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## CAST PHOTOCOPYING: A SIMPLE METHOD FOR THE ANALYSIS AND THE ILLUSTRATION OF THE OUTLINE OF CEPHALOPOD SHELLS

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*Key-words:* Paleontological techniques, Cephalopods, Ammonoidea, Taxonomy, Fossil preservation.

*Riassunto.* Viene descritta una semplice tecnica per lo studio e l'illustrazione del profilo di conchiglie di cefalopodi. Il metodo consiste nella fotocopiatura di calchi in gesso sezionati con precisione. L'utilità del metodo viene valutata per confronto con le tecniche normalmente in uso.

*Abstract.* A simple way to get accurate figures of the outline of cephalopod shells is hereunder described. It consists in photocopying carefully sectioned casts made of plaster. The usefulness of the method is evaluated in comparisons with the other available techniques.

### Introduction.

The form of the shell of cephalopods is an important distinguishing feature which is often meaningful, depending on groups and on geological times, for taxonomical separations from family rank to species rank. In coiled cephalopods the form of the shell depends on the combination of coiling and whorl section, but these two components cannot be studied and described with the same accuracy. Coiling can be quantitatively analyzed by means of geometrical parameters, which are fairly easy to be measured. These parameters, together with simple photographs (lateral views), also allow a full objective illustration of coiling. The study of the whorl section is on the contrary influenced by several problems. Numerical parameters are very difficult to be measured, due to the complex geometry which is often rich in small details, so that in practice only whorl width and whorl height can be used to give a general idea of the shape of the section. Illustrations are rarely used, even in recent papers, and when they are used, it is never clear how accurately they have been taken and how much is the "influence" of the author on the drawing. The study of the whorl section is consequently based on qualitative and subjective observations, which on the other hand are complex because, especially in the ammonoids, the variety of shapes is much wider

than the variety of terms commonly used in descriptions (for instance see the terminology given by Arkell et al., 1957).

In this note a new technique for the analysis of the whorl section of cephalopods is described. Its accuracy and usefulness are also discussed by comparison with the available, usually empirical, techniques.

#### **Description of the method.**

The method consists in photocopying conveniently sectioned casts made of plaster. The basic requirements are a photocopy machine allowing at least  $\times 1.5$  magnification, a disk saw of the kind used in thin section laboratory, silicon rubber with hardner, and plaster. The execution can be subdivided into the following steps.

1) Test of the photocopy machine. First of all the optical distortion of the photocopy machine must be tested. This test can be accomplished by photocopying at different magnifications (i.e.,  $\times 1.5$ ,  $\times 2$ ) a sheet of undeformed graph-paper or, much better, a graph-transparent film (acetate) used by professional draftsmen. On the photocopy the distortion of the reticle can be simply measured by means of a ruler.

The result of this test is basic for the application of the method. If the optical distortion of the tested machine is too high, the operator must look for a better one. For instance the photocopy machine which has been used to set-up this technique (Konika 2028 available in the Department) at  $\times 2$  magnification shows 1% of stretching in the direction of the height of an A4 sheet and 0% of distortion in the direction of the width.

2) Preparation of the cast. This step starts with the preliminary examination of the specimen under study with the intent to select which parts are really important or better preserved. In order to simplify the preparation of the cast only these parts will be moulded. In fact, for the study of whorl or diametral section a perfect reply of the whole specimen is not necessary, but a cast of slightly more than half whorl of the original is enough. This choice simplifies moulding because semi-copies of the original can be obtained by open moulding (Stahl, 1956) instead of the much more complex compound moulding (Stahl, 1956, almost equivalent to piece moulding of Rigby & Clark, 1965) necessary for a whole reply. As regard the material for moulding and casting, in the experience of the writer the best are silicon rubber (Wacker Chemie RTV-2) for moulding and plaster for casting. They are easy to handle and to process, moreover they are very common in whatever paleontological laboratory. Silicon rubber is highly stable in time and relatively cheap (60,000 - 70,000 it. lire per kg), and plaster is extremely cheap (very few thousands lire per kg) and very easy to saw.

The preparation starts by mounting the specimen in plastiline or clay. The specimen is fixed on an unimportant part (Fig. 1A), then it is surrounded by a sufficiently high retaining wall (Fig. 1B). Once the silicon rubber compounds are mixed they can be poured into the retaining wall, until the specimen is fully covered. Curing takes some hours to one day, depending on the amount of hardner used, then the specimen can be easily removed and the mould is ready for casting. Preparation of the plaster

does not require explanations, but care must be taken of drying. Drying in room temperature is much better than drying induced by artificial heating, because the latter often makes the plaster crumbly.

During the preparation of the retaining wall some care must be taken to the distance between the specimen and the retaining wall. This distance determines the

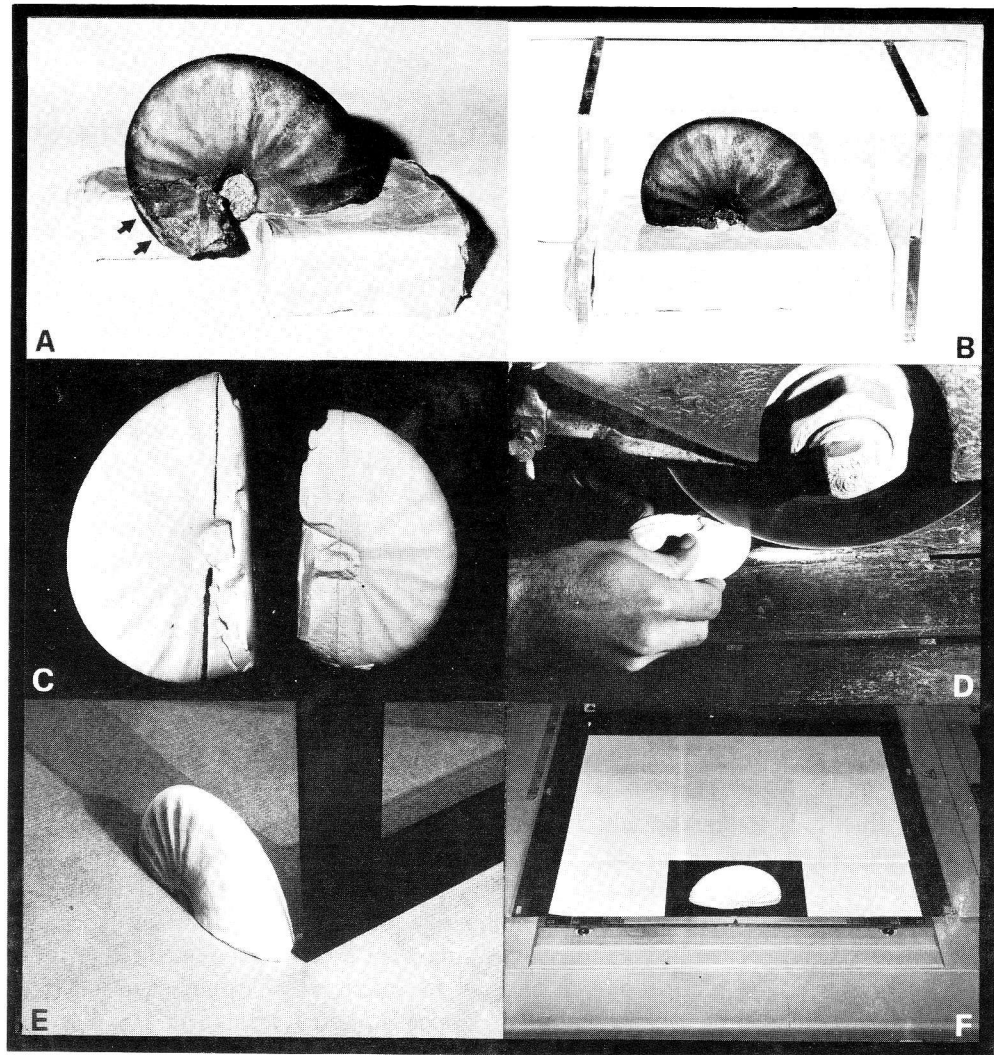


Fig. 1 - A) Specimen mounted in plastiline. Some parts of the outer whorl (arrows) are being covered. B) Preparation of the retaining wall made of transparent glass. C) Examples of semi-casts: both of them allow the preparation of one diametral section or several intermediate whorl sections. D) Sectioning of a semi-cast. E) Test of the section. In this example the diametral section is slanting, as it is demonstrated by the course of the border' shade of the square with respect to the venter of the specimen. F) Sectioned cast laid down on the photocopy machine.

thickness of the silicon rubber mould. If the retaining wall is too near to the specimen (distance less than the whorl width of the specimen) the lateral sides of the mould result so thin that they will be deformed during pouring of plaster. In this case the cast will be slightly wider than the original. A simple trick to save silicon rubber consists in the preparation of a stiff outer box (made of plaster or resin) for the mould, but in general the time requested by this additional work almost counterbalances silicon rubber saving.

3) Choice of the section and sectioning. Once the cast is dried the trace of the section can be drawn directly on the cast with a coloured soft pencil (Fig. 1C). Then the cast is sawed by means of the disk saw (Fig. 1D). Water-cooling can be closed: the plaster is so soft that it does not heat the saw, moreover water washes away the trace of the section (step 3) and may dissolve unperfectly dried low-quality plaster. The quality of the section directly depends on the sharpness of its outline: the best sections are obtained from perfectly dried casts sawed with uniform pressure.

4) Preparation of the section. The surface of the section must be orthogonal with respect to the coiling plane of the shell. The orientation of the section can be verified by means of a square (Fig. 1E). Sometimes slanting sections can be corrected by smoothing the cast on a frosted glass with just very little water.

Afterwards some information can be directly written on the surface of the section with a soft pencil. The basic information is the catalogue number of the specimen and a bar scale. If more than one whorl section is sawed from the same specimen, indications on the orientation of the section with respect to the growth direction are also useful. In fact hypothetical whorl section of a shell can be seen from inside the shell to the aperture or vice versa. As the cephalopod shell is symmetrical with respect to the coiling plane, no differences should be observed between the two opposite views of the same section, but in practice a few deformations or differences in preservation are common, so that the left and right side of the shell can be slightly different. I conventionally use to orientate the section venter-up with the aperture forward: then the two lateral sides are distinguished in left and right (Fig. 2).

5) Photocopying. The cast is laid down on the glass surface of the photocopy machine, then it is framed by white paper to save toner (Fig. 1F). In the photocopy the cast and the picture-frame will be white coloured. In-between the black, corresponding to the uncovered surface of the glass, will emphasize the outline of the section (examples on Fig. 2). An undefined number of photocopies with different magnification and brightness can be taken from the same cast, even at different times.

6) Analysis. The photocopy can be used to describe and to compare sections. Photocopies could also be used as support to biometrical analyses, but in this case the additional stiff box (see step 2) must be used. Besides the quantitative evaluation of the expansion of plaster is necessary, even if it is usually low (+0.4-0.5%).

7) Publication. Photocopies can be used as support for drawing or for illustration in photographic plates. In the first example the photocopy can be directly used for the final drawing on transparent paper. If two or more sections have been photocopied from the same cast or from different casts of the same original, in the final

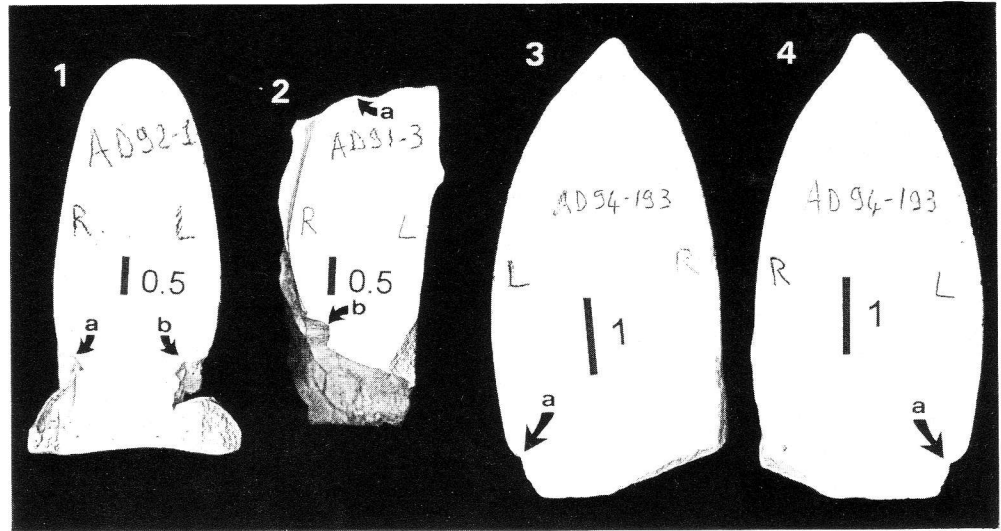


Fig. 2 - Some examples of photocopies mounted as photographic plate and printed without reduction (vertical stretching 1%). 1) Whorl section of *Flexoptychites*, specimen AD92-1: a) umbilical wall in part covered by sediment; b) umbilical seam. Bar scale 0.5 mm; x 1. 2) Photocopies may allow also the study of the ornaments. Here an intercalatory rib and a partially broken ventrolateral node are well visible on the right side of a paratype (internal mould) of *Megaceratites fallax* (Balini, 1992, fig. 4:3 and 5b), specimen AD91-3: a) compactional fracture; b) umbilical seam; some remains of the recrystallized shell are visible on the umbilical wall. Bar scale 0.5 mm; x 1. 3-4) Slightly asymmetrical whorl sections of a Ptychitidae: a) umbilical wall in part covered by sediment. The cast of the specimen AD94-193 has been cut asunder by a disk saw whose disk is 2 mm thick. The two parts have been photocopied afterwards. Bar scale 1 cm; x 1.

drawing all the sections must be drawn with the same orientation. An easy way to mirror a section consists in tracing the well visible outline from the photocopy laid face-down on a backlighted drawing table. In the second example the properly cut out photocopy can be mounted on plates (the best colour for background is black: see Fig. 2), even together with photographs. In both examples the optical distortion (see step 1) can be mentioned in figure captions.

#### Usefulness of the new method.

Several tools can be used to get pictures of the whorl section of cephalopods, however no specific literature is available, especially in comparison with the rich literature on the study of suture lines (i.e., see Kummel & Raup, 1965, pp. 759-762). The available techniques differ strongly from a technical point of view on complexity, availability and cost of the necessary equipments (Tab. 1). However the choice among them cannot be based on a merely technical approach, but first of all the scientific value of the specimen under investigation (i.e., the opportunity of damage the fossil) must be taken into consideration.

Usually entire specimens which cannot be broken or sawed, such as type specimens or isolated individuals, are studied by means of a shape tracer or by photography. In the past, the drawing with a microscope or with a Projectina-like equipment were used. Among these techniques the shape tracer is the best. This method consists firstly in pressing the tracer on one side of the specimen, then in outlining the tracer on paper. The complete section of the specimen is obtained by mirroring the first drawing or by outlining also the opposite side of the specimen. The result is a drawing on a scale 1:1 of the original. This tool has the advantage to be easy (no equipments: ideal for quick museum visits) and inexpensive. The disadvantage is the fixed power of resolution, which depends on the diameter of the needles of the shape tracer (usually 0.75 mm, sometimes 1 mm), that makes its accuracy and usefulness decreasing with the decreasing of the size of the specimens. Drawing techniques applied to three dimensional specimens do not lead to good results because of practical problems (low depth of field and high distortion of out focus details). Photographs, except for apertural views taken from orthogonal point of view, are only apparent translations in two dimensions of the shell, because they show anyhow the third dimension in perspective, so that its correct evaluation cannot be done.

When the damage of the specimen can be accepted or when the specimen is already broken, the traditional approach to the study of the whorl section consists in sectioning the fossil. Then the damaged specimen can be studied by means of the

Technique	Equipment	Availability in Paleontological Institutions	Output (magnification)	Costs (in It. lire)
<i>Shape tracer</i>	Shape tracer	rare, but common in structural geology laboratory	x 1	15000/25000
<i>Drawing with microscope</i>	1) Binocular microscope 2) mirror	1) very common 2) relatively common	>x 5-x 6	1) - 2) about 1 million
<i>Drawing with Projectina</i>	Projectina	rather rare, decreasing ?	>=x 3	>12 millions
<i>Photography</i>	Camera, macro lenses, lights, stand (*)	common	wide range	-
<i>Cast photocopying</i>	1) Silicon rubber and plaster 2) photocopy machine	1) common 2) everywhere	x 0.5 < <x 2 (**)	-
<i>Scanning</i>	1) PC, 2) flatbed scanner, 3) software	1) everywhere, 2 and 3) rare but increasing	x 1 (***)	1) - 2) > 1.5 million 3) 0.8/1.5 million

Tab. 1 - Illustration of the main features of the techniques discussed in the text. The availability of the equipment is evaluated on the basis of the direct experience of the writer with some 20 western and eastern european Institutions. Only the cost of the less frequent equipments is shown. Italian lira/US\$ parity at 1600 lire.

Notes. (\*) A photolaboratory is also necessary. (\*\*) The output refers to Konika 2028. (\*\*\*) Scanner is an input device for PC. The scanned image is x 1 of the original at standard resolution (usually 300 or 400 dpi). However some software drivers allow a direct magnification of the image by the selection of highest resolutions (800 to 1600 dpi) which are obtained by enlargement and interpolation of the original hardware controlled 300 x 300 or 400 x 400 dpi reticle.

microscope, Projectina or camera, which in these conditions are much more accurate than the shape tracer.

#### New method.

The main advantage of moulding and casting approach to the study of cephalopod sections is the full preservation of the original specimen. Sawing is also simplified because slanting sections or bad attempts failed by breakage during sectioning (common with fossils) can be repeated an undefined number of times. In fact an undefined number of replies can be prepared from the same mould. The main disadvantage is that this method does not allow the study of the covered part of the inner whorls.

As regard the comparison with drawing techniques (Tab. 2) the main advantages of the photocopy method are the easy management of medium/large sized specimens and the simple and fast management of a large number of specimens. On the contrary some disadvantages can be found with relatively small specimens. In fact photocopy machines allow only low enlargements (from x 0.5 to x 2 with Konika 2028), which are ideal for the study of medium to large sized specimens: a drawing taken from a photocopy x 2 of the original can be printed with 50% of reduction to get a final figure on a 1:1 scale of the original. Minimum enlargements are instead x 5-x 6 with microscope without demultiplier (which increases optical distortion), and x 3 with Projectina. These values do not allow the drawing of medium/large specimens in a single frame, but they force the operator to divide the drawing into two or more frames which have to be assembled and smoothed afterwards. This time consuming operation increases the error and unaccuracy, moreover lead to an assembled drawing too large to be used for publication without an additional photocopy reduction. Projectina on the other

Drawing with microscope	Drawing with Projectina	Cast photocopying
Low magnification often impossible	Minimum magnification x3	Large magnification difficult
Subdivision of medium to large specimens into several frames	Maximum height of the original 6 cm (12 cm of diameter)	Some difficulties with small specimens
From 2 to 4 steps for the final picture	2 steps for the final picture	1 step for the final picture
Several sources of error	Some source of error	Only optical distortion
Impossible estimation of errors	Difficult estimation of error	Quantitative and easy estimation of distortion
Drawing experience and skill required	Drawing skill required	Drawing experience and skill not required
Some tens of minutes per drawing	Some minutes/ few tens of minutes per drawing	Few seconds per specimen
Tiring (sight strain)	Drawing position not comfortable	Not tiring

Tab. 2 - Advantages and disadvantages of the cast photocopying method compared with drawing with a microscope or with a Projectina.

hand cannot be used on specimens exceeding 12 cm of diameter, because the maximum distance between the stage plate and the objective is 6 cm.

Another advantage of the cast photocopying technique is the notable readiness of the method. No experience or special skill is required, neither for moulding and casting nor for photocopying. Photocopying is so fast as in half an hour several tens of specimens can be copied by a perfectly untrained operator. Thus, this technique makes the study of whorl section of cephalopods a simple routine, even from a populationistic point of view.

Finally it must be pointed out that cast photocopies may be used with a scanner as graphic interface to computer world. After a test of distortion (see step 1), a flatbed scanner can be used to load photocopies or directly to scan casts (see step 6) for image storage and processing purposes. In fact the sharp contact between the white cast and the surrounding black is very good for raster to vector conversion. Once the translation is accomplished, scaling, rotation, mirroring, correction of distortion or deformation, and measurements can be easily done. Possible applications are the preparation of compound figures for publication, image databases, and the more evolute expert systems, whose development seems to be the future of systematic paleontology (Kaesler, 1993).

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