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EXPLORING ANCIENT SHELLFISH PATHWAYS: A MORPHOMETRIC PERSPECTIVE ON THE SMOOTH SCALLOP *FLEXOPECTEN GLABER*

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Background

The smooth scallop *Flexopecten glaber* is an endemic species of the Mediterranean Sea. Its biology is not yet well understood, but it is a free-living shellfish that lives on sandy or grassy bottoms in waters no deeper than 80m.

From the Roman Period onwards, populations of Narbonnese Gaul made it one of the most consumed marine species along with the flat oyster *Ostrea edulis* (Bardot & Forest, 2013). These two seafoods from the coast have been carried to the hinterland and can archaeologically be found up to 300 km from the coast.

Archaeologists are still struggling to define the routes and methods by which Romans managed to transport shellfishes in an acceptable state of freshness. To trace the geographical origin of inland shellfish, we first explored the morphological variations between populations of the various lagoons where they are likely to have been caught.

To this end, we began by analysing the biogeography of the smooth scallop from the Antiquity to the Middle Ages in the Gulf of Lion. We used geometric morphometric analysis to quantify the shape of archaeological valves.

Material

Smooth scallops are composed of two non symmetrical valves. We focussed on the right valve which is less swollen and has a large byssal indentation making it easier to cut out. A total of 729 right valves were studied. They come from 16 archaeological sites inhabited between the 1st and the 14th centuries.

Found in 76 stratigraphic contexts, the shellfish have been grouped into 27 samples. These conchylian samples were divided into 3 periods (Roman period, Late Antiquity, Middle Ages) and 5 regions, defined on the basis of the lagoon to which they are the closest (fig. 1).

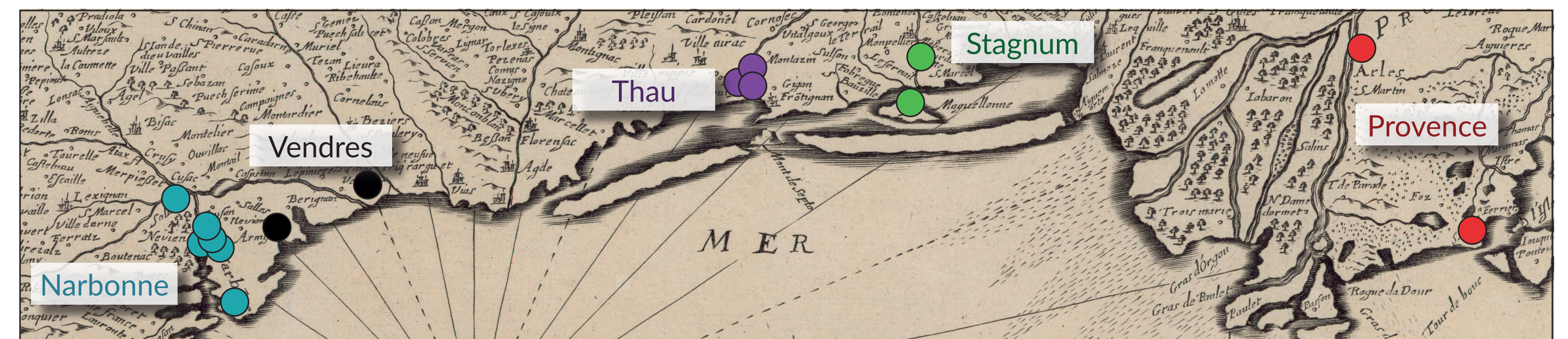
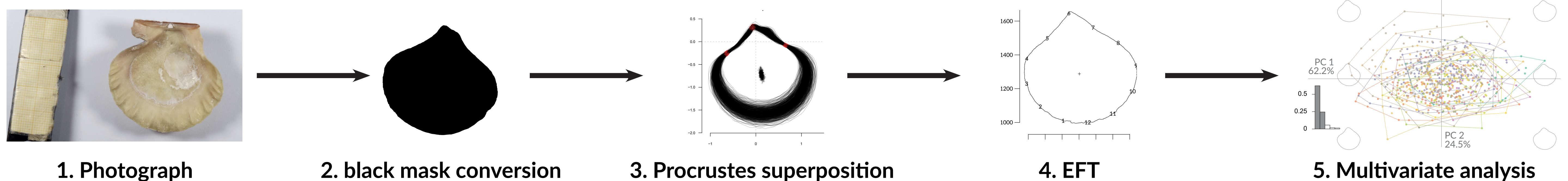


Fig. 1 - Location of sites, classified by region, where the studied samples were discovered (map N. Langlois, *Millaria Gallica*, 17th c.).

Methods

We used geometric morphometrics through Elliptic Fourier Transforms (EFT) to quantify the morphology of the valves. The quantification of the outline of the valve was obtained through the following protocol (fig. 2).



1. Photograph
The right valves were placed on plasticine according to a standardised protocol with strict positioning of the valve, inner side facing upward with anterior and posterior margins positioned parallel to the lens. Thus, inner faces were photographed using a Nikon d90 LSR camera paired with a 60 mm macro lens.

2. black mask conversion
The background of each photograph was removed and the shell image converted to a black mask using Adobe Photoshop CS6 software. Because auricles are fragile and generally fragmented on archaeological specimens, they were manually erased from the images.

3. Procrustes superposition
On the outline of each mask, 360 x,y coordinates were automatically extracted using R (v. 4.1.3) and the Momocs package (v. 1.4.0, (Bonhomme et al. 2014)). The coordinates of 3 landmarks were manually acquired and used during the superimposition. They are localised at the apical tip of the internal ligament and at both ends of the hinge line. Position, orientation, and size were standardized by a Generalized Procrustes Analysis (GPA).

4. EFT
Elliptic Fourier Transforms (EFT) were performed (Kuhl & Giardina, 1982). Outlines were decomposed into 7 harmonics and their coefficients were statistically analysed.

5. Multivariate analysis
The shape variation was first assessed using a principal component analysis (PCA) computed on the EFT coefficients. Differences between samples were explored using MANOVAs and discriminant analyses. Finally, the phenotypic dissimilarity between groups has been visualized by a neighbour-joining network computed on the mahalanobis distances.

Fig. 2 : Protocole for quantifying the shape variation of the smooth scallops right valves.

Results

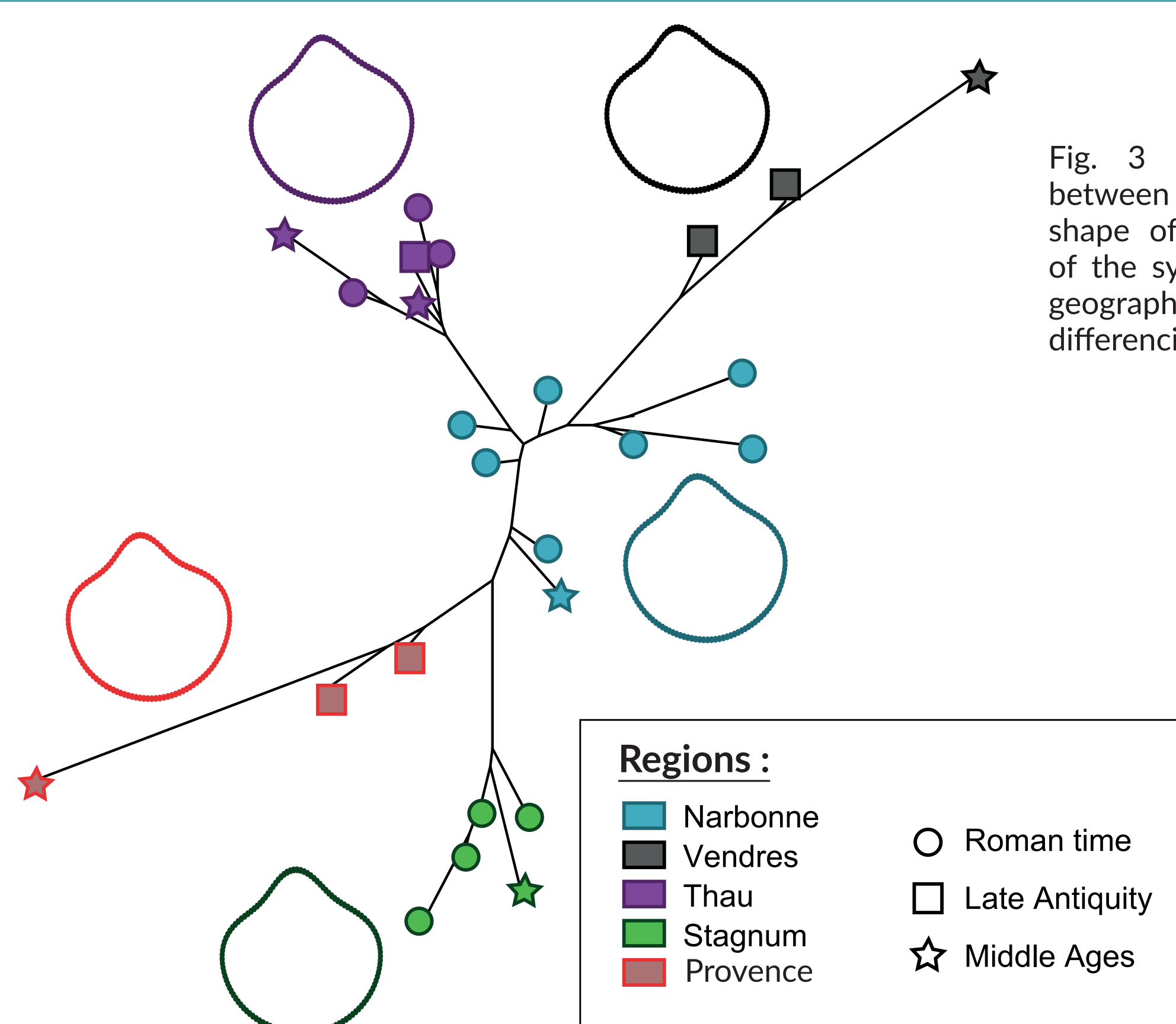


Fig. 3 - Dissimilarity network between samples based on the shape of their valves. The color of the symbols differentiate their geographical origin, while the shape differentiate their dating.

The shape of the archaeological specimens overlap based on the two first axes of the PCA that represent 62.2 % and 24.5 % of the total variance (fig. 2.5). However, a two-way Procrustes MANOVA revealed significant shape differences between populations of different lagoons ($F = 17.99, p < 2.2e-16$) and dated from different periods ($F = 4.23, p < 2.2e-16$), but also that the geographic variation is not homogeneous through time ($F = 3.39, p < 2.2e-16$).

The native lagoon is correctly identified with a mean cross-validation percentages (CVP) of 76.8% (90% confidence interval, 74.1 - 79.5 %). However, the discrimination between periods is less strong with CVP of 52.7% (49.8 - 56.0 %).

The dissimilarity network confirms this trend, with a clear regional structuring on which the period seems to have had comparatively little impact (fig.3). Thus, samples from the shores of a same lagoon are grouped in a same cluster, with the exception of samples from the Narbonne lagoon, which are in the middle of the network.

Implications

The morphometric analysis of the shape of archaeological smooth scallop valves has successfully revealed significant morphological variation between different lagoons of southern France. However, the differences between chronological phases seem to be less significant.

These results suggest that the shape of smooth scallops is a good indicator of their geographical origin. By extending our corpus to include samples from consumer archaeological sites located in the hinterland, it may therefore be possible to estimate the location of the producers who supplied them.

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