Studies on Olividae. XV. Anterior notch measurements as taxonomic characters in the genus *Oliva*.

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KEYWORDS. Mollusca, Gastropoda, *Oliva*, taxonomy, morphometry, anterior notch.

MOTS-CLEFS. Mollusca, Gastropoda, *Oliva*, morphométrie, taxonomie, échancrure antérieure.

ABSTRACT. Four novel measurements of the anterior notch are defined and their potential for *Oliva* taxonomy evidenced. Reproducibility of measurements and causes of error have been studied.

RESUME. Quatre nouvelles mesures de l'échancrure antérieure sont définies et leur potentiel pour la taxonomie du genre *Oliva* est mise en évidence. La reproductibilité des mesures et les causes d'erreur ont été étudiées.

1. INTRODUCTION

Shell morphometry appears to be the most practical, objective approach to the taxonomy of the genus *Oliva*. Sets of protoconch measurements (TURSCH & GERMAIN, 1985 and 1986), teleoconch measurements (TURSCH & GERMAIN, 1985) and measurements of the subsutural groove (TURSCH & VAN OSSELAER, 1987; VAN OSSELAER & TURSCH, 1988) have therefore been defined and tested. These measurements have repeatedly been shown to be useful and reliable taxonomic characters (TURSCH, GERMAIN & GREIFENEDER, 1986a and 1986b; TURSCH & HUART, 1988; TURSCH & GREIFENEDER, 1989; TURSCH & GREIFENEDER, 1989; TURSCH & HUART, 1990; TURSCH, MISSA & BOUILLON, 1992).

Our search for additional shell characters has led us to test the possibilities offered by measurements of the anterior notch, which is conspicuous in all Olividae (see Fig. 1).

The anterior notch does not possess any sharp discontinuity that could be utilized as obvious pointers and repeated attempts at direct measurements on the shell (TURSCH & GERMAIN, unpublished results) have been shown to lack both precision and reproducibility. Indirect measurements are far more convenient and we wish to report here that accurate observations can be made on imprints of the anterior canal. The present paper aims solely at defining these measurements and testing their taxonomic potential.

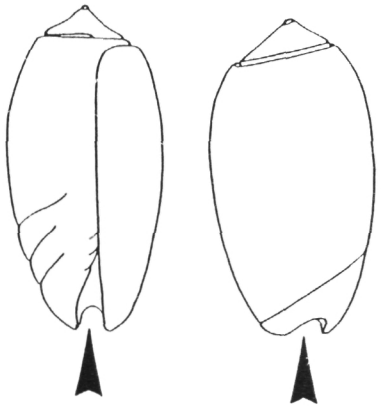

Fig. 1. Ventral and dorsal view of an *Oliva* shell. The arrows point at the anterior notch.

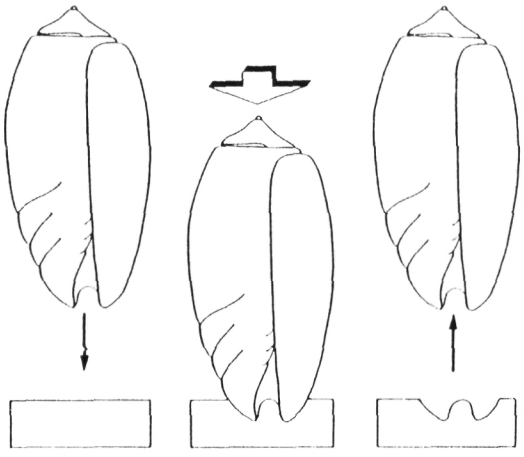

Fig. 2. Making a modelling clay imprint of the anterior notch of an *Oliva* shell.

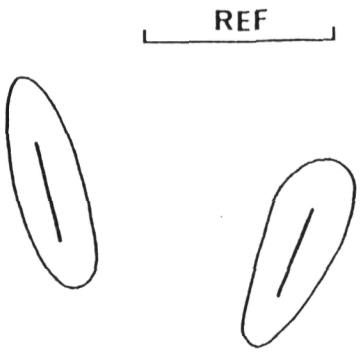

Fig. 3. Typical imprint of the anterior notch of an *Oliva* shell. REF is 1 mm reference segment. The trace of the outer lip is at the left, that of the columellar lip at the right. The deepest part of each trace is also represented (see text, section 2.3).

2. METHODS

2.1. Making an imprint

The shell to be measured is presented vertically (apex up) and then carefully lowered upon a flat, horizontal surface of modelling clay (plasticine) (Fig. 2). One should ensure simultaneous contact of the lowest points of both the columellar lip and the outer lip with the clay surface. A very slight vertical pressure on the shell then yields an accurate imprint, consisting of two distinct traces of comparable size.

2.2. Drawing the imprint

The imprint is then carefuly drawn, using the *camera lucida* attachment of a binocular lens. The size of the drawing is controlled by adjusting the magnification to obtain a length of 2 to 5 cm for each trace. A segment of 1 mm is also drawn as an internal length reference, using a precalibrated ocular reticulum. The length of this reference segment on the drawing will be called **REF**.

2.3. Geometrical construction on the drawing

The deepest part of each trace is quasi-linear. It is carefully drawn for each trace (see Fig. 3), then graphically extrapolated by tracing the lines **a** and **b** (see Fig. 4). Line a is the direction of the lower edge of the outer lip and line b that of the lower edge of the columellar lip. Points **A**, **B**, **C** and **D** are defined as the intersections of lines a and b with the contours of the traces. Lines a and b intersect at point **G**.

Point **E** and **F** are defined as the midpoints of segments AB and CD, respectively (Fig. 5).

2.4. Measurements

Let us define (see Fig. 5) the linear measurement **DN** as EF/REF (where REF stands for the length of the 1 mm internal reference segment described hereabove). DN is thus the length of the segment EF, expressed in millimeters.

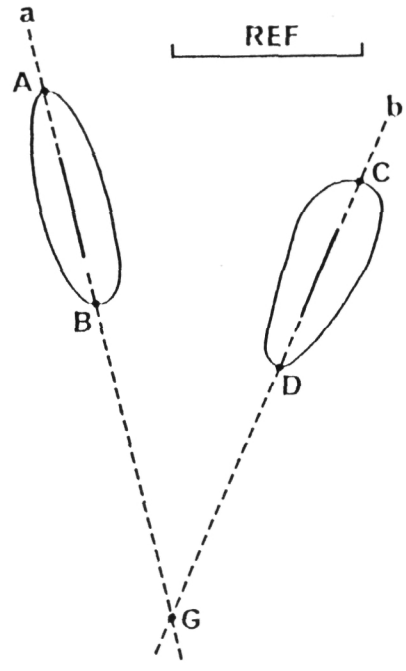

Fig. 4. First step of the geometrical construction on the drawing of the imprint (see text, section 2.3).

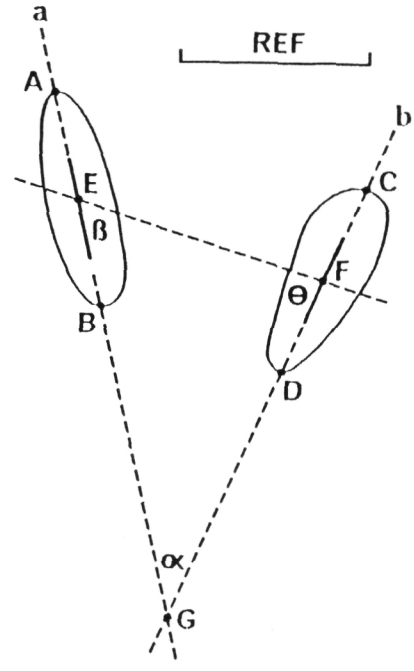

Fig. 5. Second step of the geometrical construction on the drawing of the imprint (see text, section 2.3).

Let us also define (see Fig. 5) the angular measurements α as the angle of the lines a and b; ß as the angle of the lines EF and EG; θ as the third angle of the triangle AFG. All angles are expressed in degrees. Determination of two of any of these angles automatically defines the third one, as their sum is equal to 180°.

The angles can either be measured with a protractor, or calculated from the lengths of the segments EF, EG and FG. For the latter case, a little, simplistic computer program based upon relations such as

$$\cos ß = (EF^2+EG^2-FG^2)/2*EF*EG$$

instantly yields the desired angles.

The two methods (direct protractor measurements and calculation from the lengths of sides of the triangle EFG) have been compared by performing both types of measurements on ten photocopies of the same drawing. This was done both for a large (*Oliva porphyria*, specimen BT-0345, H [height]: 114 mm) and a small species (*Oliva hilli*, specimen BT-6206, H: 12 mm).

The results are given in Table 1. It can be seen that angles α, ß and θ are more accurate when calculated than when directly measured, especially when the angles are small.

2.5. Practical tips

Best results have been obtained by using dark colored modelling clay (the better contrast makes the drawing easier). The quasi-linear, deepest part of the trace is located nearly in the middle of the groove and is easier to observe on rather shallow imprints (where shade is no problem).

A minimum of practice is strongly advised before attempting actual taxonomic work; some training greatly decreases the dispersion of the measurements. For two series of ten measurements, separated by 30 other trials, the performance of a naive observer (expressed in CV) improved from 4.80 to 2.20 for the measurement of DN, from 14.68 to 7.14 for α, from 3.61 to 2.70 for ß and from 4.12 to 2.25 for θ , all angles being calculated as decribed above.

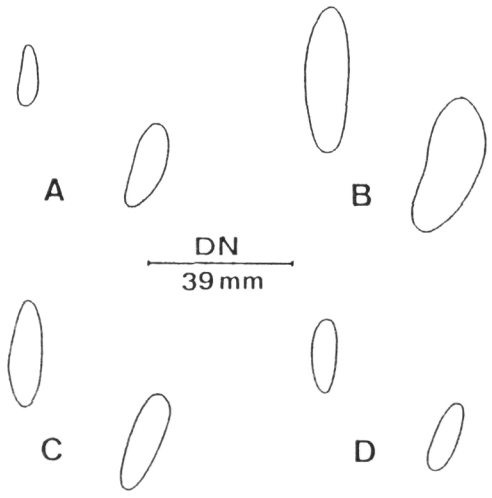

Fig. 6. Four imprints of the same shell (*Oliva sayana* BT-5315, H: 70.9 mm). The traces of the outer lip (length: OTR) are represented on the left, the traces of the columellar lip (length: CTR) are on the right. DN is 39 mm. Imprints vary both in size and in shape (see text, section 2.6). Imprints A and B are not recommended for measurements but imprints C and D do meet the requirements (see text, section 2.7).

2.6. Variability of imprints

The expressions "a very slight vertical pressure" (section 2.1) yielding "rather shallow imprints" (section 2.5) are very vague. There is no easy, practical way of measuring the pressure exerted on the shell or depth of imprint in soft material. In order to be reproducible, the process clearly needs a more accurate description.

For a given shell, the length of the traces is of course positively correlated with the depth of the imprint. Furthermore, as the *Oliva* shell is not a regular surface of revolution, it is to be expected that the shape of the traces will also vary with the depth of the imprint. The shape will also be affected with deviations to verticality. This is indeed the case as evidenced in Fig. 6 where the trace of the outer lip is represented on the left.

2.7. Choice of suitable imprints

If one produces a quantity of imprints of a given specimen on a slab of modelling clay, it will be seen at a glance that these imprints are very variable. The problem of which particular imprint to choose for measurements immediately arises. Imprints can be characterized by the absolute size of one trace (roughly proportional to the vertical pressure exerted on the shell) and by the relative size of the two traces (roughly dependent upon deviations from verticality). This will allow an empirical optimization of experimental conditions.

The graph of Fig. 7 shows the values of DN obtained for a series of purposely variable imprints obtained from the same shell (*Oliva sayana* BT-5315, H: 70.9 mm). Each imprint is characterized by the length (the largest diameter, not to be confused with AB or CD) of the trace of its columellar lip (**CTR**) and the length of the trace of its outer lip (**OTR**).

One sees that consistent values are obtained in a region where the lengths of both traces do not differ by more than 10 % and lie between 0.5 and 0.75 times the length of DN.

As an example, if we apply the above guidelines to the imprints depicted in Fig. 6, where DN is 39 mm, we can see that imprint A (OTR: 17 mm, CTR: 24 mm) should be

rejected because the lengths of its traces differ too much: CTR does not lie within the limits of OTR plus or minus 10%. Imprint B (OTR: 40 mm, CTR: 38.5mm) should be rejected because the traces are too large (more than 0.75 DN). Imprints C (OTR: 28 mm, CTR: 28 mm) and D (OTR: 19,5 mm, CTR: 18 mm) are adequate.

All these precautions might appear quite intricate but were needed mainly to avoid gross errors. In practice, the method is quite simple and very fast. It takes only seconds to produce a quantity of imprints of a given specimen and with a bit of experience, a suitable imprint will be recognized at first sight.

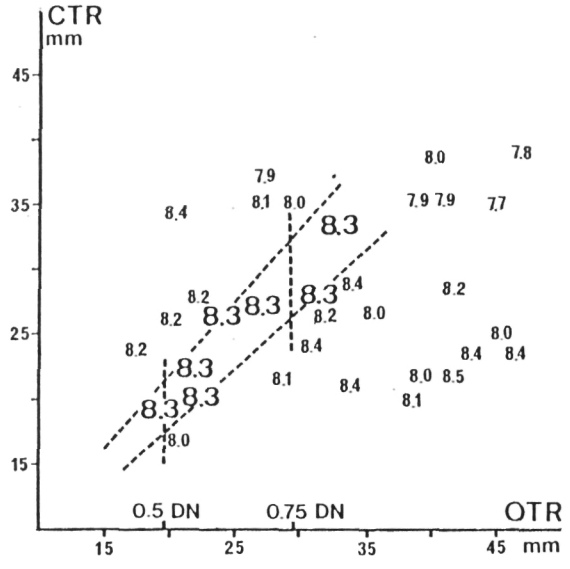

Fig. 7. Values of DN measured on a series of imprints obtained from the same shell (*Oliva sayana* BT-5315, H: 70.9 mm). To represent the variability, the values of DN are plotted for different lengths of the traces of the columellar lip (CTR) and the outer lip (OTR). The recommended working zone is delineated by broken lines (see text, section 2.7)

3. REPRODUCIBILITY and PRECISION

Before any taxonomic application, one has to assess the limits of confidence of these new measurements and to evaluate the relative contribution of the various possible sources of error.

The three consecutive phases of the process described hereabove can each lead to a different type of error:

A. error due to the inaccuracy of the geometrical construction and the measurements on the drawing.

B. error due to the inaccuracy of the drawing of the imprint.

C. error due to the non-reproducibility of the imprint process.

3.1. We have first compared the measurements performed by two independent observers on **ten photocopies of the same drawing**. In this case we deal only with error A. This was done both for a large (*O. porphyria*, specimen BT-345, height: 114 mm) and a small species (*O. hilli*, specimen BT-6206, height: 12 mm). The angles were obtained by calculation from the lengths of the sides of the triangle EFG.

The results are given in Table 2, where the dispersion of the data can be evaluated by the standard deviation S or the coefficient of variability CV, which is the standard deviation as percentage of the mean (MAYR, 1969). It can be seen that error A is very small and that the two observers obtained practically the same values.

3.2. We have then compared the measurements performed by two independent observers on **ten different drawings of the same imprint**. In this case we cumulate two types of error (A and B). This was done both for a large (*O. porphyria*, specimen BT-345, height: 114 mm) and a small species (*O. hilli*, specimen BT-6206, height: 12 mm). The results are given in Table 3.

3.3. Finally, we have compared the measurements performed by two independent observers on **ten different imprints of the same shell**. In this case we cumulate the three types

of error (A,B and C). This was done both for a large (*O. porphyria*, specimen BT-345, height: 114 mm) and a small species (*O. hilli*, specimen BT-6206, height: 12 mm). The results are given in Table 4.

3.4. In conclusion, the mean values obtained by separate observers are quite compatible: they differ by less than 0.1 mm on distances and 2° on angles. Their precision is also quite similar.

The contribution of the various types of error can be very roughly estimated by observing the evolution of the average values of the coefficients of variability (CV) obtained by two independent observers on the same shell during the three steps of the process. This was done both for a large (*O. porphyria*, specimen BT-345, height: 114 mm) and a small species (*O. hilli*, specimen BT-6206, height: 12 mm). The results are given in Table 5.

Errors of type A (geometrical construction and measurements on the drawing) are very small and probably negligible for practical purposes.

Excepted for α, the overall dispersions seem roughly independent of the size of the shell. The greatest dispersion is observed for α , which is a much smaller angle than ß or θ: the same angular error will result in a much larger relative error.

Errors of type B (inaccuracy of the drawing of the imprint) are by far the largest contributor to the total error on α. They are largely due to the extrapolation error when tracing lines a and b.

As only two of the three angles need to be determined (see section 2.4) it is preferable to select the larger angles ß and θ.

4. VARIATION WITH SIZE

Before attempting actual taxonomic work, one should first establish whether the measurements defined hereabove are dependent upon the size of the shell or not.

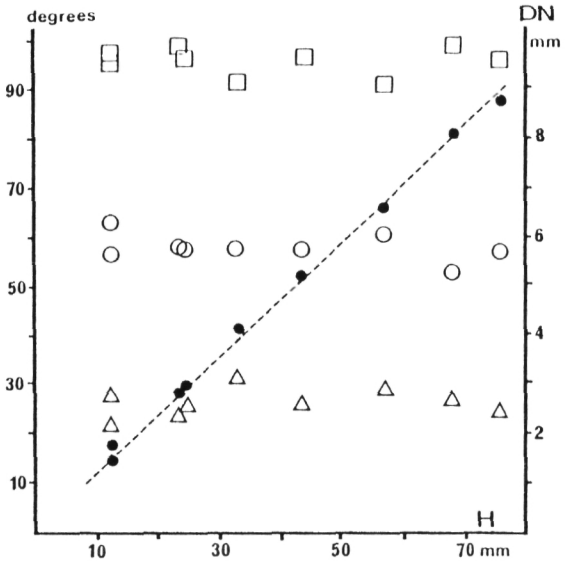

Fig. 8. Anterior notch measurements on a growth series of *Oliva sayana*. DN (black circles) increases linearly with the heigth of the shell (H). The angular measurements α (open triangles), ß (open circles) and θ (open squares) do not significantly vary with H.

The linear measurement DN (the width of the anterior notch) could be expected to be size-dependent. Indeed, DN increases linearly with the height of the shell (H) as shown in Fig. 8. DN is also correlated (not illustrated) with other linear shell measurements (the width D, the length of the lip L, etc ...). On the contrary, the angles α, ß and θ appear not to vary significantly with shell size.

As *Oliva* shells show considerable variations in size, it follows that DN values are better utilized under a reduced form (expressed as a ratio to some other linear shell measurement) such as DN/H or expressed as DN/pnw (pnw being the number of postnuclear whorls). For a given species, the angles α, ß and θ

should be treated as constants. It would indeed make little sense to utilize values as ß/pnw: it would simply amount to another expression of pnw, with the introduction of a supplementary error due to the measurement of ß.

5. TAXONOMIC APPLICATION

Discrimination tests utilizing only the measurements described here were performed on fifty *Oliva* species (unpublished), with encourageing results. To give an example amongst many others, the clear separation of five species on the basis of anterior notch characters alone (scatter diagram of DN/H versus ß) is shown in Fig. 9.

One should remember that only two of the angles α, ß and θ should be utilized at the same time in the biometric analysis of a given species (the third angle being necessarily redundant).

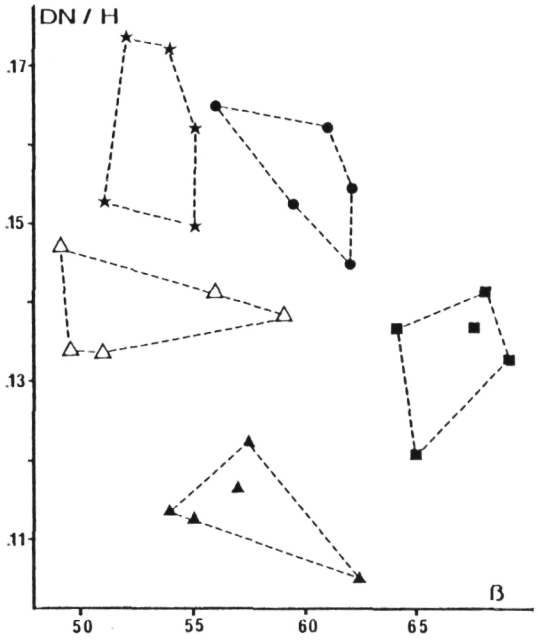

Fig. 9. Separation of five *Oliva* species on a scatter diagram of ß versus DN/H. Minimum convex polygons. Stars: *Oliva bulbiformis*; black circles: *O. carneola*; open triangles: *O. bulbosa*; black triangles: *O. australis*; black squares : *O. dubia*.

6. DISCUSSION

The measurements described hereabove are quite easy and fast (less than 5 minutes). Their precision and reproducibility have been proven satisfactory. The anterior notch has been shown to yield stable and operational taxonomic characters. At this stage, we do not know if these characters are significant at another level than specific.

One of the advantages of these characters is that the anterior notch region is habitually intact, even in severely damaged shells. These measurements do not require perfect specimens and could be performed on fossil material.

Anterior notch characters are not restricted to the genus *Oliva* and their use could be extended to other gastropod groups. Preliminary tests on other genera of Olividae (*Agaronia*, *Olivella*, *Olivancillaria*, *Ancilla*) yielded promising results (unpublished). Research along these lines is being pursued in our laboratory.

7. MATERIAL EXAMINED

"JS-" specimen numbers refer to shells in the J. Senders collection and "BT-" to shells in the B. Tursch collection (both in Brussels).

Oliva australis Duclos, 1835. AUSTRALIA: BT-1476 and BT-1478 (no loc.); BT-3600 (Brighton); BT-5301 (Freemantle); BT-4506 (Yorke).

O. bulbiformis Duclos, 1835. INDONESIA, Bali: JS-028, JS-029, BT-1549 and BT-1551. PHILIPPINES: BT-1556 (Bohol).

O. bulbosa Röding, 1798. ABU DHABI: BT-4604, BT-4605, BT-4606, BT-4607 and BT-4608.

O. carneola Gmelin, 1791. SOLOMONS: BT-0301 (Guadalcanal); BT-2516 (Langa-langa); BT-2548, BT-2549 and BT-2553 (no loc.).

O. dubia Schepman, 1911. PAPUA-NEW GUINEA: BT-4928, BT-4929, BT-4930, BT-4931 and BT-4932 (Hansa Bay, 50 m).

O. hilli Petuch & Sargent, 1986. TONGA: BT-6026 (Vava'u I.).

O. porphyria Linnaeus, 1758. W. MEXICO: BT-0345 (Bahia San Augustino, Sonora).

O. sayana Ravenel, 1834. U.S.A., Florida: BT-6671 (no loc.); BT-5315, BT-5316, BT-5318, BT-4072 and BT-4074 (off Cape Canaveral); BT-4094 and BT-4098 (Sanibel I.); BT-4097 (Tampa Bay); BT-0944 (Marco Beach); BT-6672, BT-6673, BT-6674 and BT-6675 (Port St. Joe Bay).

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	O. porphyria			*O. hilli*		
	mean	*S*	CV	mean	*S*	CV
α(m)	36.22	0.89	2.46	18.20	0.50	2.77
α(c)	36.12	0.50	1.38	17.91	0.27	1.53
ß(m)	58.57	0.77	1.31	61.43	0.74	1.21
ß(c)	58.39	0.60	1.02	61.35	0.55	0.90
θ (m)	85.70	0.67	0.79	100.95	0.68	0.68
θ (c)	85.54	0.37	0.43	100.76	0.73	0.73

Table 1. Comparison of two methods of obtention of angles α, ß and θ. Test on ten photocopies of the same drawing (imprints of *Oliva porphyria*, specimen BT-345, H: 114 mm and *Oliva hilli*, specimen BT-6206, H: 12 mm). Angles are in degrees. (m) indicates angles directly measured with a protractor, (c) indicates angles calculated from the sides of triangle EFG. *S* is the standard deviation and CV is the coefficient of variation.

	Observer B			**Observer O**		
	mean	*S*	CV	mean	*S*	CV
Oliva porphyria						
DN	13.81	0.07	0.49	13.73	0.05	0.42
α(c)	36.12	0.50	1.38	36.09	0.50	1.38
β(c)	58.39	0.60	1.02	58.13	0.19	0.33
θ(c)	85.54	0.37	0.43	85.69	0.58	0.67
Oliva hilli						
DN	1.50	0.01	0.63	1.49	0.01	0.69
α(c)	17.91	0.27	1.53	17.99	0.26	1.45
β(c)	61.35	0.55	0.90	60.78	0.41	0.67
θ(c)	100.76	0.73	0.73	101.22	0.52	0.51

Table 2. Evaluation of error A (see text, section 3.1). Statistics on ten measurements performed by two independent observers on ten photocopies of the same drawing (imprints of *Oliva porphyria*, specimen BT-345, H: 114 mm and *Oliva hilli*, specimen BT-6206, H: 12 mm). Angles are in degrees, DN in mm (c) indicates the angles are calculated (see text). *S* is the standard deviation and CV is the coefficient of variation.

	Observer B			**Observer O**		
	mean	*S*	CV	mean	*S*	CV
Oliva porphyria						
DN	14.36	0.13	0.92	14.32	0.10	0.72
α(c)	32.05	2.53	7.88	32.99	2.21	6.70
β(c)	55.24	1.49	2.70	53.14	1.28	1.54
θ(c)	92.71	1.98	2.14	93.86	1.54	1.64
Oliva hilli						
DN	1.46	0.13	0.92	1.46	0.01	0.82
α(c)	20.89	1.59	7.93	19.54	1.75	8.97
β(c)	63.17	1.27	1.85	61.16	0.86	1.34
θ(c)	96.74	1.85	1.91	99.30	1.34	1.35

Table 3. Evaluation of error A+B (see text, section 3.2). Statistics on ten measurements performed by two independent observers on ten different drawings of the same imprint (*Oliva porphyria*, specimen BT-345, H: 114 mm and *Oliva hilli*, specimen BT-6206, H: 12 mm). Angles are in degrees, DN in mm, (c) indicates the angles are calculated (see text). *S* is the standard deviation and CV is the coefficient of variation.

	Observer C			Observer O		
	mean	*S*	CV	mean	*S*	CV
Oliva porphyria						
DN	14.20	0.21	1.46	14.27	0.27	1.88
α(c)	29.11	1.69	5.81	30.90	1.57	5.07
β(c)	57.15	1.57	2.74	55.34	1.28	2.31
θ(c)	94.05	1.84	1.95	93.75	1.25	1.34
Oliva hilli						
DN	1.53	0.03	2.00	1.49	0.03	1.83
α(c)	20.30	2.66	13.09	19.66	2.30	11.68
β(c)	59.32	1.14	1.93	60.86	1.87	3.06
θ(c)	100.47	3.44	3.42	99.48	3.01	3.03

Table 4. Evaluation of error A+B+C (see text, section 3.3). Statistics on ten measurements performed by two independent observers on ten different imprints of the same imprint (*Oliva porphyria*, specimen BT-345, H: 114 mm and *Oliva hilli*, specimen BT-6206, H: 12 mm). Angles are in degrees, DN in mm, (c) indicates the angles are calculated (see text). *S* is the standard deviation and CV is the coefficient of variation.

	error A	errors A+B	errors A+B+C
O. porphyria (114 mm)			
DN	0.46	0.80	1.67
α	1.38	7.29	5.44
β	1.19	2.12	2.53
θ	0.55	1.74	1.65
O. hilli (12 mm)			
DN	0.66	0.85	1.98
α	1.49	8.45	12.39
β	0.79	1.59	2.48
θ	0.62	1.63	3.23

Table 5. Contribution of the different sources of error to the total dispersion of measurements effected on the same shell. The values given are the average of the two coefficients of variability (CV) obtained by two independent observers (see Tables 2,3 and 4).