SOME FACTS CONCERNING THE ACCURACY OF SOIL POROSITY MEASUREMENTS BY AUTOMATIC IMAGE ANALYSIS SYSTEMS

by

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Ever since the first television image analyzer made its appearance in the last decade, these quipments has been widely accepted and are being applied to almost every field of science. (Jesse, 1971, 1976). Its application to soil micromorphometry has been carried out mostly by Jongerius et al. (1972 a, 1972 b, and 1974).

In this paper, we intend to conduct, from an experimental stand point, some constructive criticism regarding the accuracy of soil measurement obtained when using optic-electronic systems, as the errors (noise, halo, shading..) in these systems have already been analyzed from a theoretical standpoint by Cole (1971). Brown (1971) believes that the probable measurement errors encountered in them are in the range of ± 2 %.

EQUIPMENT UTILIZED

The TV image analysis system used is a Carl Zeiss Microvideomat, semiautomatic version, fitted to a Zeiss Photomicroscope. This model works on similar principles as all the other image analysis systems do. We start off from an optic image that can be produced by any optic system (microscope, epidiascope.....). This image is picked up by a T.V. camera which reproduce it on a monitor, and, at the same time, it shunts the image unto a detector wherein the details we are most interested in can be selected by

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means of its gray tone and its size. Upon detecting the details, the video signal is shifted to a monitor on which the chosen selection appears and onto a computer for its quantitative analysis. The basic parameters that can be measured through the selected details are: area, inter - cepts and number of features (Fisher and Cole 1968;Fisher 1971).

ERRORS IN MICROMORPHOMETRIC TECHNICS

The errors found in a micromorphometrical study area of different nature and can be attributed to the object, to the measuring technic itself or could be caused directly by the operator.

ERRORS CAUSED BY THE MEASURED OBJECT

The impregnation phase of the soil and the posterior procurement of the corresponding thin section or polished block, constitute the basic steps to any micromorphometric study and of its successful fulfilment will depend the correct reproduction of the measurements.

Besides requiring a perfect impregnation and careful grinding it is essential to obtain thin sections or polished blocks wholly freee of any dirt and in particular to see that they do not contain any incrustations from the abrasive employed in the grinding and polishing phases.

A cause of error, without any known solution the present, is the fact that the poliester resin undergoes upon polimerizing a determined contraction which runs about 6% on the Cronolite 1108 resin being used by us.

Influence of cut orientation

The orientation of the cut can substantialy modify the dimensions of the pore sections, both for the polished block and the thin sections (channels and planes voids tend to produce sections with larger areas than their real ones , while on vesicles and vughs and packing voids the oppo - site occurs). These effects must be borne in mind when measurements are being taken over an isolated cut, but they are practically devoid of all influence on cut measure ments taken in series.

Indeed, as we show in Fig. 1 the sum of the areas for the divers cuts would give a similar surface measurement on all these cases.

Accuracy of the area measurements on the microvideomat

We have as a first step intend to compare the accuracy of the measurements on the Microvideomat areas by proceeding as follows: we measured with the microscope the diameters of a perfectly circular objects and of specific geometrical figures (poligons and circles) wich were reduced photographically, and compared their computed areas, with those obtained by direct measurement with the Microvideomat.

The errors found in measurements of these images, situated at the middle of the monitor display, were lower than 1 % in every case.

Object distortion according to position on T. V. monitor display

In order to chek a posssible T.V. image distortion in the monitor we have placed an identical object (a perfect cicle) in various spots of the display and have mea - sured the reproduced area in every case.

The results thus obtained are outlined in Fig. 2. We can see that depending on the position of the object, ma - ximum differences of up to 14 % may be obtained, notwithstanding the fact the average error is of about 2 % and can be practically eliminated by reducing the display dimen -

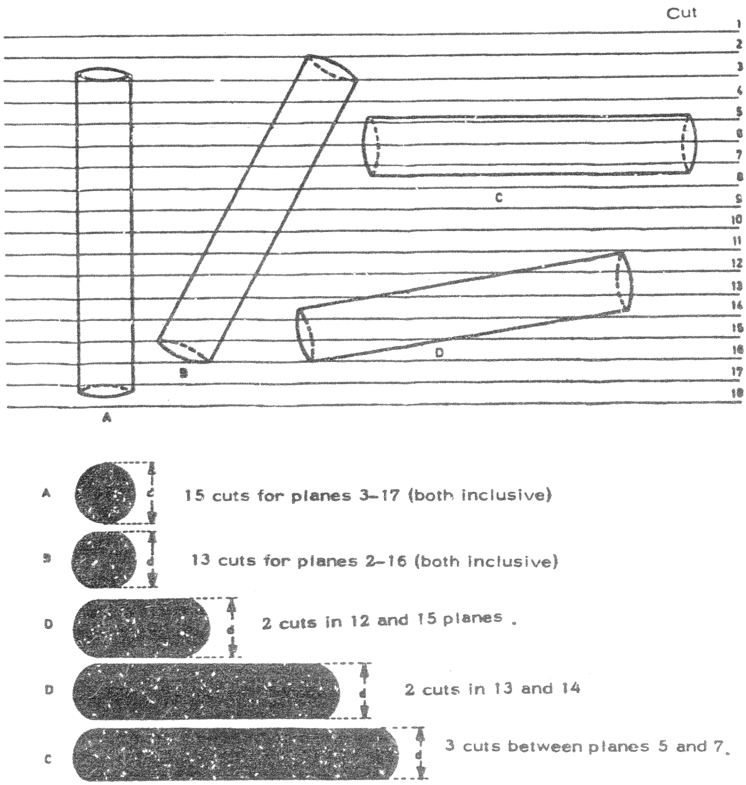
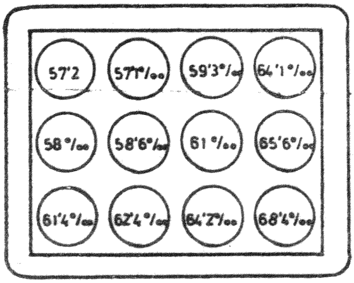


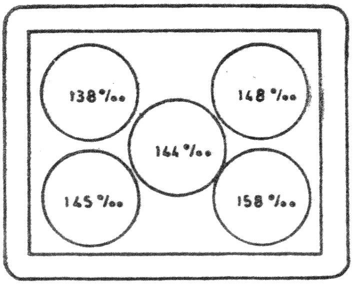
Fig. 1. Series of cuts in the same pore, with different orientations



Circle in center of field 60'2 ‰

Average error 2'1 %

Maximal errors −5 and + 14 %



Circle in center of field 144 ‰

Average error 1'8 %

Maximal errors − 4 and + 10 %

Fig. 2 Distortion of object according to its location on TV screen (areas measured as % of the whole screen area).

sions of measurement by making use of the little shutters in the set to cover up the zone we have no interest in.

Influence of orientation of the objects on the T.V. display

The void area measured directly by the set is constant and has not been influenced whatsoever by the pore orientation on the T.V. display. Now, in soil micromorphometry it is a matter of routine not only to give the total measurement of the porosity but to calculates the percentages of porosity based on the pore size, distribution, as these partial areas are of great interest, if we take into account the physical fertility of the soil.

With the Microvideomat we have been using, the object size can only be measured by the length of the horizontal intercepts of the T.V. lines with the object. Due to this, the best technic for determination of pore size distribution is the one proposed by Jongerius et al. (1972 a) which works with the intercepts and the factor of minimum chord lenght (diameter), but the result of this re-distribution is decisively influenced by the orientation of the objects on the T.V. display.

In order to evalue the influence of the orientation of the object, we have from the beginning simplified the problem by handling the analysis of one single pore so that we may proceed to consider some practical cases by taking a sieries of fields on divers soils with very different characteristics. In both of these cases 30º to 30º turns have been made on the corresponding measurements.

Ideaidez voids.

In the first case, it is evident that the morphology of the selected pore will influence in a decisive manner on the resulting measurement. Therefore, it will be readily understood that the more spherical in shape a pore may be, its orientation will each time have less influence on the measurements. Conversely speaking, on a more or less elongated pore an increase in the heterogeneity of its contours will mean that its orientation will be less decisive. To verify the aforementioned, we have idealized two pores of different morphological characteristics. One of them with a regular contour and tending to be elongated.

In Fig. 3 and 4 we depict in which way the total area will be distributed along its corresponding partial areas

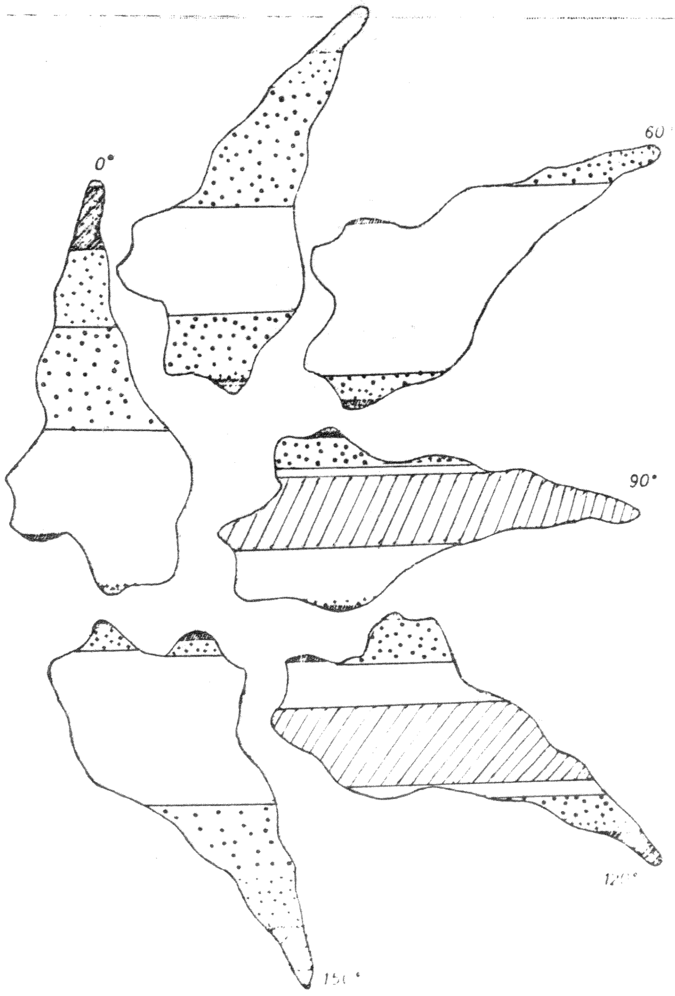


Fig. 3. Variations in the pore size distribution for a tentative pore by virtue of its orientation.

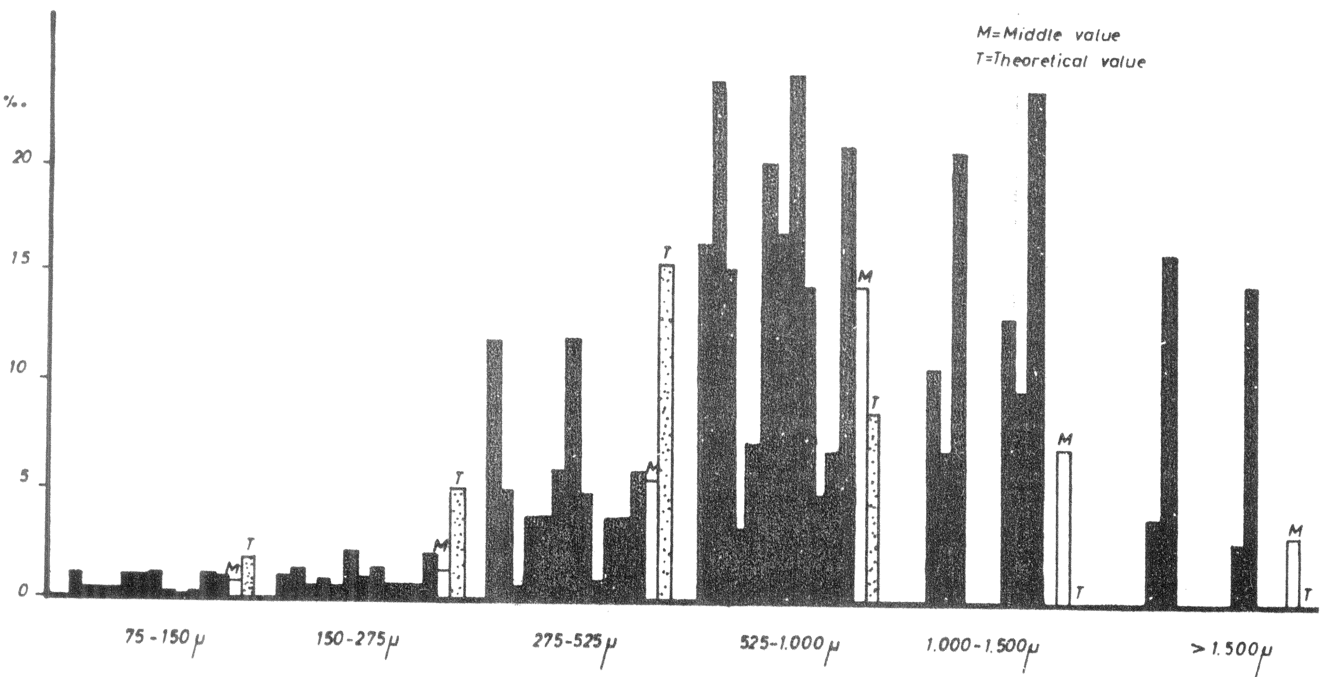


Fig. 4. Variations in the values of the pores size distribution for the pore of Fig 3, by virtue of its orientation

in the Microvideomat upon rotating the pore according to a 30º angle. In table 1 we outline the measurements thus obtained. The best distribution of the areas include position 0º and 180º. This table shows that the values obtained for the partial areas are perceptibly modified due to the pore orientation on the T.V. display.

As far as the second case is considered, we have isolated a pore of a rather irregular shape and in this case we have composed a distribution model highly theoretical to enable us to compare its partial areas with the Microvideomat measurements, knowing in advance that this theoretical distribution cannot be obtained on the Microvideomat equipment utilized.

The measurements on this theoretical distribution have been calculated in two different ways:

a) Isolating the different zones and measuring them individually on the Microvideomat (for this purpose these zones have been cutdown and reduced by photography thechnics).

b) Through direct measurement using a planimeter.

In Fig. 5 we show the shape of this pore, as well as the theoretical distribution carried out. The values obtained are shown in table 2 and Fig. 6.

Conparing the idealized measures with those taken upon rotating, (Table 2 and Fig. 6), we see that the experimental values here are also very different from those obtained starting out of the theoretical distribution, producing much lower values than the real ones for the areas corresponding to the smaller diameters, and a proportional increase of the values on the areas having the largest diameter.

Table I. Measurements for the distribution of the total

	Experimental Measurements					
Pore size \ Twisted angle	0°	30°	60°	90°	120°	150°
< 30 μ ‰	0, 0	0, 0	0, 0	0, 0	0, 0	0, 0
30 - 75 μ ‰	0, 1	0, 1	0, 1	0, 0	0, 2	0,2
75 - 150 μ ‰	1, 0	0, 3	0, 3	0, 3	1, 0	1, 0
150 - 275 μ ‰	1, 0	1, 3	0, 5	0, 8	0, 5	2, 1
275 - 525 μ ‰	11,8	5,0	0,6	3,7	3,7	5,8
525 - 1.000 μ ‰	16,5	23,9	14,9	3,2	7,1	21,5
1.000 - 1.500 μ ‰	–	–	10, 6	6,7	20,7	–
> 1.500 μ ‰	–	–	3,9	16,0	–	–
Total area (direct)	29,4	30,7	30,9	30,7	31,1	31,3
Intercepts	176	147	101	93	134	174

in partial areas for the pore shown in fig. 3.

180°	210°	240°	270°	300°	330°	Media	Theoretic
0, 0	0, 0	0, 0	0, 0	0, 0	0, 0	0, 0	0, 0
0, 1	0, 1	0, 0	0, 1	0, 1	0, 2	0, 1	0, 6
1, 1	0,2	0, 1	0, 2	1, 0	0, 9	0, 7	1, 8
0, 9	1, 4	0, 6	0, 6	0, 6	2, 0	1, 2	5, 0
11,9	4,8	0,8	3,7	3,7	5,8	5, 4	15, 2
16,8	24,2	14,4	2,8	6,8	20,9	14,4	8,6
-	-	13, 0	9, 6	23,5	-	7,0	-
-	-	2,7	14,7	-	-	3, 1	-
31,4	31,3	31,6	31,7	30,4	30,3	30,9	-
177	148	99	91	132	169	137	-

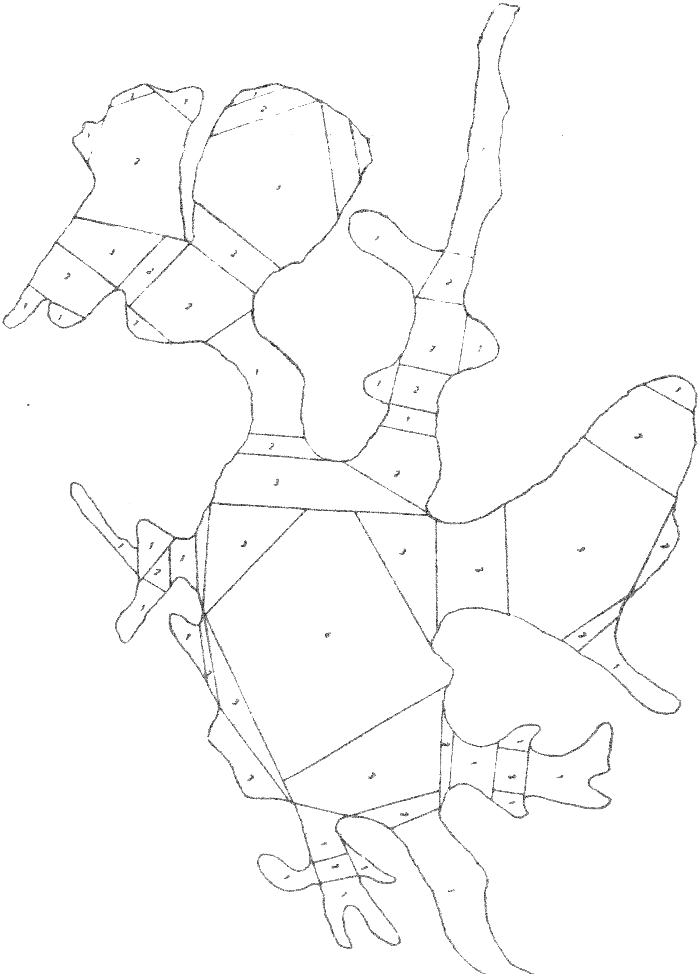


Fig. 5. Tentative pore size distribution patents for an isolated pore, according to the four diameters considered in table 4.

Pore size \ Twisted angle	Experimental Measurement 0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	Average	Theoretic
< 110 Å	2, 4	1, 5	4, 7	3, 5	3, 5	2, 2	2, 2	1, 5	2, 1	3, 4	3, 5	2, 1	2, 7	11, 2
110–200 Å	2, 2	4, 7	9, 0	8, 7	3, 2	6, 3	2, 3	4, 9	4, 6	8, 9	3, 6	3, 4	5, 1	10, 9
200–410 Å	7, 5	12, 3	11, 5	9, 3	8, 8	6, 2	7, 6	12, 2	12, 9	9, 5	9, 4	6, 1	9, 4	14, 0
> 410 Å	30, 8	22, 9	15, 3	16, 3	24, 6	27, 0	30, 3	21, 0	23, 2	16, 1	25, 2	28, 0	23, 4	6, 5
Total area %	42, 9	41, 4	41, 0	40, 9	41, 4	41, 7	42, 4	43, 1	43, 6	40, 6	43, 0	42, 8	42, 7	-
Intercepts	349	350	385	420	407	355	340	353	392	410	418	358	-	-

Table 2. Measurements for the distribution of the total area in partial areas for the pore shown in fig. 5

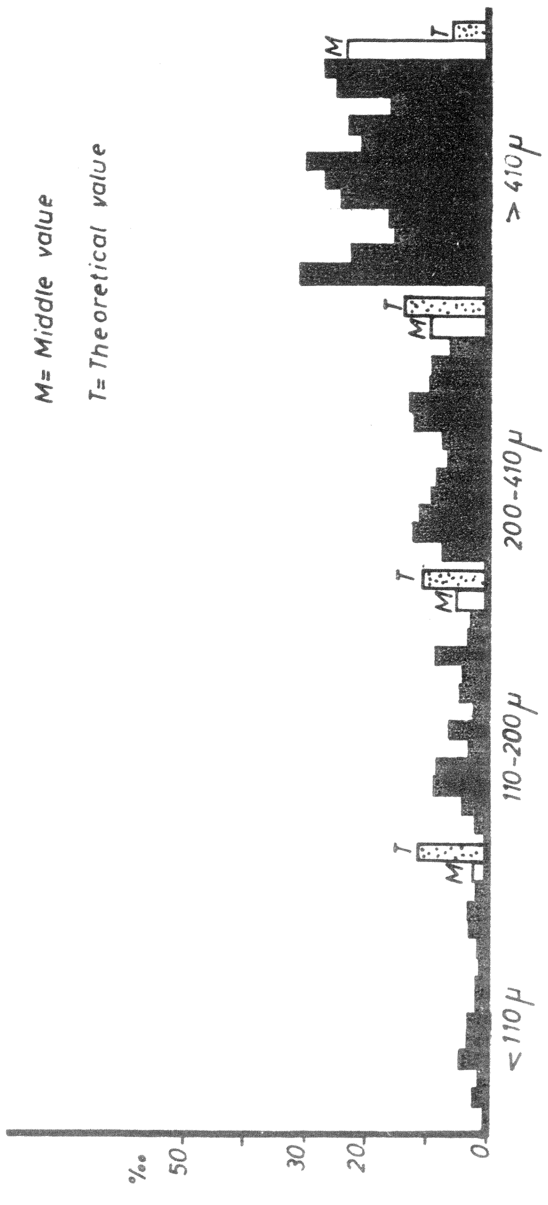
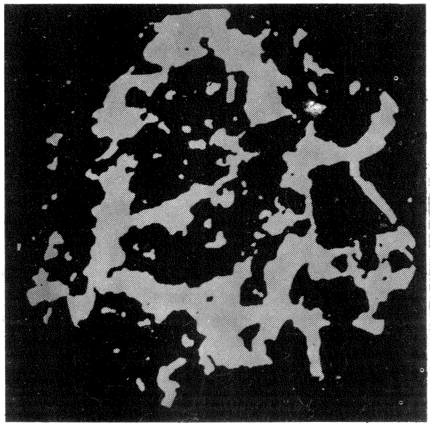
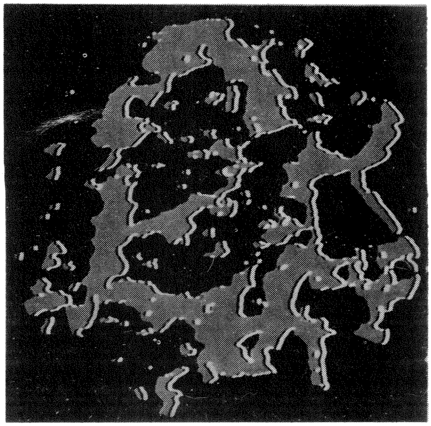


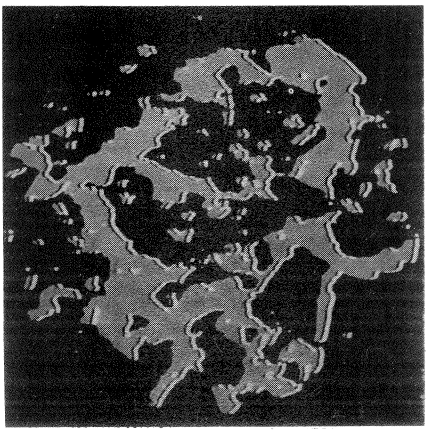
Fig. 6. Tentative pore size distribution patents for and isolated pore, according to the four diameters considered in fig. 5.



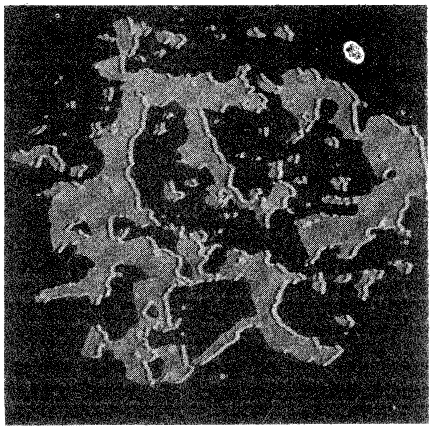
Discriminated image in position for measurement of areas.



Counting of intercepts. Position 0º.



Counting of intercepts. Position 45º.

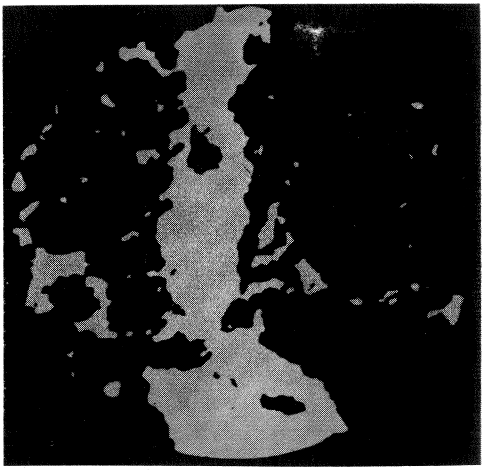


Counting of intercepts. Position 90º.

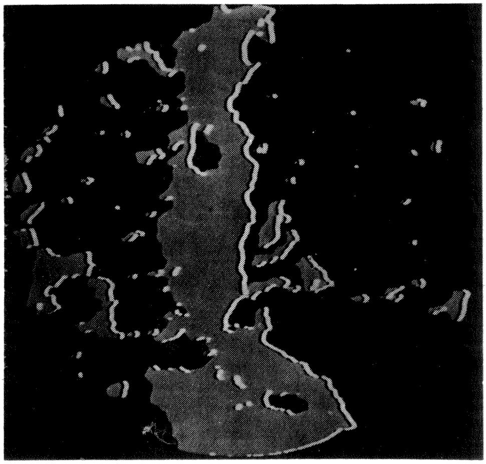
Fig. 7. Soil 36.

The diameter of the selected circular field is equal to the vertical length of the standard display screen.

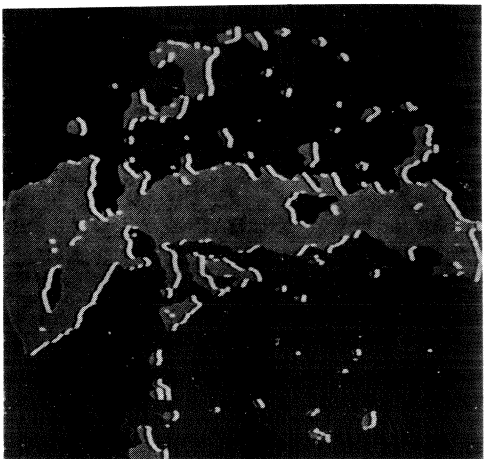
Fig. 8. Soil 12.



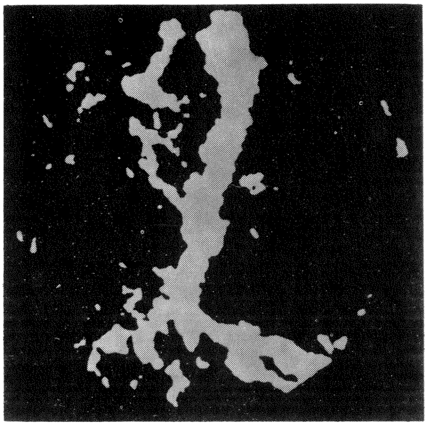
Discriminated image for measurement of areas.



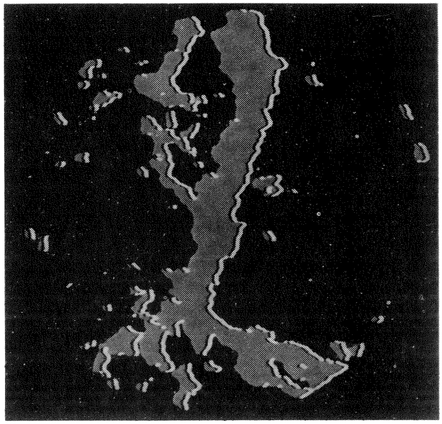
Counting of intercepts. Position 0º.



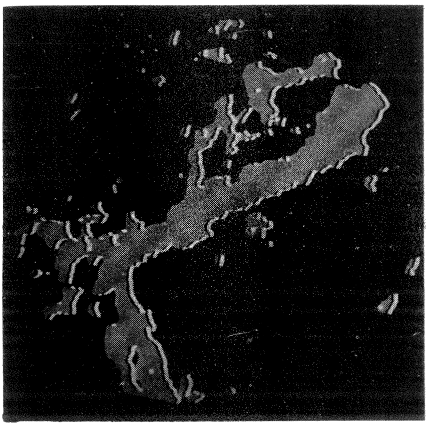
Counting of intercepts. Position 90º.



Discriminated image in position for measurement of areas.



Counting of intercepts. Position 0º.



Counting of intercepts. Position 45º.

Counting of intercepts. Position 90º.

Fig. 9. Soil 22.

Microscopic fields

As far as that which respects the second point in this discussion, 20 microscopic fields have been selected to study these practical cases on soil measuring. The results obtained on each one have been similar, and for which reason we only reproduce here the values on three of them. In Figs. 7,8,9, we show the micromorphology of the selected voids and their measurements that are resumed in tables 3,4 and 5.

As we can observe, for fields with a definite number of pores (Table 3 and Fig. 10) very homogeneous values can be obtained in any position. These values are similar, even in the case of the table 4 in which there is a very elongated voids, whose orientation does not exert too great an influence. We can only find important oscillations for the case of the table 5 and Fig. 11, which presents a small plane void which runs all along the selected microscopic field, and its orientation, naturally, influences decisively on the measurements. As a matter of fact in this case it is very easy select the correct orientation for all the field before proceeding with the measuring.

To summarize, we should like to point out, that although the orientation of the pores on the TV screeen does not modify the values of their total area, it does have a definite influence on the pore size distribution.

Errors caused by the Operator

The measurements of a physical magnitude is always subject to error. Still more, when one thinks of a semi - automatic system in which the operator has to intervenene.

The biggest error an operator can make is the one that can be produced through incorrect detection.

The detection is made by virtue of the gray tone in the details of the image. Consequently, in theory no problem is present at the time of selecting a white particle on a black

Experimental Measurement														
Twisted angle / Pore size	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	Average	
< 30 µ ‰	2,5	2,6	2,3	2,2	1,9	2,0	2,4	2,7	2,7	2,3	2,1	2,1	2,3	
30-75 µ ‰	8,7	9,0	10,0	9,0	5,4	8,3	7,8	7,8	9,5	9,1	8,8	9,1	8,5	
75-150 µ ‰	18,8	20,8	19,2	18,2	22,5	17,6	18,8	21,8	19,3	18,2	17,7	17,6	19,2	
150-275 µ ‰	33,9	30,0	21,6	23,2	30,7	34,0	32,6	26,7	20,2	21,9	30,3	33,1	28,2	
275-525 µ ‰	70,0	72,4	74,9	71,3	65,9	61,6	71,0	73,9	71,7	71,3	65,8	63,0	69,4	
525-1.000 µ ‰	64,8	65,4	63,7	83,1	61,4	76,7	67,6	72,3	65,7	81,8	60,6	69,7	69,4	
1.000-1.500 µ ‰	20,8	14,5	36,7	20,4	54,6	34,1	20,9	12,3	33,2	19,4	22,5	24,3	26,1	
> 1.500 µ ‰	21,9	27,4	14,5	14,7	0,5	8,6	20,3	24,6	19,1	15,3	30,1	18,2	17,9	
Total area %	241,4	242,1	242,9	242,1	242,9	242,9	241,4	242,1	241,4	239,3	237,9	237,1	241,1	
Intercepts	2495	2515	2450	2390	2355	2375	2440	2490	2445	2400	2360	2390	2425	

Table 3. Measurements of one same field, turning it at 30 to 30º. Soil 36.

Experimental Measurement													
Pore size \ Twisted angle	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	Average
< 30 μ ‰	1,3	1,0	1,1	1,4	1,4	1,4	1,4	1,2	1,2	1,3	1,4	1,2	1,3
30-75 μ ‰	4,4	3,9	4,4	5,3	6,2	5,9	4,7	4,4	4,8	5,9	6,6	5,8	5,2
75-150 μ ‰	11,8	10,4	10,2	10,6	9,7	11,0	11,4	10,9	10,7	11,5	11,3	12,0	11,0
150-275 μ ‰	14,4	14,0	12,3	14,0	13,2	11,4	14,3	15,1	14,1	14,8	12,6	11,7	13,5
275-525 μ ‰	20,2	24,9	32,2	31,1	23,3	26,3	21,1	23,9	33,4	29,5	24,9	25,4	26,3
525-1.000 μ ‰	79,7	52,7	47,8	30,8	44,2	56,6	79,2	67,3	44,3	30,9	45,2	59,0	53,1
1.000-1.500 μ ‰	38,9	75,7	43,7	38,1	56,5	46,5	39,5	40,4	44,8	31,8	42,3	46,6	45,4
> 1.500 μ ‰	32,2	18,8	48,3	68,7	44,1	38,0	24,8	35,4	47,4	77,2	60,0	42,6	44,8
Total area ‰	202,9	201,4	200,0	200,0	198,6	197,1	196,4	198,6	200,7	202,9	204,3	204,3	200,6
Intercepts	1410	1340	1350	1375	1430	1450	1420	1405	1400	1430	1480	1460	1412

Table 4. - Soil nº 12 Measurements of one same field, turning it at 30 to 30º.

Pore size / Twisted angle	Experimental Measurement												
	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	Average
< 30 μ ‰	1,7	1,5	1.3	1,3	1,4	1,6	1,8	1,7	1,3	1,3	1,7	1,8	1,5
30-75 μ ‰	4,2	5,4	5,1	4,2	4,2	5,2	4,5	5,7	4,7	3,8	4,5	5,4	4,7
75-150 μ ‰	10,2	10,1	8,3	6,7	8,9	8,0	8,9	8,6	8,2	8,2	9,2	10,2	8,8
150-275 μ ‰	13,6	17,7	15,7	12,7	10,4	13,7	12,7	19,3	13,0	14,6	15,9	14,5	14,5
275-525 μ ‰	37,5	29,9	36,8	31,0	38,4	28,4	32,0	27,1	31,7	35,4	44,6	42,1	34,6
525-1.000 μ ‰	82,3	42,1	32,7	61,6	67,8	97,8	80,8	48,7	42,8	61,8	52,1	85,7	63,0
1.000-1.500 μ ‰	13,5	4,5	12,8	42,2	19,9	14,0	9,2	3,7	8,3	34,6	23,4	5,2	15,9
> 1.500 μ ‰	---	54,7	53,0	7,4	20,4	----	20,1	50,9	55,7	4,6	15,7	---	23,5
Total area %	165,7	167,7	165,7	167,1	171,4	171,4	170,0	165,7	165,7	164,3	167,1	170,0	167,5

Table 5. Soil 22. Measurement of one same field, turning it at 30 to 30º.

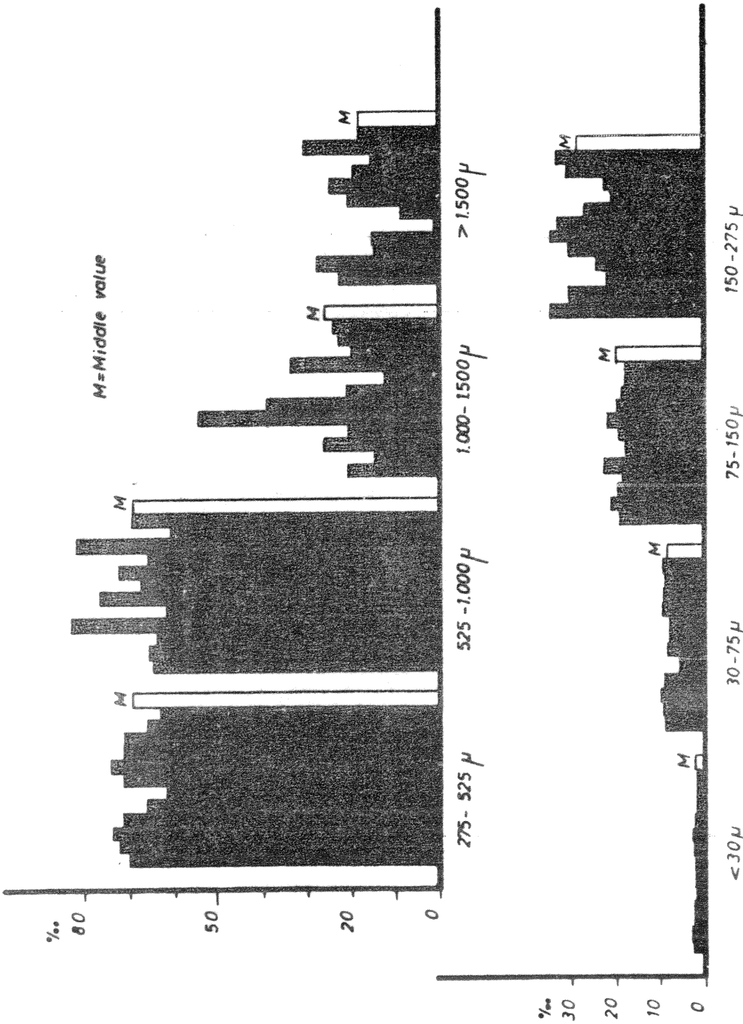


Fig. 10.– Variations in the values of the pores size distribution for the soil nº 22 of Fig. 9, by virtue of its orientation.

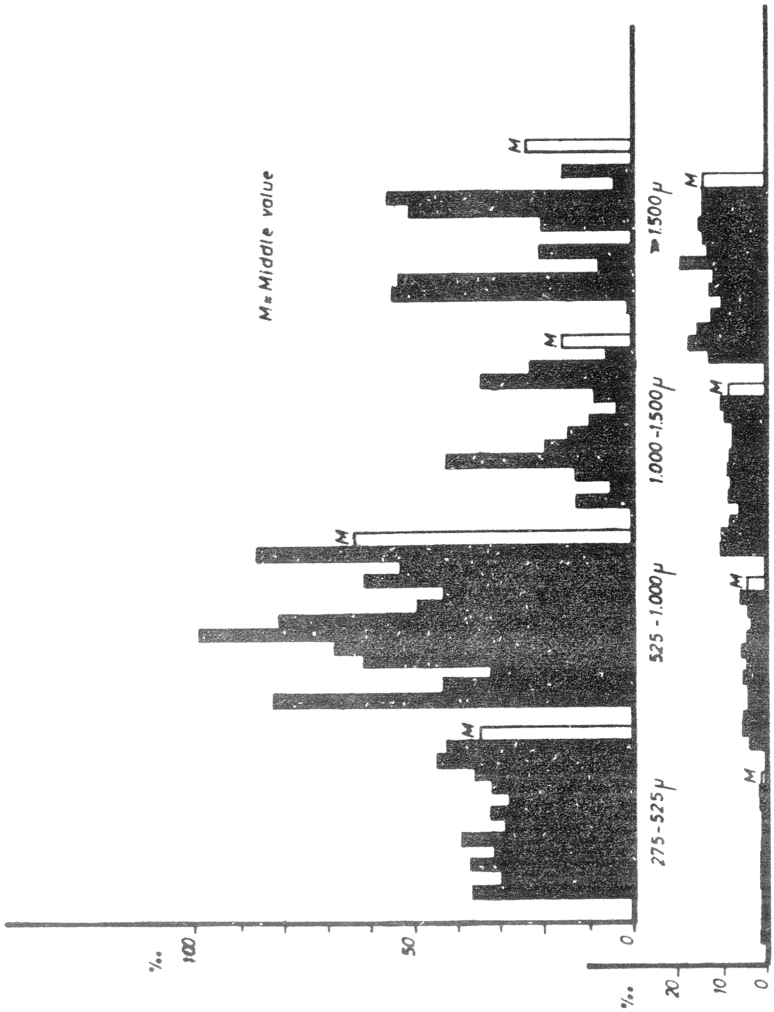


Fig. 11. - Variations in the values of the pores size distribution for the soil nº 36 of Fig. 11, by virtue of its orientation.

background; but if just so happens that for the Microvideomat the limit between the white particle and the black bacground represents a narrow transition band with all the tonalities of the gray without any solution of continuity, between the white and the black (this is the "Halo" effect). As a consequence, depending on the exact threshold of detection selected, the dimensions of the area of the discriminated particle may be modified in a certain value.

To try to help us in differentiating on the magnitude of the error that can be made at the moment of detection, we have made a trial using five fields for two different operators. In addition each operator has made the discrimination on five different occasions in one particular field. The results are shown in table 6. Fields nº 1 was a completely circular black object, with defined edges, surrounded of a white background. Fields 2 and 3 correspond to soil thin sections. For the measurement of field nº 4 a photographic negative-positive doublet was utilized. Finally, field nº 5 was measured using the fluorescence ilumination technics over polished block.

Upon examining this table we realize that the error caused by detection is practically negligible on contrasted images, with defined contours and of a sufficiently large size (field nº 1) while on some porosity measurements of soil samples such large deviation errors have been made, that in one case in particular we find a meximum error of − 12 % corresponding to a average error for this observer and soil of ± 6,3 %. Such important errors, however, are not always so high. Cut of the 80 measurements conducted on our samples of soil there are only 11 measurements which present a maximum error over + 5 % or − 5% and only in one particular case the average error goes as high as + 6 %.

In view of the aforesaid reasons, it is our impression that discrimination is the most difficult operation, which

Field	1		2		3		4		5	
Operator	A	B	A	B	A	B	A	B	A	B
measurement First	138	139	51	52	108	106	245	250	116	98
Second	138	138	48	45	106	101	243	235	120	115
Third	138	139	46	47	106	103	249	245	109	99
Fourth	139	138	46	49	105	106	244	228	105	125
Fifth	138	139	47	46	105	103	240	224	110	125
Sixth	138	140	47	50	105	103	244	235	110	110
Seventh	138	139	48	51	107	102	243	240	107	114
Eighth	139	139	50	46	106	104	240	230	108	113
Ninth	139	139	48	48	108	101	248	232	104	107
Tenth	139	140	46	47	105	105	241	239	104	109
Average measurement	138,4	139,0	47,7	48,1	106,1	103,4	243,7	235,8	109,3	111,5
Average Deviation	0,5	0,5	1,3	1,9	0,9	1,5	2,3	6,2	3,8	7,0
Average error %	± 0,4	± 0,4	± 2,7	± 3,9	± 0,8	± 1,4	± 0,9	± 2,6	± 3,4	± 6,3
Max.% of error	- 0,4	+ 0,7	+ 6,9	+ 8,1	+ 1,8	+ 2,5	+ 2,2	+ 6,0	+ 9,8	-12,1

Table 6. Results of the measurements performed using two different operators on the same fields, each of said operators obtaining up to a total of 10 measurements from each field. The values for the areas are shown in ‰ and the relatives to error in %.

can bring about, if not carefully done, the biggest errors in measurement.

As a conclusion to this chapter on errors, we should like to point out that in order to obtain reproducible porosity values through these optic-electronic methods, extreme care sould by taken in sample preparation and in the posterior measurements.

These will require a lot of attention regardin the illumination casted on the object - it must be homogeneous and with adequate intensity -, orientation and position of the object s on the TV display, resolution on the optic-electronic system, and, above all, to finalize the process exerting meticulous detection. If the above is complied with, we believe that this technic will turn out excellent values for the total areas of the pores. And in reference to the distribution of these areas within partial areas (pore size distribution), we believe that the accuracy of the values descend quite a lot as the orientation of the object on the TV display has a decisive influence with the equipment we have been using.As a consequence the values for the corresponding areas of the larger diameters are undervalued to the detriment of the areas of the smaller diameters.

TIME CONSUMED IN MEASURING

When measuring the total porosity area, time is not an important factor to take into consideration, as this is done instantaneously.

Notwithstanding this, the pore size distribution is a process which takes some time with the basic manual equipment used. In each field, between the discrimination and the processing of data by means of a computer, from 5 to 8 minutes are required.

With normal work magnification (31 x) the surface covered for each fiel has true dimensions of 5,7 x 5,7 mm. The slides or polished blocks employed by us are 50 x 70 mm. which represents a total of 98 useful fields which would take up over 8 hours per sample.

This time may be drastically reduced by using equipment fully automatic for the exploration of the thin sections, discrimination and processing of data.

The automatic equipment is very fast in its functioning. However the measurements obtained in soil micromorphometry are not exact and in wiew of the variability of the soil materials it is very difficult to schedule its discrimination in advance. There-fore, we consider, that the correct procedure to follow must consist of a mixed process, with full automatization for the regulation of luminous intensity, discrimination for the minimum factor chord and the processing of data, with manual operation for the selection of the fields, search for the most favourable orientation of the voids and detection of the voids from the rest of the components.

STATISTICAL MEANING OF RESULTS

In order to determine the number of data to be drawn from each soil (following the hypothesis that it is the case of a simple aleatory sample) we have started out fundamentally to correct the maximum significance and minimum error, from the results obtained for the total areas of porisity. These have been performed on the basic of the measurements mentioned in the study "Micromorphometry of voids in olive grove soils" by Dorronsoro et al. discussed in these Proceedings.

By taking pilot-guide samples we found that the number of fields measured for a 90 and 95 % confidence limits and with a series of variable errors are equal to those we indicate in tables 7 and 8. In no instance have we taken into

Soil	1	10	12	22	33	36
Area in %	22, 1	7, 6	8, 0	6, 5	25, 9	19, 4
Number of fields measured	91	22	92	137	55	77
error= 0, 6	497	95	101	425	849	746
error= 0, 7	365	70	74	-	624	548
error= 0, 8	280	-	57	-	478	420
error= 1	179	-	-	-	306	269
error= 1, 9	50	-	-	-	85	74
error= 2, 2	37	-	-	-	36	-
error= 2, 6	-	-	-	-	45	-

Table 7. number of fields to be measured on each soil to obtain the error outlined in the first column ; for a 90 % fiducial limits

consideration an error estimate of 10 % over the value of the area for each soil and a confidence limit of 90%. Under these conditions, the number of fields under measurement oscillates between 37 and 74 (62 to 105 for a confidence limit of 95 %) for 5 of the 6 soils analyzed. One of them required repeated measurings of 425 fields for 90 % confidence limit. This value is so excessive due to the type of voids present in this soil(large planes) depending on whether these planes fall into the analyzed fields or not, the values of porosity of these vary to a large extent.

Soil	1	10	12	22	33	36
Area in %	22, 1	7, 6	8, 0	6, 5	25, 9	19. 4
Number of field measured	91	22	92	137	55	77
error= 0, 6	701	134	143	600	1 197	1. 053
error= 0, 7	515	99	105	-	880	773
error= 0, 8	394	-	80	-	673	592
error= 1	252	-	-	-	431	379
error= 1, 9	70	-	-	-	119	105
error= 2, 2	52	-	-	-	98	-
error= 2, 6	-	-	-	-	56	-

Table 8.
Number of fields to be measured on each soil to obtain the error outlined in the first column, for a 95 % fiducial limits.

Although it would be perfectly feasible to measure in a micromorphometric study the 425 required fields, if we disregard the five most extreme values of the ones found for this soil, the number would be reduced to only 234 fields.

As we see with these results, we can assert that in spite of the large heterogeneity of the soils, the values on total areas of porosity we have obtained from the 6 soils under study, are significant with confidence limits of 90 and 95 %, accepting a maximum error of 10 % for the measured area.

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SUMMARY

In this work we present a faultfinding study concerning the accuracy of the porosity measures obtained through image analysis systems.

We discuss from an experimental point of wiew the various types of error that can be made upon using these technics as are the ones incurred through : cut, object, orientation on the monitor display, image distortion in the monitor and errors caused by the operator himself, (detection).

A few additional remarks are also offered in regard to the speed factor of these technics and on the statiscal significance of the results obtained.

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