were distributed, it was found that *P. mokattamensis* is a member of ostracod association representing shallow water conditions in the Maghagha Formation of the Nile Valley. On the other hand, during the deposition of the Qarara Formation in the Nile Valley (= Midawara Formation in Fayoum), the area was subjected to shallow water conditions during the interval of *Acarinina aspensis* Zone to *Morozovella lehneri* Zone of early middle Eocene, and saw a transient shift toward outer shelf or deeper environments in the latest period, in the interval of *Truncorotaloides rohri* Zone of late middle Eocene (see Elewa and Ishizaki 1994; Nishi et al. 1994; Elewa et al. 1995). Therefore, the gradual change in reticulation expressed by the increasing prominence of the longitudinal ridges (from degradation to aggradation according to Peypouquet et al. 1986; in other words, from weak ornament to strong ornament) from *P. mokattamensis* (MTA in the present study) to *P. ducassae* (MTC in the present study) to *P. humboldti* (MTB in the present study) may be related to a gradual increase in depth from shallow to deeper and in salinity (the saturation of CaCO<sub>3</sub> in the water) from reduced to normal (environmentally induced polymorphism).

Paleogeographically, the species under consideration represents a group of ostracods that is the most characteristic taxon of the epicontinental seas of the southern Tethys (Keen et al. 1994). Al Sheikhly (1981) believes that there is a close relationship between the geographical distribution of *Paracosta* and the Paleogene phosphate belt running from the Middle East through North Africa. At the same time, Peypouquet et al. (1986) are convinced that the aggradation-degradation phenomenon should be related to physico-chemical conditions prevailing at the water/sediment interface immediately preceding phosphate deposition, and in general to be related to upwelling of deeper water on to a shelf with protected bays. In contradiction, the studied *Paracosta* species and its morphs either inhabited a shallow water environment as a whole, during their life cycles, or show a distinct adaptability with the vertical change in depth from

shallow to deeper environments. This may interpret the lack of economic phosphate deposits in the Paleogene of Egypt as well as the same interval of the surrounding areas of the Middle East and North Africa. In general, it seems that the studied *Paracosta* species is pandemic and tends to adapt to changes in depth and saturation of  $\text{CaCO}_3$  in the water through the ability to exhibit polymorphism during its life cycle. On the other hand, the ancestor of this species (*Paracosta mokattamensis praemokattamensis* Bassiouni, according to Bassiouni and Elewa 1999) is possibly an endemic species and was recorded by Bassiouni (1969a) from the Eocene of Jordan. Nevertheless, auxiliary studies of the geographical distribution of the latter species is needed to demonstrate its routes of migration.

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