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Morphom: a Fortran program for storage and analysis of shape measurements of sedimentary particles.

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ABSTRACT

A computer program based on the method described in a previous paper (Gallart, 1981) stores and analyzes morphometric data for samples of up to 52 elements. After the input and updating of the data, Cailleux's, Kuenen's and Zingg's indices are computed by the program, and the results can be presented by listing spare samples, writing the half matrices of the equivalence probability among samples for every index, and plotting Tricart's or Zingg's modified diagrams which represent the sample mean values and the equivalence test for a selected probability. Some glacial, glaciofluvial and periglacial samples taken from the Pyrenees are shown as an example.

Palabras clave: Sedimentary petrology. Pebble morphometry. Computer-assisted textural analysis.

RESUMEN

Basándonos en una modificación logarítmica de los índices morfométricos clásicos (Gallart, 1981), hemos desarrollado un programa de ordenador capaz de almacenar, tratar y comparar muestras de hasta 52 elementos. Además de entrar y corregir los datos, el programa calcula los índices de Cailleux, Kuenen y Zingg, ofreciendo los resultados de tres formas distintas: en forma de listados por muestras, con los índices detallados por elementos y conteniendo la estadística de cada muestra; en forma de matrices de las probabilidades de equivalencia entre muestras para cada uno de los índices, y en forma de diagramas modificados de Tricart y de Zingg, donde se indican los puntos que representan cada muestra y los rectángulos del test de Student para un riesgo preseleccionado. Finalmente presentamos como ejemplo unas muestras de sedimentos glaciales, fluvioglaciales y periglaciales procedentes del Pirineo.

INTRODUCTION

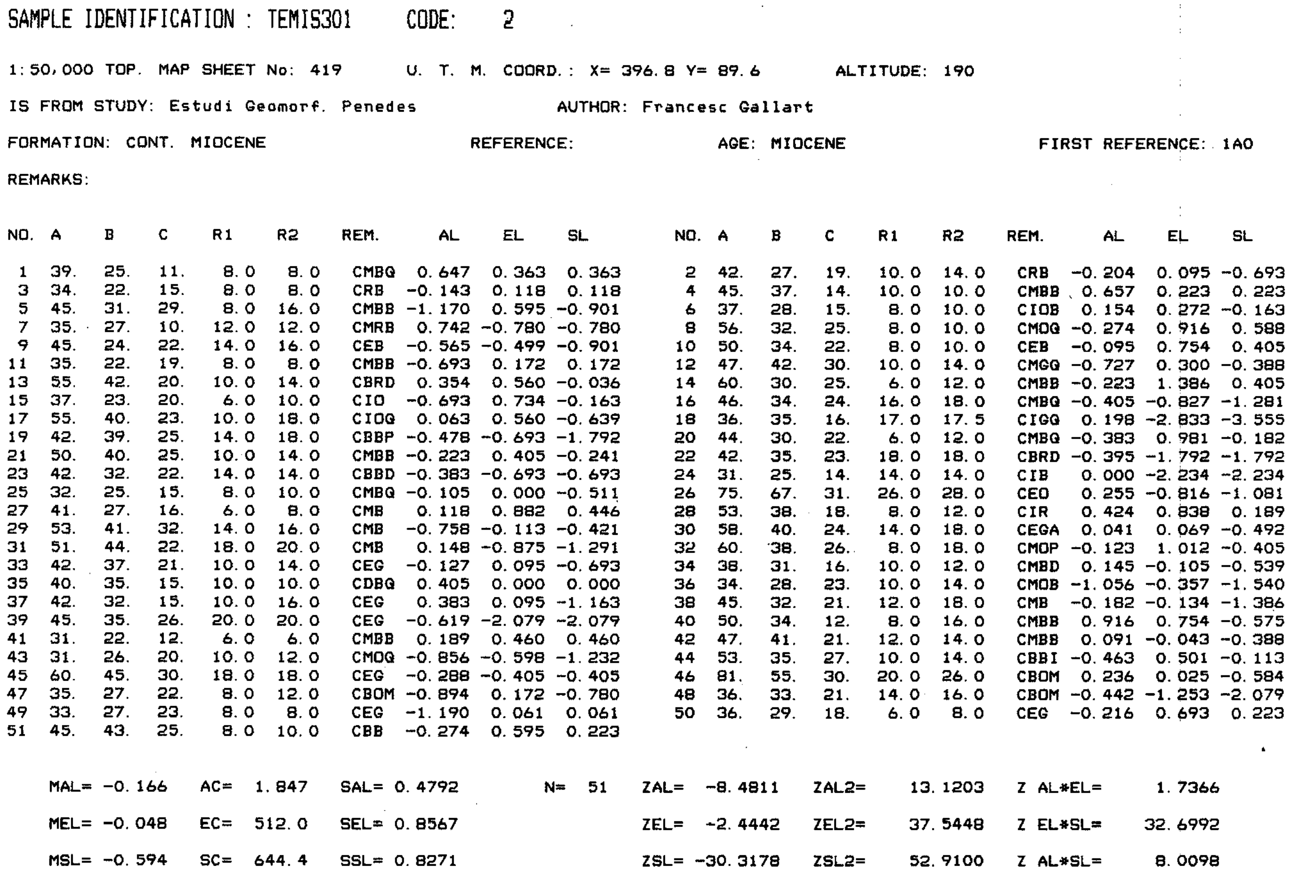
A logarithmic transformation of most common indices used for morphometric analysis of sedimentary particles was proposed in a previous paper (Gallart, 1981). The transformation is given by:

$i = \ln (I-1)$ for indices defined between 1 and infinite.

$i = \ln ((1/I)-1)$ for indices defined between 0 and, where i is the new index, I is the original index, and ln is the natural logarithm.

The new indices show distributions much closer to the Gaussian curve than classical ones can do and, therefore, statistical analysis is more suitable. Furthermore, in the previous paper, a modified Tricart's diagram (Cailleux and Tricart, 1959) with logarithmic scales has been proposed; in such a diagram, samples are represented by their mean values and by the rectangles which represent the half distance between samples corresponding to a preselected probability of the null hypothesis Ho, computed by the Student's t test: two samples whose rectangles are tangent for one of the indices have the preselected probability of equivalence on that index, if the samples are closer, the probability of equivalence is higher and vice versa (see figs. 3 and 4).

The usefulness of this method is reduced by the time consumed during calculations even if a programmable calculator is used. Consequently, a digital computer program has been written



```
SAMPLE IDENTIFICATION : TEMIS301    CODE:   2

1:50,000 TOP. MAP SHEET No: 419     U. T. M. COORD.: X= 396.8 Y= 89.6      ALTITUDE: 190

IS FROM STUDY: Estudi Geomorf. Penedes            AUTHOR: Francesc Gallart

FORMATION: CONT. MIOCENE                 REFERENCE:              AGE: MIOCENE                    FIRST REFERENCE: 1A0

REMARKS:

NO. A    B    C    R1    R2    REM.    AL     EL     SL          NO. A    B    C    R1    R2    REM.    AL     EL     SL

 1  39.  25.  11.   8.0   8.0  CMBQ  0.647  0.363  0.363         2  42.  27.  19.  10.0  14.0  CRB  -0.204  0.095 -0.693
 3  34.  22.  15.   8.0   8.0  CRB  -0.143  0.118  0.118         4  45.  37.  14.  10.0  10.0  CMBB  0.657  0.223  0.223
 5  45.  31.  29.   8.0  16.0  CMBB -1.170  0.595 -0.901         6  37.  28.  15.   8.0  10.0  CIOB  0.154  0.272 -0.163
 7  35.  27.  10.  12.0  12.0  CMRB  0.742 -0.780 -0.780         8  56.  32.  25.   8.0  10.0  CMOQ -0.274  0.916  0.588
 9  45.  24.  22.  14.0  16.0  CEB  -0.565 -0.499 -0.901        10  50.  34.  22.   8.0  10.0  CEB  -0.095  0.754  0.405
11  35.  22.  19.   8.0   8.0  CMBB -0.693  0.172  0.172        12  47.  42.  30.  10.0  14.0  CMGQ -0.727  0.300 -0.388
13  55.  42.  20.  10.0  14.0  CBRD  0.354  0.560 -0.036        14  60.  30.  25.   6.0  12.0  CMBB -0.223  1.386  0.405
15  37.  23.  20.   6.0  10.0  CIO  -0.693  0.734 -0.163        16  46.  34.  24.  16.0  18.0  CMBQ -0.405 -0.827 -1.281
17  55.  40.  23.  10.0  18.0  CIOQ  0.063  0.560 -0.639        18  36.  35.  16.  17.0  17.5  CIGQ  0.198 -2.833 -3.555
19  42.  39.  25.  14.0  18.0  CBBP -0.478 -0.693 -1.792        20  44.  30.  22.   6.0  12.0  CMBQ -0.383  0.981 -0.182
21  50.  40.  25.  10.0  14.0  CMBB -0.223  0.405 -0.241        22  42.  35.  23.  18.0  18.0  CBRD -0.395 -1.792 -1.792
23  42.  32.  22.  14.0  14.0  CBBD -0.383 -0.693 -0.693        24  31.  25.  14.  14.0  14.0  CIB   0.000 -2.234 -2.234
25  32.  25.  15.   8.0  10.0  CMBQ -0.105  0.000 -0.511        26  75.  67.  31.  26.0  28.0  CEO   0.255 -0.816 -1.081
27  41.  27.  16.   6.0   8.0  CMB   0.118  0.882  0.446        28  53.  38.  18.   8.0  12.0  CIR   0.424  0.838  0.189
29  53.  41.  32.  14.0  16.0  CMB  -0.758 -0.113 -0.421        30  58.  40.  24.  14.0  18.0  CEGA  0.041  0.069 -0.492
31  51.  44.  22.  18.0  20.0  CMB   0.148 -0.875 -1.291        32  60.  38.  26.   8.0  18.0  CMOP -0.123  1.012 -0.405
33  42.  37.  21.  10.0  14.0  CEG  -0.127  0.095 -0.693        34  38.  31.  16.  10.0  12.0  CMBD  0.145 -0.105 -0.539
35  40.  35.  15.  10.0  10.0  CDBQ  0.405  0.000  0.000        36  34.  28.  23.  10.0  14.0  CMOB -1.056 -0.357 -1.540
37  42.  32.  15.  10.0  16.0  CEG   0.383  0.095 -1.163        38  45.  32.  21.  12.0  18.0  CMB  -0.182 -0.134 -1.386
39  45.  35.  26.  20.0  20.0  CEG  -0.619 -2.079 -2.079        40  50.  34.  12.   8.0  16.0  CMBB  0.916  0.754 -0.575
41  31.  22.  12.   6.0   6.0  CMBB  0.189  0.460  0.460        42  47.  41.  21.  12.0  14.0  CMBB  0.091 -0.043 -0.388
43  31.  26.  20.  10.0  12.0  CMOQ -0.856 -0.598 -1.232        44  53.  35.  27.  10.0  14.0  CBBI -0.463  0.501 -0.113
45  60.  45.  30.  18.0  18.0  CEG  -0.288 -0.405 -0.405        46  81.  55.  30.  20.0  26.0  CBOM  0.236  0.025 -0.584
47  35.  27.  22.   8.0  12.0  CBOM -0.894  0.172 -0.780        48  36.  33.  21.  14.0  16.0  CBOM -0.442 -1.253 -2.079
49  33.  27.  23.   8.0   8.0  CEG  -1.190  0.061  0.061        50  36.  29.  18.   6.0   8.0  CEG  -0.216  0.693  0.223
51  45.  43.  25.   8.0  10.0  CBB  -0.274  0.595  0.223

     MAL= -0.166   AC=  1.847   SAL= 0.4792        N=  51   ZAL=  -8.4811   ZAL2=    13.1203   Z AL*EL=    1.7366

     MEL= -0.048   EC=  512.0   SEL= 0.8567                 ZEL=  -2.4442   ZEL2=    37.5448   Z EL*SL=   32.6992

     MSL= -0.594   SC=  644.4   SSL= 0.8271                 ZSL= -30.3178   ZSL2=    52.9100   Z AL*SL=    8.0098
```

Figure 1. — Listing of a 51-element specimen. The 5 first lines give the heading information (identification, location and other references) which constitute the non-processable information stored in the METRIA. DAT file A, B, C, R1, R2 and REM are the measurement products forming the processable information, stored in the MORPHOM. DAT file; A, B and C are the three ellipsoid axes, R1 and R2 are the minimum radii, and REM are the remarks on lithological details of the elements (C represents limestones). Al are the transformed Cailleux's flatness indices. EL are the transformed Cailleux's roundness indices and SL are the modified roundness indices with the second minimum radii. The last three lines give the statistical results for the whole sample; M = means, S = standard deviations, N = number of elements, and Z are the different sums. AC, EC and SC are the Cailleux's indices corresponding to the means computed with the transformed ones, and are presented to make any comparison easier with results obtained with classical indices. On account of the skewness of the classical indices, comparisons must be made with their medians, as recommended by Cailleux and Tricart (1959). Such a listing can also be obtained for Kuenen's and Zingg's indices. New calculations of other indices computed from the same measures of the elements need some modifications in the program.

Figura 1. — Listado de una muestra de 51 elementos. Las cinco primeras líneas contienen la información de la cabecera (identificación, localización, y otras referencias); esta información es improcesable y está contenida en el fichero METRIA. DAT. Los valores A, B, C, R1, R2 y REM son los resultados de las mediciones, que constituyen la información procesable, contenida en el fichero MORPHOM. DAT: A, B y C son los tres ejes del elipsoide; R1 y R2 son los dos radios mínimos del plano AB; y REM son indicaciones sobre el matiz litológico de cada elemento, entendiendo que las muestras son de litología homogénea (en este caso, C indica calizas). AL es el índice de aplanamiento de Cailleux modificado, EL es el índice de desgaste de Cailleux modificado, y SL es el índice de desgaste modificado, tomando el segundo radio mínimo. Las tres últimas líneas contienen los resultados estadísticos de toda la muestra: M son las medias, S son las desviaciones típicas, N es el número de elementos de la muestra, y Z son los distintos suamtorios. AC, EC y SC son los índices de Cailleux que corresponden a las medias de los índices modificados, y que son mostrados para facilitar la comparación con datos procedentes de trabajos con los índices clásicos. Las comparaciones deben realizarse con las medianas de los índices clásicos, ya que su asimetría causa una notable desviación de las medias (véase Cailleux y Tricart, 1959). Este tipo de listado puede obtenerse directamente también para los índices de Kuenen y de Zingg. El cálculo de otros índices basados en las mismas medidas de los elementos requeriría algunas modificaciones del programa.

EQUIVALENCE HYPOTHESIS HO PROBABILITIES

CAILLEUX'S FLATNESS

	VIPU1P	VIPU3P	VIPU5P	VIPU6P	VIPU8P	VIPU10P	VIPU11P	VIPU13P	BRTI1P	BRTI2P
VIPU3P	0.0001									
VIPU5P	0.0000	0.2533								
VIPU6P	0.0001	0.9160	0.2123							
VIPU8P	0.0000	0.7880	0.3508	0.7013						
VIPU10P	0.0001	0.2711	0.9984	0.2300	0.3690					
VIPU11P	0.6741	0.0006	0.0001	0.0006	0.0003	0.0002				
VIPU13P	0.8421	0.0002	0.0001	0.0002	0.0001	0.0001	0.8239			
BRTI1P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		
BRTI2P	0.4884	0.0000	0.0000	0.0000	0.0000	0.0000	0.2846	0.3827	0.0008	
BRTI3P	0.2652	0.0000	0.0000	0.0000	0.0000	0.0000	0.1370	0.1958	0.0027	0.6979

CAILLEUX'S FIRST ROUNDNESS

	VIPU1P	VIPU3P	VIPU5P	VIPU6P	VIPU8P	VIPU10P	VIPU11P	VIPU13P	BRTI1P	BRTI2P
VIPU3P	0.0000									
VIPU5P	0.4618	0.0000								
VIPU6P	0.5612	0.0000	0.9681							
VIPU8P	0.0208	0.0000	0.0468	0.1215						
VIPU10P	0.0002	0.0000	0.0000	0.0000	0.0000					
VIPU11P	0.3666	0.0000	0.0475	0.1279	0.0001	0.0005				
VIPU13P	0.6590	0.0000	0.1502	0.2774	0.0007	0.0001	0.5724			
BRTI1P	0.0000	0.3806	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		
BRTI2P	0.8273	0.0000	0.8144	0.8474	0.2255	0.0057	0.4170	0.6071	0.0000	
BRTI3P	0.0608	0.0000	0.0072	0.0200	0.0001	0.1865	0.1858	0.0855	0.0000	0.1143

CAILLEUX'S SECOND ROUNDNESS

	VIPU1P	VIPU3P	VIPU5P	VIPU6P	VIPU8P	VIPU10P	VIPU11P	VIPU13P	BRTI1P	BRTI2P
VIPU3P	0.0000									
VIPU5P	0.2686	0.0000								
VIPU6P	0.9639	0.0000	0.2200							
VIPU8P	0.8589	0.0000	0.2703	0.8077						
VIPU10P	0.0000	0.0000	0.0004	0.0000	0.0000					
VIPU11P	0.0286	0.0000	0.2434	0.0168	0.0162	0.0093				
VIPU13P	0.0710	0.0000	0.4747	0.0469	0.0504	0.0019	0.6129			
BRTI1P	0.0000	0.0106	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		
BRTI2P	0.8339	0.0013	0.3814	0.8520	0.7474	0.0055	0.1354	0.2082	0.0000	
BRTI3P	0.0412	0.0000	0.2023	0.0313	0.0359	0.1719	0.6347	0.4131	0.0000	0.1098

```
VIPU1P   IS THE POINT NO.  15
VIPU3P   IS THE POINT NO.  19
VIPU5P   IS THE POINT NO.  23
VIPU6P   IS THE POINT NO.  24
VIPU8P   IS THE POINT NO.  27
VIPU10P  IS THE POINT NO.  31
VIPU11P  IS THE POINT NO.  33
VIPU13P  IS THE POINT NO.  36
BRTI1P   IS THE POINT NO.  44
BRTI2P   IS THE POINT NO.  47
BRTI3P   IS THE POINT NO.  48
```

Figure 2. — Half matrices of the probabilities of the null hypothesis for the Cailleux's indices of a group of 11 samples. The more the corresponding probability of equivalence, the less different the samples are in the selected index. Samples named VI are shown here by courtesy of Miquel Vilaseca, and those named BR of Josepa Bru. Both groups of samples, which are the same for two following figures, are schist elements taken from glacial, glaciofluvial and periglacial formations from the south face of the Pyrenees.
The glossary of the end is used to identify the samples in the following graphs (figs. 3 and 4).

Figura 2. — Medias matrices de las probabilidades de la hipótesis de equivalencia para los índices de Cailleux de un grupo de 11 muestras, calculadas mediante la prueba de Student. Cuanto mayor es la probabilidad de equivalencia, menor es la diferencia entre muestras. Las muestras denominadas VI han sido cedidas amablemente por Miquel Vilaseca, y las denominadas BR por Josepa Bru. Ambos grupos de muestras, que son las mismas de las dos figuras siguientes, están formados por elementos de esquisto procedentes de formaciones glaciales, fluvioglaciales y periglaciales de la vertiente Sur de los Pirineos.
El diccionario de la parte inferior se usa para identificar las muestras de las dos figuras siguientes.

to store the data, to compute Cailleux's, Kuenen's (Kuenen, 1956) and Zingg's (Zingg, 1935) modified indices with their means and standard deviations, and to compare samples of up to 52 elements by calculating thee quivalence probabilities and by plotting the modified Tricart's and Zingg's diagrams. The storage of the original measurements enables calculation of any other index requiring three axes and two minimum radii, and also comparison with any other sample, without re-entering the measures. Each 52-element sample needs roughly one hour for the hand measurements, using a caliper, fifteen minutes for entering the data, and a few minutes more to list, compare and plot the results by using the program.

The program has been designed in a minicomputer Digital VAX-730, using the high level programming language FORTRAN-77, and with the Operating System VMS. The implied peripherals are an alphanumeric terminal VT-100 (D. E.C.), and a line printer PRINTRONIX. In addition to our own software, the functions GAUCDF and TCDF taken from Prince (1982) are needed, and the lineprinter is used in the plotting mode with the help of the graphic package VPLOT, from the Digital Electronic Corporation Users Society. Some modifications are needed to use the program with another terminal or a vectorial plotter.

In the present paper the structure and utilisation of the program are explained, with some examples of glacial and glaciofluvial samples taken from the Catalan Pyrenees.

FUNCTIONS OF THE PROGRAM

The program has four main functions which are selected when the program starts or after finishing one of them: input and updating of data, error correction, sample listing, and statistical and graphical comparison of samples.

Data input and file organisation

Morphometric data are organized in samples which include up to 52 sedimentary particles of uniform petrography, usually sized between 4 and 15 cm on the maximum axis.

First the terminal asks for the number of elements in the sample and then the new sample is codified by the program: it shows the code-number and asks interactively for the header data of the sample, as follows:

1. IDENTIFICATION [8]
2. 1:50.000 MAP SHEET No. [4]
3. U.T.M. COORDINATE X [5]
4. U.T.M. COORDINATE Y [5]
5. ALT. AB. SEA LEVEL [4]
6. IS FROM STUDY [16]
7. AUTHOR [24]
8. FORMATION / UNIT [24]
9. REFERENCE WITHIN UNIT [8]
10. AGE [18]
11. FIRST REFERENCE [4]
12. OTHER REFERENCES [4]
13. OTHER REFERENCES [4]
14. REMARKS [80]

Figures in brackets show the maximum number of characters to be used.

These data are stored in the file of unprocessable information (METRIA. DAT file) which is organized as a direct-access file with fixed-length records (154). Such an organization has been selected in order to minimize the time consumed during the transfer of the data between the memory and the disk; a single READ sentence is enough to transfer the whole sample from the disk to the memory, and it is not necessary to search for the sample because it is directly found by its code-number. Any modification can be made by overwriting the modified record.

This file is handled by METRIA, a subroutine of the MORPHOM program, in order to simplify the latter. Any change of the data stored in the METRIA. DAT file is to be made by the MORPHOM-METRIA program, but its record length allows editing by the EDIT utility of the VMS system. If EDIT is used, after editing it is necessary to modify the file organisation from sequential to direct access.

After the header information, the program asks for the measures of each element of the sample: the three ellipsoid axes (a, b, c), the two minimum radii measured in the main plane a-b (ri and r2), and four characters which represent the details of the lithological description of each element, which is roughly uniform for the whole sample. The monitor shows the the items to be answered:

```
No.   A   B   C   R1   R2   REM.
```

and the characters entered are placed by the program in their right places, except the ordi-

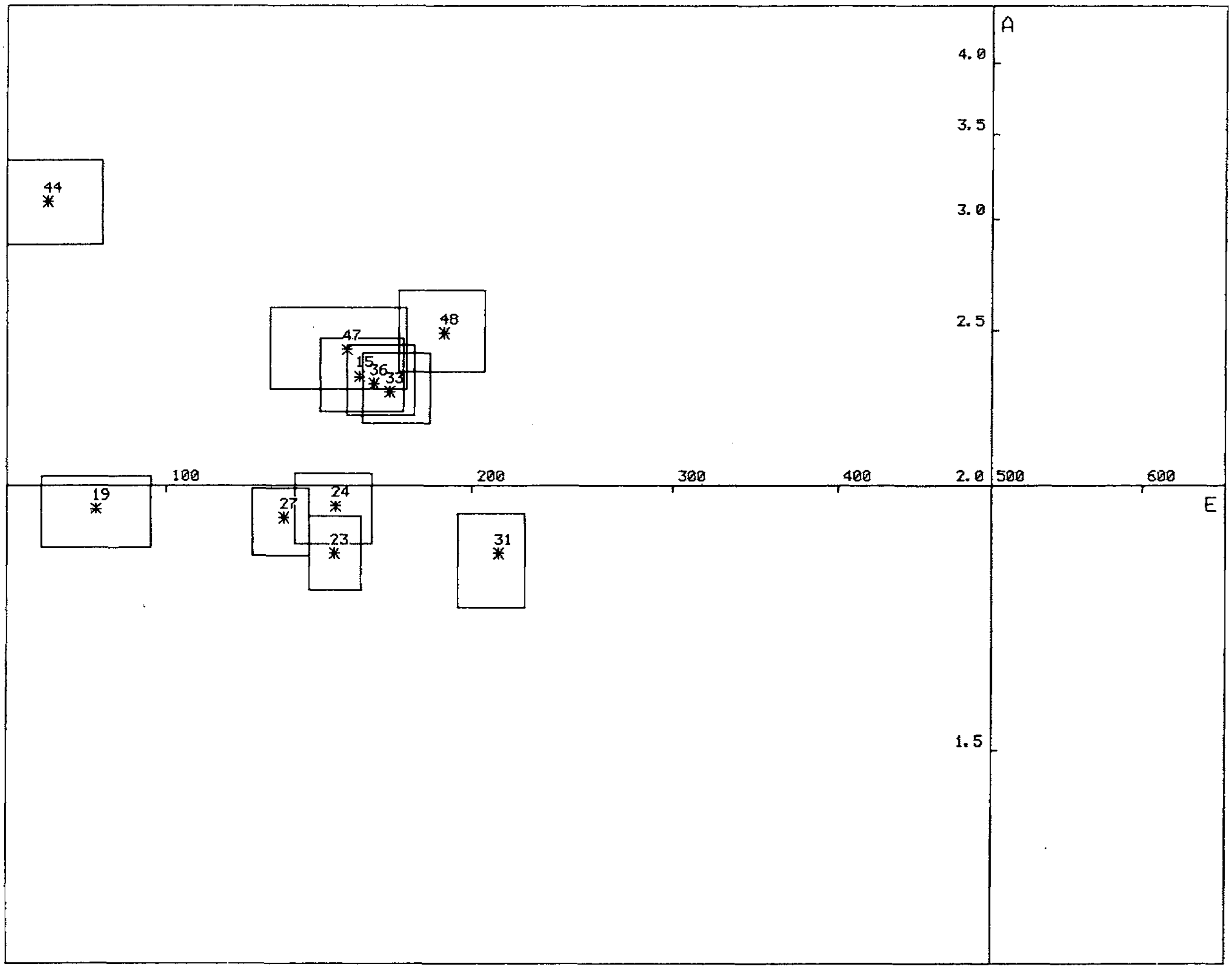


Figure 3. — Modified Tricart's diagram for the same specimens of the previous figure, drawn for a probability of equivalence of 0.05: two samples whose rectangles are tangent on one of the indices have this probability of equivalence (see introduction). The sample 44 is periglacial; samples 47, 48, 15, 36 and 33 are of glaciofluvial origin; and the rest are glacial. The first three named samples are from Tirvia, in the Vall Ferrera valley, and the fourth is from the complex of Puigcerda, in the Cerdanya depression. The arrangement of the samples follows the model proposed by Tricart and Cailleux (1962) for limestone elements, but modified because of the flat tendency of the schists.

Figura 3. — Diagramas de Tricart modificados para las mismas muestras de la figura anterior, dibujado para una probabilidad de equivalencia de 0,05: dos muestras cuyos rectángulos son tangentes en uno de los índices tienen esta probabilidad de equivalencia en este índice; las muestras cuyos rectángulos se cortan se consideran equivalentes, mientras que aquellas que quedan separadas se consideran distintas. La muestra 44 es periglacial; las muestras 47, 48, 15, 36 y 33 son fluvioglaciales; y las restantes son glaciales. Las tres primeras muestras enumeradas proceden de Tirvia, en un valle afluente de la Noguera Pallaresa, y las restantes son del complejo de Puigcerdà, en la depresión de la Cerdanya. La disposición de las muestras es similar a la propuesta por Tricart y Cailleux (1962) para elementos calizos, pero algo desplazada a causa de la tendencia de los esquistos a dar formas aplanadas.

nal number of every element, which is set by the program itself. After entering the last element, the program asks if the user wants to enter another sample; if the answer is YES, the input sequence restarts, and if it is NO, the program asks for the new function which is wanted.

These measures are stored in the file of the processable information (MORPHOM. DAT file), which is organized as a direct-access file with fixed-length records (1452). As explained for the METRIA. DAT file, this file organisation makes any transformation easier and minimizes the time consumed during transfer of information, but the record length of the file MORPHOM. DAT is too long to be edited with the EDIT utility; in addition to the modification made by the program, editing of the file can also be made with the help of the TECO utility of the VMS operating system.

Error correction

The following options can be used in order to modify thedata:

1. Name modification: the name is modified in the two files at the same time.
2. Header modification: the different contents of the header (unprocessable information) can be modified. This job is done by the METRIA subroutine.
3. Measures modification: the content of the processable information can be modified by using the ordinal number of the element which contains the error.

After selection of the kind of modification to be used, the program asks for the code of the sample to be modified, then it shows the item to be modified and, if it is the header or a sample element, asks for the field that is wrong. This option can also be used to examine the content of any sample.

Sample listing

The program asks for the codes of the samples to be listed; a file named MORPHOM. TXT, using a page for each sample, is written by the program (see fig. 1), with all the information of the header (code, name, location, etc.), the measures of each element of the sample (a, b, c, r1, r3, lithology), and the values of the transformed indices to be selected among the following:

1. Cailleux's flatness (a+b/2c), and Cailleux's roundness with the two radii (2r1/a and 2r2/a).
2. Cailleux's flatness (a+b/2c), Kuenen's roundness (Kuenen, 1956) with two radii (2r1/b and 2r2/b).
3. Zingg's indices (b/a, c/b and c/a).

After the sample listing, the statistics of the indices are given, using the logarithmic transformation. The results offered for every index are the mean, its respective classical value, the sum, the sum of squares, and the sum of cross products.

The program informs about any error produced during computations; errors are frequent because very discoidal or very rounded elements can give limiting values which are reported as infinite by the logarithmic transformation. The program is protected against such errors, by computing the nearest possible value of the index by subtracting 0.5 mm from the original minimum value; it reports the number of the element which produced the error and the name of the corresponding sample.

In this option, as in the following one, a directory of the names and code-numbers of the samples contained in MORPHOM. DAT and METRIA. DAT can be obtained.

Comparison of samples

After selecting the samples and indices to be used, as in the listing mode, the program writes a file named MORPHOM. TXT with half matrices of the probabilities of the null hypothesis (Ho) computed by the Student's t test, for every index separately, and for groups of less than 25 samples (fig. 2). The t value for pairs of samples is computed by the program and the TCDF subroutine from Prince (1982) is used to find the corresponding probability. Such matrices are useful for comparing separate indices; the equivalence probability values give a direct idea of the similarity of the selected index for each pair of samples, and they can be used to define equivalence by selecting a threshold value: two samples are considered different if the probability is less than the selected value.

Finally, when requested, the program draws a modified Tricart's or Zingg's diagram with the previously selected indices. An original dia-

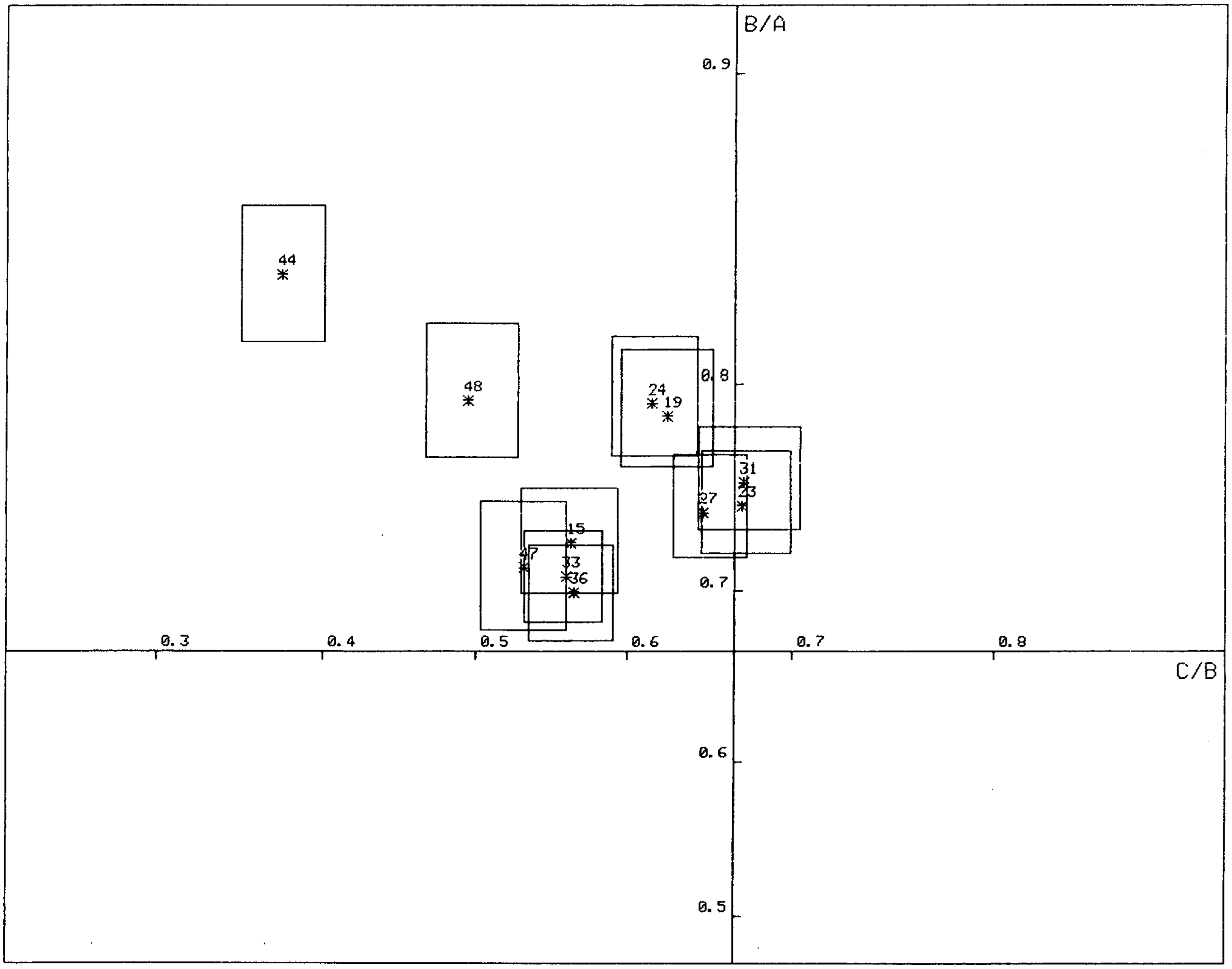


Figure 4. — Modified Zingg's diagram for the same samples as in the two previous figures, drawn for a probability of 0.1 of the null hypothesis. Some of the clusters are conserved, but a special form of the elements of the sample 48 is observed. The periglacial sample (44) is neatly discoidal, while glaciofluvial ones are more bladelike, and glacial ones more spheroidal. Zingg's classification, represented by the axes, seems to be too conventional for the forms studied here. Note also that dispersion of the Zingg's indices is much higher than the Cailleux's indices.

Figura 4. — Diagrama de Zingg modificado para las mismas muestras de las figuras anteriores, dibujado para una probabilidad de 0,1 de la hipótesis de equivalencia. Se conservan algunas de las agrupaciones, pero se observa una forma especial para la muestra 48. La muestra periglacial (44) es netamente discoidal, mientras que las fluvioglaciales tienden a dar formas en hoja de cuchillo, y las glaciales son más esferoidales. La clasificación de Zingg, indicada mediante los ejes de coordenadas, parece ser demasiado convencional para las formas de estas muestras. Nótese también que la dispersión de los índices de Zingg es muy superior a la de los de Cailleux.

gram is proposed in the second option by representation of the Cailleux's flatness index against the Kuenen's roundness index, both on logarithmic scales. The diagrams include numbered points which represented the codified mean values of the samples, and rectangles which represent the half distances between means corresponding to a value of the null hypothesis selected from 0.1, 0.05, 0.02 and 0.01 (see introduction and figs. 3 and 4). The program computes the distance between samples for every index and compares it with the critical distance corresponding to the preselected probability; the critical distances most similar to the actual ones are selected and used to drawn the rectangles. It is in fact a comparison between pairs of samples, and consequently, the diagram may contain slight errors, which can be identified by inspection of the half matrices of the equivalence probabilities and corrected by modifying the order of request of the samples to be compared. The rectangles can be highly assymmetrical if the standard deviations of the close samples are much different; a modification of the order of the request can also reduce such asymmetries. In spite of these difficulties, the diagrams are very useful for simultaneous comparison of groups of samples, and usually some clusters are immediately apparent.

The threshold probability to be used can be selected after inspection of the matrices, but usually 0.1 is enough for the first trial; if separation of the samples or groups of them is evident, the probability can be reduced for a more accurate analysis. The coordinate centre of the drawing is automatically selected by the program to avoid disappearance of any sample; the program also warns if the samples are too different to be shown in the same diagram.

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