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Some fundamental aspects of paleontological methodology: its problems and incidence

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SUMMARY

Two trends which presently exist in relation to the concept of Paleontology are analyzed, pointing out some of the aspects which negative influence. Various reflections are made based on examples of some of the principal points of paleontological method, such as the influence of a punctual sampling, the meaning of size-frequency distribution and subjectivity in the identification of fossils. Topics which have a marked repercussion in diverse aspects of Paleontology are discussed.

RESUMEN

Se analizan someramente las dos grandes tendencias que se pueden señalar en el desarrollo de la paleontología y que se concretan en las dos posiciones que se mantienen actualmente: una paleontología con una caracter meramente cronoestratigráfico, es decir una paleontología concebida como servicio a la geología, y una paleontología con entidad propia. En este sentido el papel que desempeña el paleontólogo en la observación directa de los afloramientos es muy importante y decisiva. Se comentan algunos aspectos que actúan o pueden actuar en sentido negativo sobre la paleontología. Se señalan algunas características acerca del número de ejemplares a tener en cuenta para las investigaciones de orden cuantitativo y la significación que tiene el estudio de la fauna por tamaños. Un ejemplo de foraminíferos planctónicos permite entrever el comportamiento de algunos taxones estrechamente relacionados.

A partir de la complejidad de los procesos que intervienen y conducen a la formación de un yacimiento fosilífero, o de niveles fosilíferos en general, se hacen una serie de reflexiones sobre aquellos aspectos que se consideran más fundamentales del método paleontológico. Una tanatocenosis del Plioceno ilustra la influencia que tiene el muestreo puntual en la aparente alteración que ésta presenta en función de la relación entre el número de valvas derechas e izquierdas en Bivalvia. Los resultados se contrastan con los obtenidos en una tanatocenosis actual de una playa de la que se dispone de muestreos mensuales por espacio de 25 meses consecutivos. Se comentan otros aspectos relacionados con las incidencias del muestreo puntual en relación con las variaciones laterales y verticales. El tipo de distribución del tamaño-frecuencia de las poblaciones es el resultado de la interacción de factores de índole muy diversa. Se analizan los diferentes factores que intervienen y su influencia en la interpretación de dicha distribución. Una de las varias aplicaciones que tiene la distribución del tamaño-frecuencia es la construcción de curvas de supervivencia. En este sentido se comparan las dos curvas de una población de *Hydrobia stagnalis,* calculadas independientemente a partir de los estadios de crecimiento, representados por vueltas de la espira, y a partir de la altura total de la concha. La variabilidad del parámetro, en este caso la altura de la concha, en cada estadio de crecimiento desempeña un papel significativo en relación con el momento en que se produce la muerte de los individuos.

Se comenta el efecto de la subjetividad en las determinaciones taxonómicas teniendo en cuenta los resultados publicados por otros autores.

RESUM

Hom analitza breument les dues grans tendències que poden assenyalar-se al desenvolupament de la paleontologia, i que es concreten en les dues posicions que es mantenen actualment: una paleontologia amb un caracter merament cronoestratigràfic, és a dir una paleontologia concebuda com a servei a la geologia, i una paleontologia amb entitat pròpia. En aquest sentit el paper que acompleix el paleontòleg en l'observació directa dels afloraments és molt important. Es comenten alguns aspectes que actúen o poden actuar en sentit negatiu sobre la paleontologia. S'assenyalen algunes característiques sobre el nombre d'individuus que cal tenir en compte en investigacions d'ordre quantitatiu i la significació que té l'estudi de la fauna per mides. Un exemple de foraminífers planctònics permet entreveure el comportament d'alguns taxons înitimament relacionats. A partir de la complexitat dels procesos que intervenen en la formació d'un jaciment fossilífer i encondueixen, o de nivells fossilífers en general, hom fa una sèrie de reflexions sobre aquells aspectes que es consideren més fonamentals del mètode paleontològic. Una tanatocenosi del Pliocè il·lustra la influència que té el mostratge puntual en l'aparent alteració que aquesta presenta en funció de la relació entre el nombre de valves dretes i esquerres a Bivalvia. Els resultats es contrasten amb els obtinguts en una tanatocenosi actual d'una platja de la que hom disposa de mostratges mensuals per espai de 30 mesos. Es comenten altres aspectes relacionats amb la incidència dels mostratges puntuals en relació amb les variacions laterals i verticals.

El tipus de distribució de la mida-freqüèència de les poblacions és el resultat de la interacció de factors d'índole molt diversa. S'analitzen els diferents factors que intervenen i llur influència en la interpretació d'una distribució d'aquesta mena. Una de les diverses aplicacions que té la distribució de mida-freqüència és la construcció de les corbes de supervivència. En aquest sentit es comparen ambdues corbes d'una població de *Hydrobia, stagnalis* calculades independentment a partir dels estadis de creixement representats per voltes d'espira, i a partir de l'alçada total de la closca. La variabilitat del paràmetre, en aquest cas l'alçada de la closca, a cada estadi de creixement acompleix un paper significatiu en relació amb el moment en que es produeix la mort dels indiviuds.

Es comenta l'efecte de la subjectivitat en les determinacions tenint en compte els resultats publicats per altres autors.

INTRODUCTION

It is not my intention to establish a basis of what paleontological method is or how it should be. However, I do want to make some observations on these aspects which seem more transcendental to me and are used almost continually. The various sections to be discussed might be seen, at firstglance, unconnected, but without doubt, they form part of the same context. I would even dare to say that the existing relations between some of them inevitably make them dependent one upon another.

Instead of developing an example which could illustrate just one part of paleontological method, although no less interesting, I have preferred to discuss more general questions which will permit a more diverse consideration.

Bearing in mind the various topics included in this Symposium, it is likely that some of the topics put forth below may be repetitive and probably they will be dealt with more extensively. Some criteria and opinions will be in agreement, others in disagreement, It is possible that some of the points dealt with here may be interpreted as negative aspects of paleontology or of paleontological method, due to the hardness of my critical treatment. I have discussed some of the points to be treated here with various collegues on several ocasions and they have argued that one reaches the conclusion that paleontology «is not useful», that it is of no «practical utility». I hold forth that fossils themselves are totally objectives; we, paleontologists and geologists, with our interpretations make fossils indicate one thing or another.

I have always maintained, and I believe that it is valid, that in any objective and sincere investigation, a positive or negative result is equally acceptable. It is obvious that a possitive result is more spectacular, more profitable and, without doubt, more personally satisfying. But a negative result is no less important because it shows that that way is closed, that it does not lead anywhere, saving in this way great efferts or at least calling one's attention.

Within the historic development of paleontology, it is possible to differentiate diverse stages. I think that almost everyone agree in accepting at least two: one of a static type, which unfortunately is still fairly fashionable, and another dynamic one which some have referred to as «modern». The static term is applied to the conception that the purpose and the sense of paleontology is to give a name to each fossil and at the most, to indicate an age for the fossil.

It is from the introduction of the concept of population in taxonomy, of quantitative data and of taphonomic and paleoecological studies that paleontological research abandons this static tendency to acquire a dynamic character.

One proof of this change is the great number of publications written in the last two or three decades concerning these diverse aspects of paleontology. Certainly, a large influence is due to the compilation of all these dynamic tendences in various works: Muller (1950), Simpson et al. (1960), Ager (1963), Hecker (1965), Babin (1971), Roger (1974) and Raup and Stanley (1978), to cite only a few. The list of contributions would be extensive.

Perhaps, the most significant aspect of this new concept is that it offers a basis and assistance to classical paleontology. Unfortunately, studies of this kind are still infrequent, specially in Spain.

A taphonomic study of an outcrop or a stratigraphic section is an ardous lengthy task requiring plenty of patience and prudence in the interpretations, but on the other hand, not all the sections or outcrops permit a taphonomic study to the same extent.

To these difficulties other approaches should be added that involve somewhat different, more complex problems. The following are, in my opinion, among the most significant ones: In general, what is interesting to a geologist in relation to paleontology is the datation of sediments. That is to say that paleontology is a simple instrument at the service of Geology. It is an immediate purpose and practice. Applied geology, with some honorable exceptions, has mainlyled to this situation. It has also often contributed to the concept and importance of biostratigraphy «in the strict sense of the word». The areas which constitute micropaleontology are perhaps those which in some aspects —for example a taxonomic aspect— have been most affected. In reality, macrofauna itself has not avoided this influence of applied geology. In fact, it must be recognized that by means of certain techniques of applied geology, access has been gained to regions and sections, which, on accord of their peculiar characteristics, would otherwise have been impossible to penetrate.

Closely related to certain aspects of the foregoing point is the following: should a palaeontologist remain in the laboratory or should he be in the field, doing the sampling by himself? These are really two contrary positions. Unfortunately, the former is still common and is found in many institutions. A colleague once referred to this position as «drawer paleontology». This was once refflected in rather extreme form by a Director of a Geological Service who drew my attention to the fact that most paleontologists «were women or men with certain physical deficiencies», which clearly implies that the direct observation of the outcrop is unnecessary. Fortunately this extreme is anecdotical. The recommended practice is that the paleontologist himself should do the sampling. Even in the case of micropaleontology. A multitude of aspects and data which at the time of interpretation of the results will be very important exist in an outcrop. Of course there are cases in which it is imposible for the paleontologist himself to do the sampling.

As my last point, I would like to discuss that aspect of fossils seen from a point of view as collectionable objects. The fact of their collectionability has made a strong impact on the image of the static paleontology. I do not have any prejudice against collectioning, as long as it is not carried to extremes. We are presently in an exaggerated stage in regards to this point. Just look at the commercialism of fossils. The saddest part is that it is coming to a total destruction of deposits in order to obtain perfect samples. Even worse is that some scientific entities support these collectionistic tendencies by selling fossils.

We should not forget the important contribution private collections have made in the field or paleontology. But in some cases, thanks to the unselfishness of some collectors important material has been salvaged.

RECENT AND FOSSIL THANATOCOENOSES

All paleontologists are conscious of the complexity of the processes involved in the formation of a fossil outcrop. In general, however thin a fossil horizon may be, it represents the accumulation of a large number of stages and generations which follow each other in time. The usual result is the obtainment of a sample with a high degree of homogeneity.

Much has been written about the alterations which fossil levels represent in relation to the original biocenosis. In practice all outcrops show some alteration. The degree or intensity of this alteration is what varies. In a certain way if there was not a certain amount of accumulation, it would be difficult to speak of a deposit as such. Prudence in use and interpretation of data will give a true sense of the degree of alteration.

Most benthonic macrofauna deposits correspond to shallow zones extending from the tidal zone to the offshore. The deposits in which microfauna of planktonic forms prevail amost exclusively could correspond to other conditions and other characteristics of deeper zones. In this sense, the knowledge of the formation of present-day thanatocoenosis has a great importance.

The Department of Paleontology of the University of Barcelona, in collaboration with the Department of Paleontology of the University of Salamanca, is carrying out a joint project on the study of present-day thanatocoenosis and those of the Neogene. For present-day thanatocenosis as well as those of Neogene deposits, various sectors have been selected which «a priori» present different conditions. Specifically, in the study of the marine Pliocene, Civis (1975) and Martinell (1976) have written doctoral theses, and other theses are in the process of being written on the Empordà Basin (Girona), Baix Llobregat (Barcelona), Almeria-Alicante, and the Valle del Guadalquivir.

Some data in reference to specific aspects of these have been recently published: Martinell and Pedemonte (1974), Civis (1977), Martinell (1977), Porta et al. (1979), Andres (1980), Martinell and Marquina (1980), Domènech and Martinell (1980), Porta and González (1980).

For study of the present thanatocoenoses in deeper marine waters several transects are utilized as made during the maping of the marine sheets of Almeria area.

HOW AND WHERE ARE THE FOSSILS

The proper situation of fossil constitutes in my opinion, one of the fundamental bases of paleontological method.

The lack of precision in situating fossils is a common occurence as can be deduced from paleontological and stratigraphical literature. This imprecision is observed in terms of geography as well as stratigraphy. It introduces, on one hand, contradictions in chronostratigraphic order and on the other hand, it does not permit the knowledge of the correct vertical extension of a taxon or its precise situation in a certain bed. The complications increase in the case of areas or classical stratigraphic sections no longer in existence, these by the significance of their fauna meriting special attention.

This imprecisness is just as much if not more important in the field of paleoecology. Due to the inexactness in stratigraphic positioning, the argument has been made for the creation of associations with paleoecological relationships when in reality one is dealing with forms which are separeted stratigraphically. On the other hand, paleoecological antagonism can be falsely interpreted in the same way. The rather extreme situation is acheived with the appearance of works on «global paleoecology» which unfortunately are still being published. As I have indicated several times, the prudence of the investigator definitively conditions the results.

Fortunately, the number increases daily of researchers and institutions who are concerned with this problem. Together with the paleontological collections, taxonomic card-indexes are elaborated as with a general card-indexes, with geographic and stratigraphic position of the samples, of fossiliferous outcrop. Both contain a large quantity of field and laboratory data with a high degree of accuracy and precision. The automatic processing of paleontological data permits the control of numerous observations in this field, data of great utility in the various branch of paleontology and paleoecology.

COUNTING A FIXED NUMBER OF SPECIMENS AND SAMPLE SIZE

In respect to micropaleontological studies, specifically foraminifera, the Utrecht team (Zachariase et al., 1978) has presented a number of highly illustrative data. This refers not only to the way in which foraminifera counts are performed but also to the determination of the number of individuals which can be considered sufficient for studies which require quantification. The determination of the number of individuals should without doubt produce a rarefaction effect in the sample. It influences the diversity index, the survivorship curves, etc., especially when few dominant species exist.

In macrofauna, rather than the determination of the number of individuals, one is accustomed to establishing the quantity of sample to be studied. Species/wight or species/volume curves often give good results.

SIZE FRACTIONS IN THE FAUNISTIC STUDIES

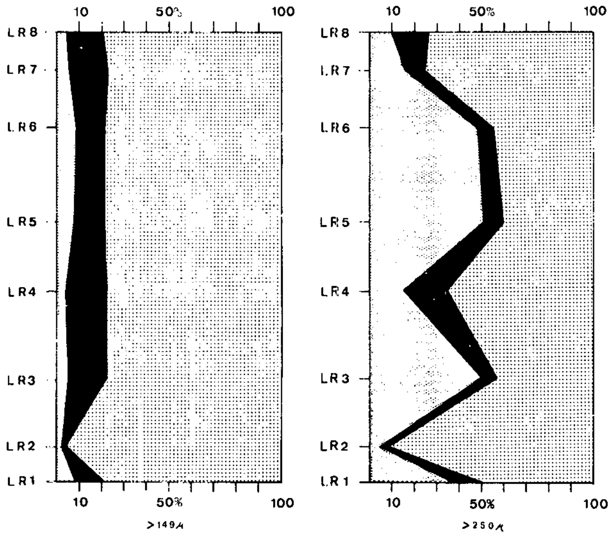
Studies on foraminifera made in order to stablish the relationships which fauna presents at different taxonomic levels, i.e. family, genus and species, often do not take into account the different size fractions. The quantitative differences are often notable and influence paleoecological and biostratigraphic aspects. Differences in this sense have been pointed out by various authors: Civis (1975) in Baix Llobregat (Barcelona, Spain), Brolsma (1978) and Zachariase (1978) in the Pliocen of Capo Rossello (Italy). Differences on Holocene marine molluscan assemblages from Tierrabomba (Colombia, South America) and Quaternary of Cabo Salou (Tarragona, Spain) have been pointed out (Porta et al., 1963, and Porta et al., 1975). These dissimilarities are of diverse origin: differences in size between forms, variations in the rate of mortality, biological competition, etc. It is logical that the use of a given size fraction (for example, 250 μ) can give different results both in the composition of the fauna and in the relationship between planktonic and benthonic foraminifera.

The use of different sizes fraction in the study of fauna can illustrate population dynamics. This especially holds true when working with closely related taxons in which the presence of an interactions between the taxons can be noted.

The example of the foraminifera from a section corresponding to the Langhian of the Province of Tarragona (Spain) can illustrate something in this sense. The outcrop is composed of clayey grey marl and is rich in foraminifera. The planktonic/benthonic ratio is always at least 60 %, except for the lowest stratigraphic sample in which the planktonic foraminifera do not reach 50 %.

Part of the following data corresponds to the Fernández Guerrero «Tesina» (Master degree) presented in the Department of Paleontology of the University of Salamanca (1975). The >.149 μ and >.250 μ fractions were studied separately. In each fraction, 400 individuals were counted. *Globigerinoides trilobus trilobus* (REUSS) and *Globigerinoides trilobus inmaturus* (LE ROY) behave inversely of each other in the two fractions. Textfig. 1 shows this relationship. To simplify the diagram the two taxons have been marked and the remaining planktonic and benthonic foraminifera have been grouped. In the graph it is clear that for the > 149 μ fraction *G. trilobus inmaturus* dominates over *G. trilobus trilobus.* This domination is constant throughout all the section. In the >250 μ fraction *G. trilobus trilobus* is the dominant form. The inversion in relation to size can be interpreted in terms of a higher mortality rate of *G. trilobus inmaturus* given that we are dealing with a thanatocoenosis.

The elimination of the smaller forms by fossildiagenesis or other mechanical factors would be a very selective feature, difficult to explain. The presence of an inverse correlation between the two taxons could also indicate the existence of an interaction between them. Could it correspond to a biologic competition?



Text-fig. 1. Differences between the quantitative variation of planktonic foraminifera *Globigerinoides trilobus trilobus* and *G. trilobus inmaturus* obtained from the counts on the >.149 fraction and those derived from counts on the >.250 fraction. Values in %. Langhian from La Riera (Tarragona). latticed: *G. trilobus triobus;* solid: *G. trilobus inmaturus;* dotted: other planktonic and bentonic foraminifera.

PUNCTUAL SAMPLING PROBLEMS

Details which require paleontological study make a precision of results indispensable. This calls for precision in the method used, an exactness which begins with the taking of the samples.

The different sampling techniques in relation to the desired end are well know and are found in many works and texts. More and more often papers are beginning to quantifiy data. If there is no control of the method used, allowing an adequate comparison of the results, little porgress will have been made. A certain degree of homogenity in the methodology is needed so that comparisons can have some meaning.

Experience teaches and advises that it is desirable to perform several types of sampling so that the quantification of the data can reflect the closest approximation to reality. Once having made a punctual sampling, which is the type normally made, one tends to generalize the results within a more or less extensive area; a generalization which does not always represent reality. It can even give a distorted view if the quanutitative data are supported by statistic proff. The group of factors which come into play is so large and interactions among them are so many that figures by themselves are not enough.

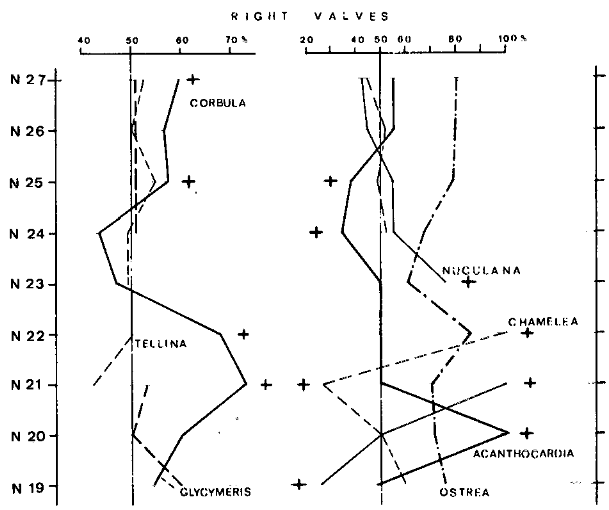
Let us look at some variations in specific examples. Although microfauna and macrofauna have a number of common aspects there do exist variations in their treatment.

Even performing an adequate sampling from a statistical point of view, some taphonomic aspects may hide the true features of an outcrop.

In the Pliocene of the Valle del Guadalquivir (Huelva, Southern Spain) between Palos de Moguer, Bonares and Rociana, a clayey fine sand level rich in molluscs exists. When the Sevilla-Huelva highway was constructed, a cut exposed this level near the town of Niebla. When we heard about it, the slope of the cut was already coveared by vegetation and we could only make a vertical sampling by excavating a small channel. It was determined that the minimum quantity of sample needed was 4 kilos of sediment and a systematic sampling was made at 1 meter intervals.

Various features indicate that the fauna is found practically «in situ», and has hardly undergone any alteration: various forms of Bivalves are in life position, almost all of the species found represents all growth stages and many delicate morphological characteristics such as the spines of *Acanthocardia* were preserved.

For each sample, the index of the relationship between right and left valves was calculated in those species with a larger number of individuals which were represented throughout the whole section. The results of this calculation are shown in text-fig. 2. *Tellina, Glycymeris, Nuculana, Acanthocardia* and *Chamelea* are the forms which in the majority of the samples present a more «normal» behaviour. Nevertheless, in some samples not all the species behave in the same way. It is evident that the epifaunic or infaunic condition can be significant, but even within the same group the behaviour of the species is not the same for all of them.



Text-fig. 2. Variation of the right valve proportion in some of the bivalvia studied. Sevilla-Huelva highway near Niebla (Huelva). Pliocene. + samples with significative differences at $\chi^2_{0.95}$ fiducial level. *Ostrea* Values in all samples are signifiant.

In text-fig. 2 an asterisk marks the samples in which the difference between valves is significantly demonstrated by the test at a 0.05 level.

This data, strictly analyzed, may indicate the existence of a considerable alteration of the fauna, in relation to the original biocenosis. The quantitative data does to contradict the visual observation which suggests only a very slight alteration. It is logical to think that because the sampling is so punctual, it could produce this apparent anomaly. It is highly possible that if the sampling were made on a more extensive surface, this anomaly would be corrected.

A different case is that which has been observed in the study of present-day thanatocoenosis in the area of Cabo Salou (Tarragona). Some partial data have been recently published (Martinell and Porta, 1980). On one of the sand beaches of Cabo Salou, samplings have been made at montly intervals. One of the aspects which is related to this theme is the distribution of right and left valves in some infaunic bivalvia: *Chamelea gallina, Mactra corallina, Spisula subtruncata, Donax trunculus* and *Donax semiestriatus.* The data which we present corresponds to 25 consecutive months. The individualized data for each moth indicates that for *Chamelea gallina* the relation between right and left valves is practically the same for all the months. Only in 7 months of a total of 25 is the difference significant for a fiducial χ^2 level of .05. If the data of 25 months is taken all together, only *Spisula subtruncata* and *Mactra cossallina* show significant differences.

In general, the entire accumulation gives rise to a homogenization of the monthly fluctuation.

Whith this present-day thanatocoenosis the valves had obviously been transported. The evidence for transportation is manifested by fragmentation of the *Mactra corallina,* species with a relatively thin shell. Furthermore, we find constituent elements from two biocoenosis: «Biocoenose des Sables Fins des Hautes Niveaux» and «Biocoenose des Sables Fins Bien Calibrés» according to the terminology of Picard (1965). Neverthless, this transport is not manifested so clearly in realtion to the degree of dispersion of both valves.

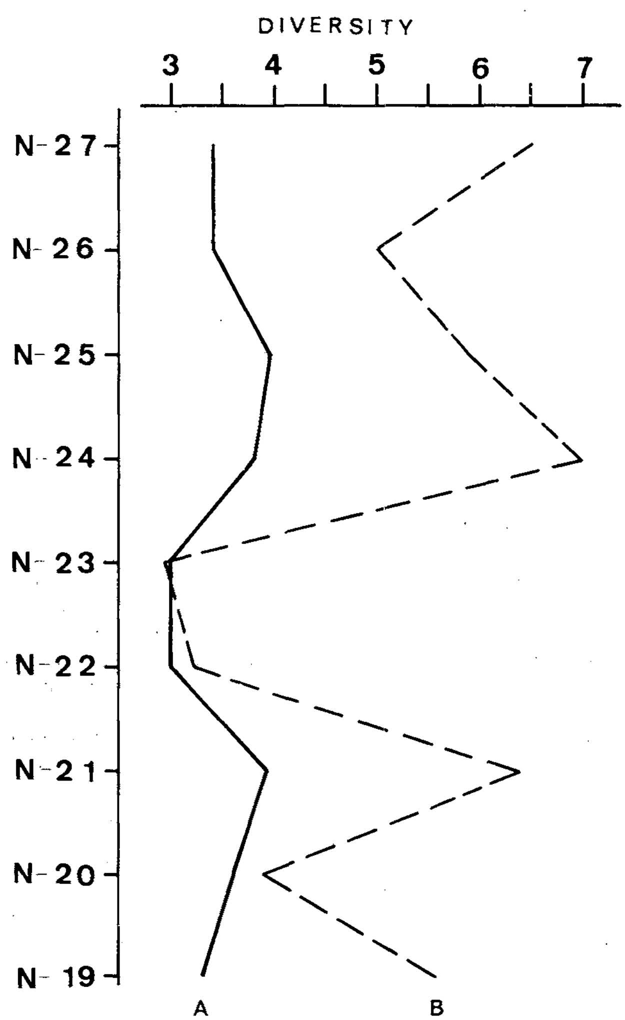
Another significant aspect of the influence of the punctual sampling is lateral variations in quantitative order. These variations can sometimes be important as has already been demonstrated in some cases. I think that the case presented by Brolsma (1978) concerning the Pliocene of the Capo Rossello (Sicily, Italy) in which he studied foraminifera within a 5 m distance is highly illustrative. The number of species as well as the proportion of the number of individuals in each species undergo notable variations (see fig. 9 of Brolsma). These influence the diversity index which ranges between 3.5 and 8 according to Brolsma's data.

Another example of these variations in the diversity index reffers to the Gastropod fauna of the Pliocene of Ciurana (Girona, Spain) published by De Renzi and Martinell (1979). The diversity index calculated according to the formula of Shannon and Weaver varied between 1.50 and 3.40 within a single unit in a horizontal distance of 120 meters. The problem before us is the interpretation of these differences. Do they correspond to random variations in the sampling? Do they have a taphonomic meaning? Do they represent differences in ecological conditions? It is almost certain that all these and others are involved to a greater or lesser degree.

I do not think that general rules can be made for their interpretation. Only the consideration of all the observations, both in the laboratory and particularly in the outcrop will permit the attempt at interpretation. As to this aspect, I reaffirm the absolute neccesity for the paleontologist to directly study the outcrop.

Neither is the interpretation of the variations of the diversity index throughout a stratigraphic section free from problems. Evolutionary changes should be added to the afore mentioned points as causing lateral variations. In this sense, it is logical that the faunas which have a faster evolutionary rate have a greater importance. The calculation of the diversity index based on different formulas may be interesting. Margalef (1977) has pointed out the correlation which generally exists.

In the stratigraphic section situated near Niebla (Huelva), the diversity index was calculated for all nine samples, according to the formula of Shannon-Weaver and that of Margalef (1951). For the first formula, the diversity index values range around 3.51. For the second formula, the values are somewhat higher. In text-figure 3 it can be seen that the path of the two curves is fairly parallel. This indicates the existence of a correlation between both indices. Only sample N-20 shows an anomaly. Nevertheless this sample is not the one which shows the largest significant alteration in the relation between the number of right and left valves. On the contrary in the sample in which a larger alteration (sample N-21) is shown, this alteration is not reflected in the relationship between the two diversity indices.



Text-fig. 3. Diversity index of vertically succesive samples calculated on Bivalvia. from the Pliocene outcrop near Niebla (Huelva). A) According to Shannon-Weaver index. B) According to Margalef index.

Sample N-23 shows another slight anomaly. This is the sample which contains the least number of species and the least number of individuals.

The application of only one technique evidently does not resolve the problems, but it helps to approach other questions. Identical values of the diversity index can be obtained whit associations and/or fossil assemblages whose faunistic composition is very different. The similarity coefficients can be of great help in these cases.

All of these variations influence the chronostratigraphy and the correlations between sections. Therefore it must be remembered that since these variations exist between samples when these are taken randomly, these variations can influence the chronostratigraphic interpretation of outcrops and also the correlation between sections.

I thought it would be interesting to present these examples so as to give an indication of how dangerous it can be to try to generalize some results of punctual observations based on partial studies.

If all of this occurs in sections which present a good exposition of fossils with extensive outcrops and therefore we can examine them and make tests, what can be thought of deductions from a core? or of various stratotypes which have been established in conditions which correspond almost exactly to those of a punctual sampling?

COMPLEXITY OF SIZE-FREQUENCY DISTRIBUTIONS

The size-frequency diagram as applied to the study of populations has been and is widely used. The form of the distribution can give rise to very diverse interpretations: variability of one characteristic, determination of the type of fossil assemblage (Boucot 1952, Olsson 1957, Fagerstrom 1963), construction of survivorship curves, etc. It is evident that the size-frequency distribution does not present the same features for live populations as for dead populations. Neither does it have the same meaning for all organisms. In the majority of Invertebrates which present continuous growth, that is to say, that they do not clearly show a juvenile growth stage and an adult stage as from which growth stops, the meaning of the variability is not the same as for those organisms which present two well-defined stages. In the first case, it corresponds to an ontogenetic variability and in the second to variability proper.

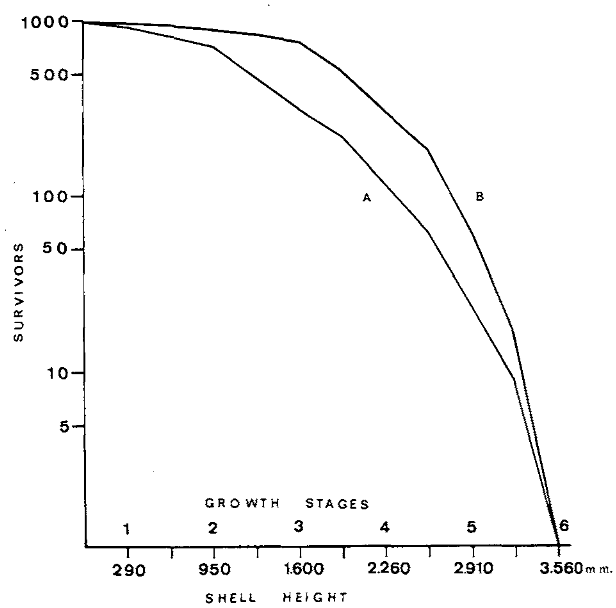
But the process is much more complex. To the birth/death rate, seasonal reproduction effects must be added. This gives rise in a certain moment to the fact that the population contains groups of ages in very differents proportions. This interaction of different factors has been already pointed out by Craig and Hallam (1963) among others, discussing its influe[illegible]e on the form of the size-frequency curve.

In [illegible]y outcrop there exists a greater or lesser degree of accumulation which along with the processes of fossil diagenesis, can affect the form of the size-frequency distribution. In fossiliferous strata, in which a multitude of generations are found, some seasonal features can be attenuated because the sample taken is usually homogenized.

Depredatory action, especially that of gastropods, can also influence to produce a higher death rate when an unbalance exists in biological cycle. Added to this is the different hydrodynamic behaviour perforated valves may have from non-perforated ones (Lever and Thijssen, 1968). In this particular case, it can be interesting to construct size-frequency curves separately for perforated and non-perforated valves. There is no doubt as to how the death rate determines the size-frequency curve of fossil populations. The age or the size of the individual corresponds to the moment in which it died.

A multiplicity of variables is evident as well as their interaction; these act in the control of the form of size-frequency distribution in a fossil population. It is not always easy differentiate in each case the importance of each of them. As a consequence, all aspects of an outcrop must be taken into account before making an interpretation of the shape of the curve. It is also necessary to compare the behaviour of various species before giving a global vision of the outcroup.

It is logical to ask oneself what value can be attributed to the use of the size-frequency distribution as a criteria for the separation of taxons in the majority of Invertebrates.

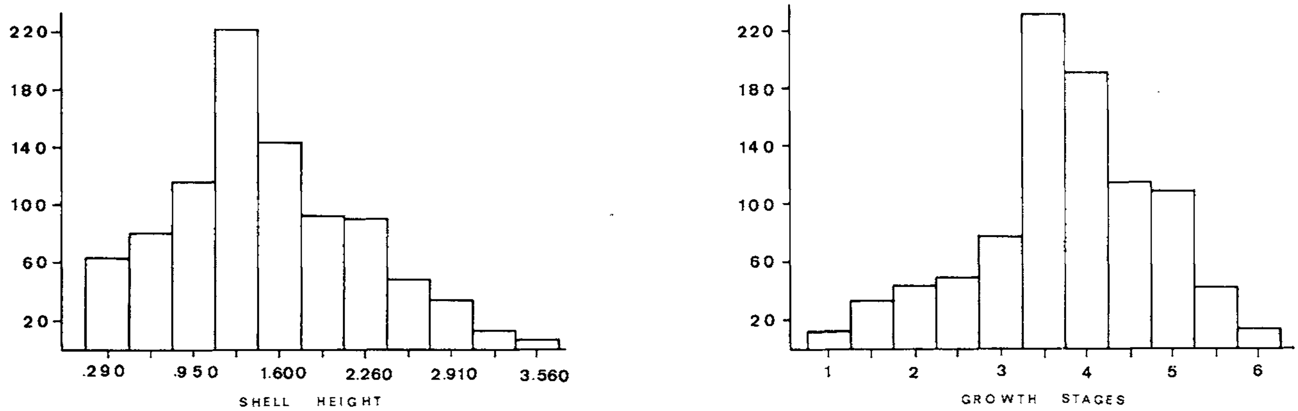


Text-fig. 4. Survivorship curves of *Hydrobia stagnalis* from the Pleistocene of Cabo Salou (Tarragona). The curves were prepared separately from shell height size-frequency distribution (class = *.330 mm.). B) from growth stage size-frequency distribution (each growth stage* = ½ spiral whorl).

SURVIVORSHIP CURVES DEDUCED FROM SIZE-FREQUENCY DISTRIBUTIONS

Survivorship curves can be constructed from growth stages (bands or rings) or from the size-frequency distribution of a population. In bivalves, for example, it is not always easy to determine these growth rings; many do not present well-marked growth bands. The determination of growth rings in a numerous population is laborius, in some cases even impossible due to the non-conservation of the shell wall structure.

To be able to compare survivorsihp curves based on both methods, a population of *Hydrobia stagnalis* from brackish sediments in Salou (Tarragona) related to a gravel barrier of Neotyrrhenian age was taken. The conditions of the deposit

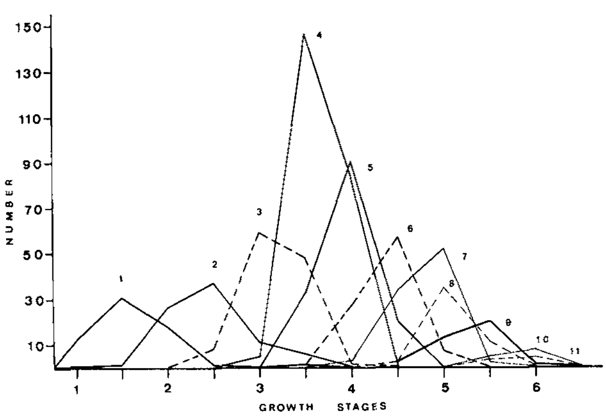


Text-fig. 5. Size-frequency distributions of *Hidrobia stagnalis*. Right histogram represent the shell height distribution in mm. Left histogram represent growth stages size-frequency distribution (growth stages as text-fig. 4).

indicate a lack of transport, which eliminates size selection and its influence on the shape of the curve. A part of this data was previously published (Porta, 1980). In the determination of growth stages, each half whorl was used as a standard and to determine size, the total height of the shell was measured. In both curves, the same number of class was used. In this way the comparation of the two curves could be more precise. As text-fig. 4 indicates the two curves are practically identical. Nevertheless, a slight displacement occurs at the point where the curve changes slope. In the curve based on size-frequency, this change takes place before that of the growth stages curve. Steep slopes indicate high mortality and gentle slopes low mortality.

In the histograms as can be seen in text-fig. 5 the modal values are also displaced: they correspond to class number 4 (1.270 mm.) for the height of the shell and to class number 6 (3 1/2 whorl stage) for the growth stages.

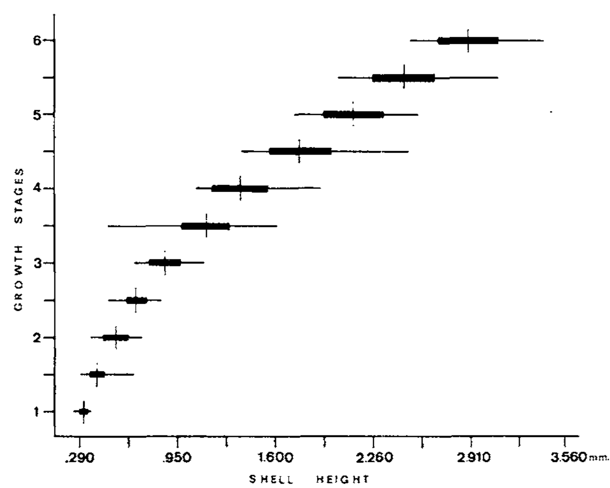
Taking into account that within the same size interval individuals are found which belong to different growth stages, the number of growth stages represented in each interval was investigated. The number of individuals was also determined.



Text-fig. 6. Relationship between number specimens of *Hydrobia stagnalis* and growth stages in each class size.

text-fig. 6 graphically expresses this distribution. The maximum number of individuals is found in the 3 1/2 whori stages which corresponds to the class whose mean is 1.270 mm. We have here a proof of the meaning of the relation which ecists between the moment of death and the variability of the parameter used: in this case the shell height.

The variation range of the shell height in each growth stage is notable. The distribution of the observed range seems normal and reaches its maximum value in the 3 1/2 whorl stage. In text-fig. 7 the mean of the height has been pointed out.



Text-fig. 7. Relationship between height shell in mm. and growth stages in *Hydrobia stagnalia*. Growth stages as in text-fig. 4. The mean and standar desviation are show for each stage.

In respect to the relation between size-frequency curves and survivorship curves, Cadee (1968, p. 94) has pointed out that for different species, with well-differentiated distributions of size-frequency, very similar survivorship curves can be obtained. Cadee (op. cit.) belived that this was due to growth differences. Whithout doubt, the type of growth is involved but dealing with thanatocoenosis we have already indicated that the mortality rate plays an equal if not more important role than that of growth. Cadee also points out that in different samples of the same species, as in *Tellina donacina* and *Nassarius pygmaeus,* for example, juvenile forms are present in some while absent others. The absence of juvenile forms in *Tellina donacina* is interpreted to be the result of depredatory action of fish, and in *Nassarius pygmaeus* as migratory processes.

The abundance of forms of *Tellina donacina* is a specific case which can be explained according to Cadee by irregularities in the bottom topography which give rise to small depressions in which the forms would accumulate. In my opinion the absence of juvenile forms can also be explained by the absence of mortality in these juvenile stages. The fact that the adult individuals emigrate indicates that we are dealing with live forms.

The influence which depredatory action, slight transport or morphology of the bottom can have on the shape of the survivorship curve is evident. But is also evident that many of these factors can be determined with a carefull observation of the outcrop or stratigraphic section.

All these factors are more than sufficient to illustrate the interferences which take place in a representation as simple as the size-frequency distribution of a population. As some authors have already remarked the determination of the type of fossil assemblage is not so simple using the size-frequency distribution as was thought in the beginning. The data which we may obtain will always be objective. The problem resides in the interpretation which we give it.

SUBJECTIVITY IN TAXONOMY

Another of the fundamental points of paleontological method is taxonomy. Evidently, this is a broad, diverse and complex field. I will refer only to some aspects which are ussually passed over inadvertently and, in my opinion, too little importance is attached to them. We are all conscious of the greater or lesser degree of subjectivity which a specific identification implies.

This aspect of subjectivity has been well expressed and also quantified by Brolsma (1978). An identification test and count of a lot of 200 specimens of planktonic foraminifera were made by four micropaleontologists. The differences in the taxonomic determinations were significant even between specialists. For example, at specific level the four paleontologists identified 51, 32, 36 and 17 taxons. Only two species names were used by the four micropaleontologists. Logically the aproximations at the genus level were closer: 30, 25, 25 and 14 generic determinations. In relation to bathymetric interpretations the differences are also notable. Diverse grafical features of these results and the calculation of the similarity coefficients of Sanders (based on the number of specimens given the same name by the four paleontologists) are found in the afore cited work of Brolsma. It is evident that no matter which paleontologists make tests of this kind, a number of conditionings exists which result in greater as lesser degree of similarity in the results. In this specific case, Brolsma maintains that school relationship has a more influence than experience in the determination of the same faunas.

If this disparity is notable between specialists and in taxonomic group such as planktonic foraminifera, which is relatively small in species, what will happen with the determinations made by those who are not specialists or in groups with a larger number of species? Disparity as well as similarity in identification can incide in biostratigraphy.

Although it can be argued that the impact of these differences on the chronostratigraphic scale is not very great, it does have an importance in the position of the units limits. Paleontology has passed through the stage of broad lines and has entered the stage of detailed and precise studies. It is precisely here where the influence is accentuated. This results in divergent interpretations of one section, in the correlations and also in many other fields; paleoecology, paleoclimatology, paleobathymetry, etc.

EPILOGUE

To some extent, I am conscious of the fact that all I have expressed may reflect a high dosis of pessimism. Nevertheless, I am not pessimistic. I feel optimistic towards the future. This is not destructive criticism but some thoughts on certain positions and cautiousness or prudence in interpretations.

If this thinking has been possible, it is thanks to other authors who have initiated new tendencies offering new perspectives and approaches. I think that the most important is not to believe that a technique or a method can resolve all the problems. Each new methodology or theory without doubt gives something new and this is definitely positive. It can be frequently observed that the appearance of a new tendency provokes a reaction in an avalanche of papers: some critical, others presenting modifications, new perspectives, etc. The result is a progressive advance. Almost always, the same conclusion is reached: that the question is much more complex than in the beginning it was thought to be.

The complexity of Paleontology advises prudence and calmess in decisions. In other Geology fields, which lack the flexibility the organic world presents, a greater interpreative rigidity results and perhaps also a greater rapidity. On the other hand, apart from biological flexibility, geological processes must be taken into account.

Those who consider Paleontology to be a simple tool only see the negative part of the results. They are not usually interested in the requeriments or the conditions necessary for an interpretation. This position is very similar to that of many of those responsible for scientific policies: they will speak highly of the achievements of pioneer research centers, but they want to remain ignorant of how these achievements were reached.

With hope placed in the future we will continue working.

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