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THE BEHAVIOUR OF STONES AND STONE IMPLEMENTS, BURIED IN CONSOLIDATING AND CREEPING KALAHARI SANDS

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SUMMARY

This study reveals that the Quaternary mantle of reworked Kalahari Sands undergoes a post-sedimentary composite process at the archaeological site of Gombe (Kinshasa, Zaïre). There is a biological activity which consists of an upworking of soil particles, mainly by termites and worms. This causes a diminishing dry volume weight of the sediment. In response, the mantle reconsolidates.

When the soil surface is horizontal, the particles which are not brought up will sink down in the soil profile as a result of the reconsolidation. When the soil surface is inclined, it is only the resettlement of the sediment which can give rise to creep, caused by wetting and drying. Creep of the dead mineralogical material alone seems to be very improbable once the structure and settlement of the sediment are in equilibrium with a given slope. Only a new phase of bioturbation can induce further creep movements.

The experiments have shown that stone implements in reconsolidating Kalahari Sands do not exactly accompany the compaction movement of the sediment. Depending on their form, their size, their orientation and the water content of the sediment around them, stone implements can undergo differential movements during the reconsolidation process. This can result in a dispersion of the implements over levels of different ages.

As creep is a phenomenon, going hand in hand with the resettlement of the sediment after biogenic upworking, partially analogous movements of stone implements can be expected in a creeping Kalahari Sands mantle.

Partial or total reconcentration of the stone implements at the base of affective biogenic activity can be expected. This can lead to typical stone-line profiles which must be interpreted very carefully.

KEY WORDS Consolidation Creep Dry unit weight Pressure Structure Water content

INTRODUCTION

Archaeological investigations have recently been carried out at the site of Gombe (Kinshasa, Zaïre) (Cahen (1967)). Gombe, under its former name 'Kalina' is a famous prehistoric site in Central Africa. Its ecological, stratigraphical and archaeological context is similar to the great majority of other open-air sites on which relies the present-day prehistoric nomenclature and chronology, as established within the Central African Kalahari Sands belt.

The site of Gombe is located in the Kinshasa plain and forms a small peninsula, protruding northward into the Zaïre river. The substrate consists of Mesozoic sands and sandstones, the top of which is capped by an impermeable silicified carapace, 1–2 m thick. The overlying mantle, 3–5 m thick, is considered as a proluvial formation, derived from the Tertiary so-called Kalahari Sands, making up the highlands surrounding the Kinshasa plain (De Ploey (1965)). This author stated that the mantle was deposited during the dry semi-desertic period, which coincides at least partly with the latest maximum of the Würm glaciation in Europe. A discontinuous veneer of rounded quartz gravels with a mean diameter of 2 cm separates the undulating top of the silicified bedrock from the overlying mantle.

A number of trenches, dispersed over the northern part of the peninsula showed a complete absence of any sedimentation structure in the mantle. Granulometric analysis of samples, taken systematically at depth increments of 5 or 10 cm never showed significant differences (Figure 1). The dry unit weight

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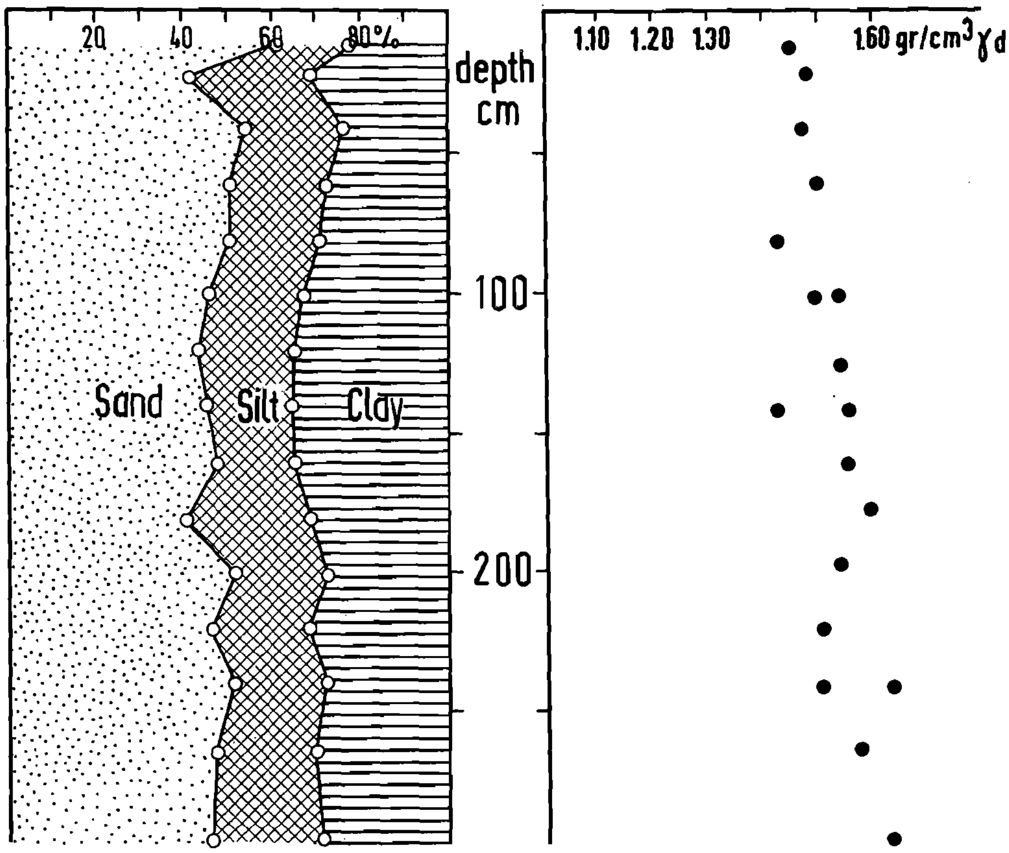


Figure 1. Granulometric composition (sand: >63 μm, silt: 63 – 2 μm, clay: <2 μm) and dry unit weight (γd) of the sand mantle at the Gombe peninsula (trench 2); the dry unit weight increases as a general rule with depth, but seldom exceeds 1·60 g/cm³

of undisturbed samples increased slightly with depth, and averaged 1·55 g/cm³. It was determined by weighing dry undisturbed soil parts, the volume of which was measured in a graded glass filled with water. This was possible through sealing the surface of the samples by a water resistent gum. The values obtained are thought to be overestimations because the samples had been shrunk before treatment.

Actual biogenic reworking of the sand mantle is uncontestable as termites and worms were seen in the field and biogenic structures were visible in the pit walls as well as in the undisturbed samples. It is thought that the lack of sedimentation structures is due to long biogenic activity in the past.

As a first approximation, the archaeological content of the more than 3 m-thick sand mantle can be summarized as follows: traces of occupations from Iron Age times are replaced at about 40 cm below the top of the mantle by a continuous succession of worked stones. The number of artefacts remains, however, quite restricted, except 30 or 40 cm above the base of the mantle, where a considerable concentration occurs, containing 45–95 per cent of the total artefact population. In fact, this basal concentration rests greatly upon the silicified bedrock. A charcoal sample from the base of the mantle was dated as older than 43,800 B.P. (GrN 7,277).

The study of the artefacts revealed a considerable amount of worked stones, fitting perfectly together: original core stones, one of them composed out of more than 100 flakes and fragments, could be reconstructed. The archaeological evidence is that artefacts fitting together in this way, are strictly contemporaneous (Cahen (1976)). The problem is that fragments of the same core stone can often be found, dispersed within the mantle over a vertical distance of more than 1 m. According to C^{14} dates, obtained from different levels, a vertical distance of 1 m can represent more than 10,000 years. Possible explanations for this vertical distribution of contemporaneous artefacts could be reduced, mainly on archaeological grounds, to one hypothesis: the worked stones should have undergone subsurface vertical movements, without appreciable lateral transport.

Given the general importance of the site for Central African prehistory, and taking into account archaeological reasons to believe that vertical post-sedimentary redistributions of artefacts are not a local phenomenon, it was thought important to investigate this problem by means of experiments. Furthermore it was thought that this problem is of pedological and geomorphological interest.

EXPERIMENTS IN A NON-CREEPING MANTLE

Preliminary remarks

Sand and artefacts, used in the experiments as later described, were taken from the field. The experimental sand sample can be defined as a silty–clayey sand: 58·1 per cent of its weight consists of sand ($>63\,\mu$m), 28·0 per cent of silt ($63\,\mu$m–$2\,\mu$m) and 13·9 per cent of clay ($<2\,\mu$m). The plasticity index amounts to 11 per cent, the plastic limit water content being 12 per cent. Some characteristics of the artefacts used are given in Table I. If not mentioned, the numbers, designating artefacts, refer to this table.

The first purpose of the experiments was to verify the old idea that stones can sink through a loose sediment layer (Delhaye (1947), Laporte (1962)). Therefore, stone implements were put down upon and/or buried in artificial sand columns, held in boxes of different forms and sizes. The sand was alternately wetted and dried in order to simulate a balancing water table and/or percolation, of rainwater. The term cycle, used further, comprises one phase of wetting, followed by one phase of drying.

Detailed unit weights were measured during the experiments by means of a small, sharp-edged plastic receptacle, which was filled by pushing it carefully into the sediment. A small perforation in the bottom of the receptacle prevented air and soil to be compressed. Mean dry unit weights were obtained by weighing the filled boxes, taking into account the volume and the mean water content of the sediment and the weight of the box.

Artefacts put upon the surface (Figure 2)

A plastic box, with slightly flexible faces was used. The dimensions were 57 cm × 47 cm × 9 cm height. This box was filled with sediment, the mean dry unit weight being about 1·45 g/cm^3. Stone implements 1, 2, 4 and 5 were put on the surface. Wetting was achieved by infiltration of water from certain points at the surface. A hot air stream (sediment temperature at the surface: ± 40°C) activated the drying out. The maximum water content varied between 25 and 35 per cent, the minimum between 12 and 0·5 per cent. Intra-cyclic and extra-cyclic movements were recorded: every object penetrated deeper in the wetting sediment and rose during the time the sediment was drying out. The difference between the amount of penetration and rise led to an extra-cyclic descending movement. The mean vertical position after each cycle, measured between 3 points on each object and the top of the sediment is given in Figure 3(1). The degree of penetration is highest for the stone implements with the highest proportion of weight/vertical projection surface. The penetration rate seems to be a linear function of the logarithm of the number of cycles applied. The question arises whether this will hold in the case of a very high number of cycles.

Table I. Stone implements, used in experiment 1

Number	Length, width, height (cm)			Specific weight (g/cm^3)	Weight/vertical projection surface (g/cm^3)
1	3·35	2·83	0·51	2·34	0·78
2	9·53	4·28	1·81	2·66	2·61
3	7·41	3·88	2·03	2·50	3·13
4	10·07	8·48	7·32	2·31	8·20
5	7·43	6·26	4·01	2·43	6·95

Figure 2. Experiment 1, stone implements 1, 2, 4 and 5 on the surface; hot air stream created by a fan and an electric heating apparatus; water was supplied at the right corner of the box in the foreground

Artefacts laid down upon and buried in the sediment

Artefacts 2 and 5 were laid upon the surface. Artefact 4 was buried at a depth of 5 cm, which is an arbitrary position after a supposed high number of cycles. An iron pin, fixed on object 5, and protruding through the sediment made cyclic records of vertical movements possible. The experiment ran for 46 cycles. The higher initial mean dry unit weight (1·53 g/cm^3) can be the reason why objects 2 and 5 descended over a smaller distance than in the foregoing experiment. However, this cannot explain that the 'heaviest' object 4 descended this time considerably less than object 5 (Figure 3b). It seems therefore that the proportion of weight/vertical projection surface of an implement becomes less significant with increasing depth and that the linear relation between the amount of penetration and the logarithmic cycle scale is only an approximation of a curved line becoming more horizontal as a result of an increasing number of cycles.

Artefacts buried at 30 cm or more below the surface

Experimental layout. A box was used as shown in Figure 4. The basal part is provided with two side-boxes separated from the central part by a perforated side. The central part was filled with sediment in which artefacts were buried. Wetting was realized by maintaining the water level in one side-box until water reached nearly the same level in the opposite one. A falling water table was simulated by emptying one side-box until water had left the other.

The removable column could be filled with sand. In this way a real depth of 30 cm was reached. Depths of 60 and 90 cm were simulated by putting down weights upon the sand in the column. The calculation of the amount of weights to be added was based on the assumption of a mean dry unit weight of 1·5 g/cm^3. A depth of 212 cm was simulated by exertion of a vertical stress of 255 kg on the 800 cm^3 surface of the basal part of the box. This was realized by leverage. The position of buried stone implements was measured with reference to the edges of the box before and after each experiment. The number of cycles varied between 7 and 10.

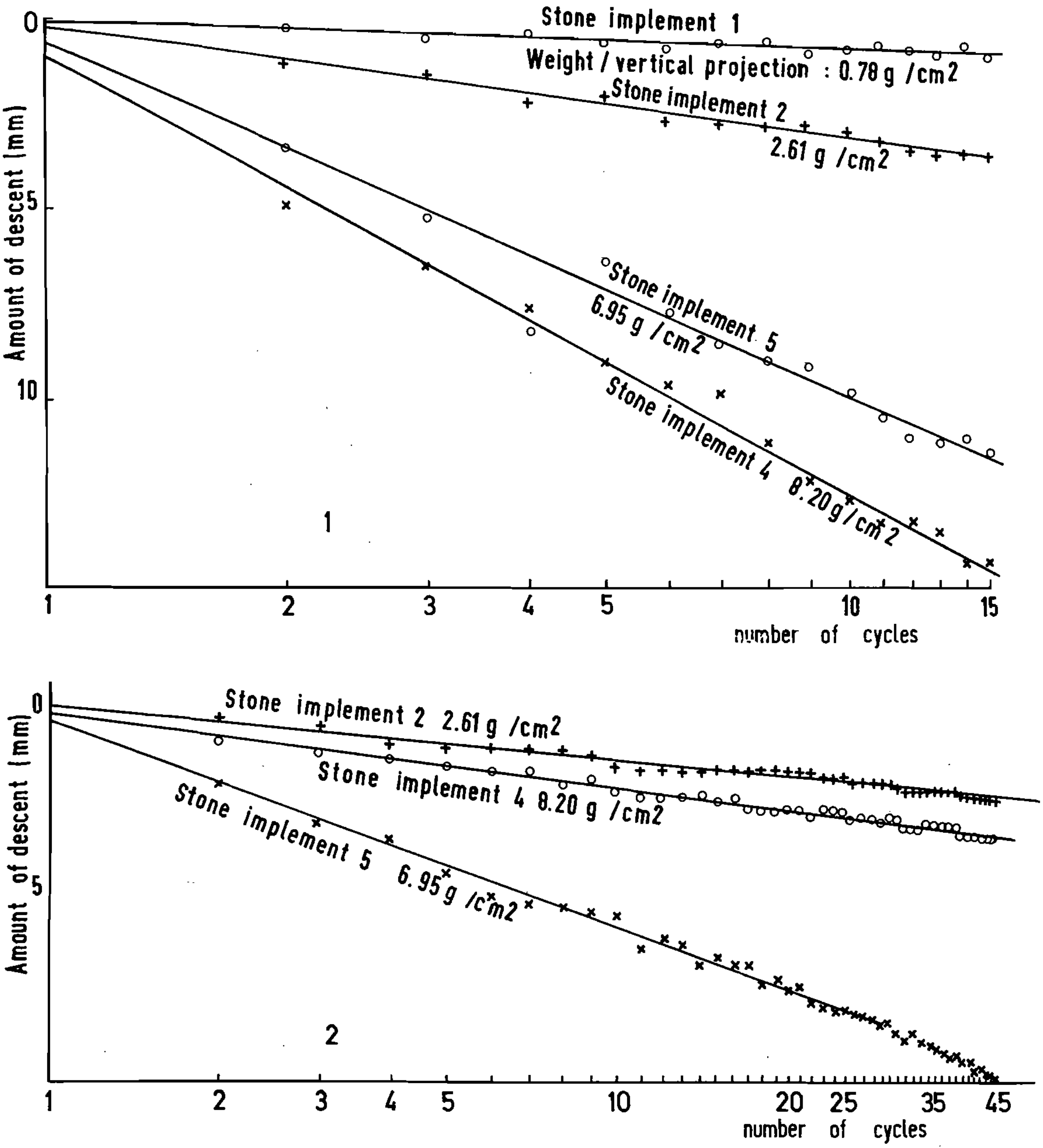


Figure 3. The vertical descent of stone implements in reworked Kalahari Sands as a function of the logarithm of the number of cycles; (1) all implements laid down upon the surface—the 'heaviest' implements sink fastest (2) the 'heaviest' implement 4 buried at 5 cm depth reacts as the 'light' implement 2

Results. The artificial soil column underwent consolidation during each experiment. This was shown by a decrease in height of the column during the experiments and by an increased dry unit weight in the basal part of the box after each experiment (Table II). These final dry unit weights exceeded systematically the already overestimated values at respective depths in the field. Nevertheless, the results of the experiments were confirmed by an oedometer test (Figure 5).

From the vertical position, measured before and after each experiment (Table II), it seemed that the artefacts followed more or less the descending movement of the surrounding sediment during the consolidation process. However, the absolute amounts of descent of the artefacts during one experiment lay sometimes within a rather wide range (Table II, depth of 60 cm and 212 cm). It was not clear if this was due to differential movements within the consolidating sediment or to stone movements, relative to the enclosing sediment.

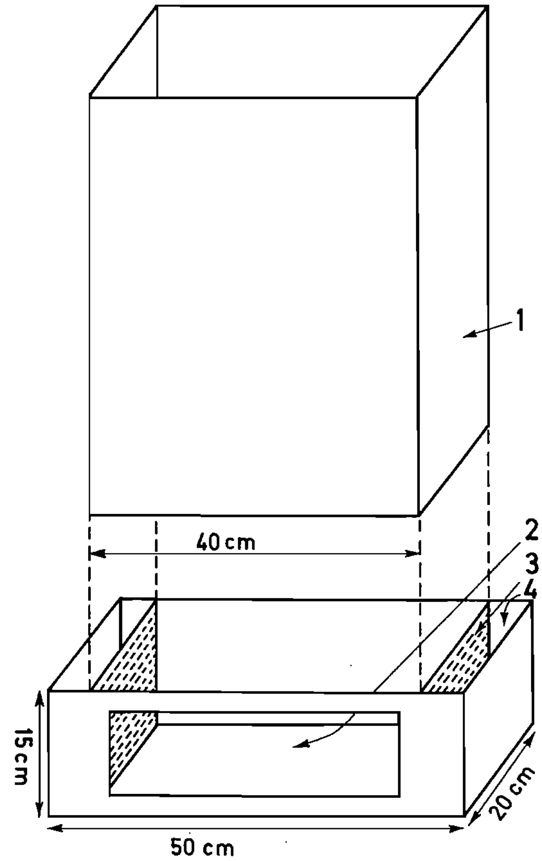


Figure 4. Box used to simulate depths from 30 cm to over 200 cm; a removable column (1) without bottom can be fixed on the box; a plexi-glass side (2) is provided; wetting of the sediment is realized from the side-boxes (4) which are separated from the sediment by a perforated (diameter of perforations 1·5 mm) wall (3)

Additional measurements. This problem was elaborated in a new series of tests, where consolidation was simulated by vertical compression of a small sand column. The vertical position of wooden blocks, buried in the sediment, was recorded before and after each test of simulated consolidation. This was done in the shearing box of a mono-axial shearing apparatus. Rather high vertical stresses—between

Table II. Data concerning simulated depths of 30, 60, 90 and 212 cm

Simulated depth	Dry unit weight (g/cm^3) in basal part of box		Calculated or estimated vertical pressure (g/cm^2)	Absolute descent of stone implements	
	Before experiment	After experiment		(no.)	(cm)
−30 cm (earth column)	1·50	1·55	±45	2	0·58
				3	0·64
				5	0·57
±60 cm (30 cm earth column + 45 g/cm^2 dead load)	1·57	1·60	±90	1	0·01
				2	0·05
				5	0·35
±90 cm (45 cm earth column + 67·5 g/cm^2 dead load)	1·55	1·63	±135	2	0·84
				3	0·69
				4	0·85
±212 cm (vertical pressure by leverage)	1·53	1·70	318	4	0·94
				2	1·68
				3	0·91

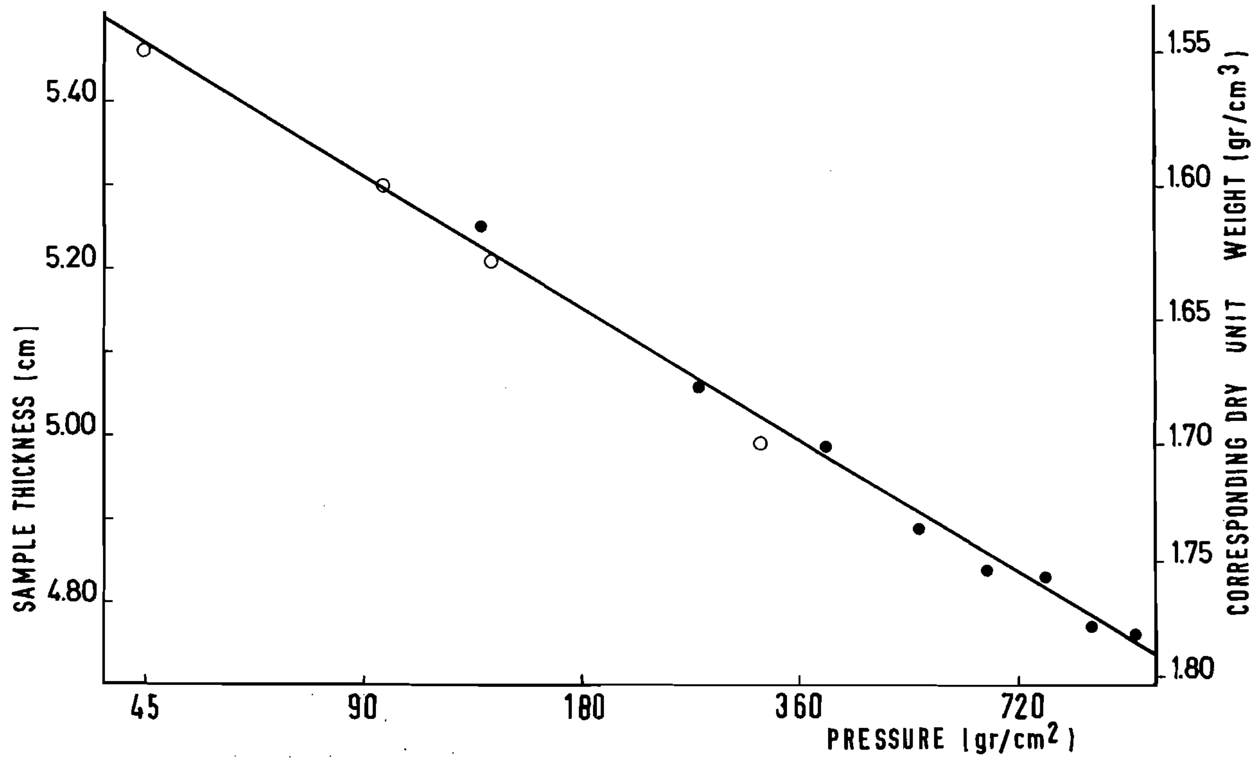
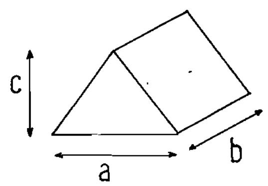


Figure 5. Compression line of the 'Kalahari Sand', obtained in the oedometer test (very slow) (closed circles) and completed by experiments described in the text (open circles); accepting a dry unit weight of 1·50 g/cm^3 in the field, the expected dry unit weight at 200 cm depth should be near to 1·70 g/cm^3

Table III. Movement indices for wooden blocks: measurements described under *Additional measurements*

Block number	Sediment	Orientation of block	Number of measurements	Mean movement index *i*
1	wet	top up	6	1·16 ± 0·12
a = 3·76 cm	wet	down	10	0·89 ± 0·21
b = 4·95 cm	dry	up	5	1·51 ± 0·21
c = 1·75 cm	dry	down	5	1·28 ± 0·21
2	wet	up	5	0·95 ± 0·14
a = 2·22 cm	wet	down	5	0·97 ± 0·15
b = 1·70 cm	dry	up	5	1·25 ± 0·16
c = 1·13 cm	dry	down	5	1·38 ± 0·17
3	wet	up	5	1·18 ± 0·05
a = 4·44 cm	wet	down	5	0·98 ± 0·08
b = 3·40 cm	dry	up	5	1·37 ± 0·24
c = 2·26 cm	dry	down	5	1·28 ± 0·20

Dimensions of the blocks:



850 g/cm² and 1,000 g/cm²—were exerted in order to obtain a compression of the sand, uniform over the whole depth of the sediment column. This permits the calculation of the amount of absolute descent of an arbitrary horizontal plane in the column, when the total amount of vertical compression and the initial height of the column are known.

Wooden blocks, instead of quartzite artefacts were used. There was no objection to this, because, as stated in *Artefacts laid down upon and buried in the sediment*, the weight of an object becomes much less important with increasing depth. The prismatic form of the 3 wooden blocks (Table III) was chosen as a result of a frequently occurring shape in the artefact population.

The 3 blocks were buried with their points directed alternately upward and downward and in wet (19 per cent water content) and dry sediment. The vertical movement indices are given in Table III. The vertical movement index $i = \Delta ho/\Delta hs$

where Δho = the absolute amount of descent of the centre of gravity of the object during exertion of vertical stress upon the soil column.
Δhs = the absolute decrease in height of that part of the soil column, situated between the horizontal bottom of the box and the horizontal plane in which the centre of gravity of the object lies before exertion of pressure.

When $i < 1$: the object penetrates sediment situated originally above. In relative terms the object rises; $i > 1$: the object penetrates sediment situated originally below. In relative terms the object descends. For the sake of completeness, it has to be mentioned that two identical blocks no. 2 were always used together: one with the point directed upwards, the other with the point directed downward.
Some factors strongly influence the vertical movement index (Table III).

1. The water content of the sediment: i lies systematically higher in wet sediment for the same object in the same position.
2. The position of the object: i is systematically higher for the objects 1 and 3 when their points are directed upward.
3. The size of the object: objects 2 and 3, only differing in size, react in a different way, depending on their orientation.

EXPERIMENTS IN A CREEPING MANTLE

Preliminary remarks

It is known that stone objects, buried in a mantle, undergoing frost-creep, can be orientated with their long axes parallel to sediment motion (Rudberg (1958, 1962)). Therefore, the possibility that stones should undergo vertical movements in a creeping mantle was taken into consideration. It must, however, be stressed that the information, obtained in the experiment described hereafter, refers only to creep in a frost-free environment.

Experimental layout

A box, 40 cm × 20 cm × 15 cm high, was filled with sediment as indicated on Figure 6. Four rather angular quartz pebbles with a mean diameter of about 2·5 cm were buried. Their initial vertical position is given in Table IV. Two thin fibres were placed in the sediment in a vertical position by means of a thin iron pin. Thin glass blades were inserted in a vertical position in the top of the sediment in two lines, l and m. The mean dry unit weight amounted to 1·5 g/cm³ before and to 1·53 g/cm³ after the experiment. The following wetting techniques were used in an arbitrary sequence:
—creation of a spray of very fine drops (diameter ± 1 mm) on the sediment;
—infiltration of water from ridge *A* on Figure 6;
—wetting by putting water in the basal space *B* of the box.
This technique was only applied three times because it provoked considerable erosion on the edge *C* of the sediment block.

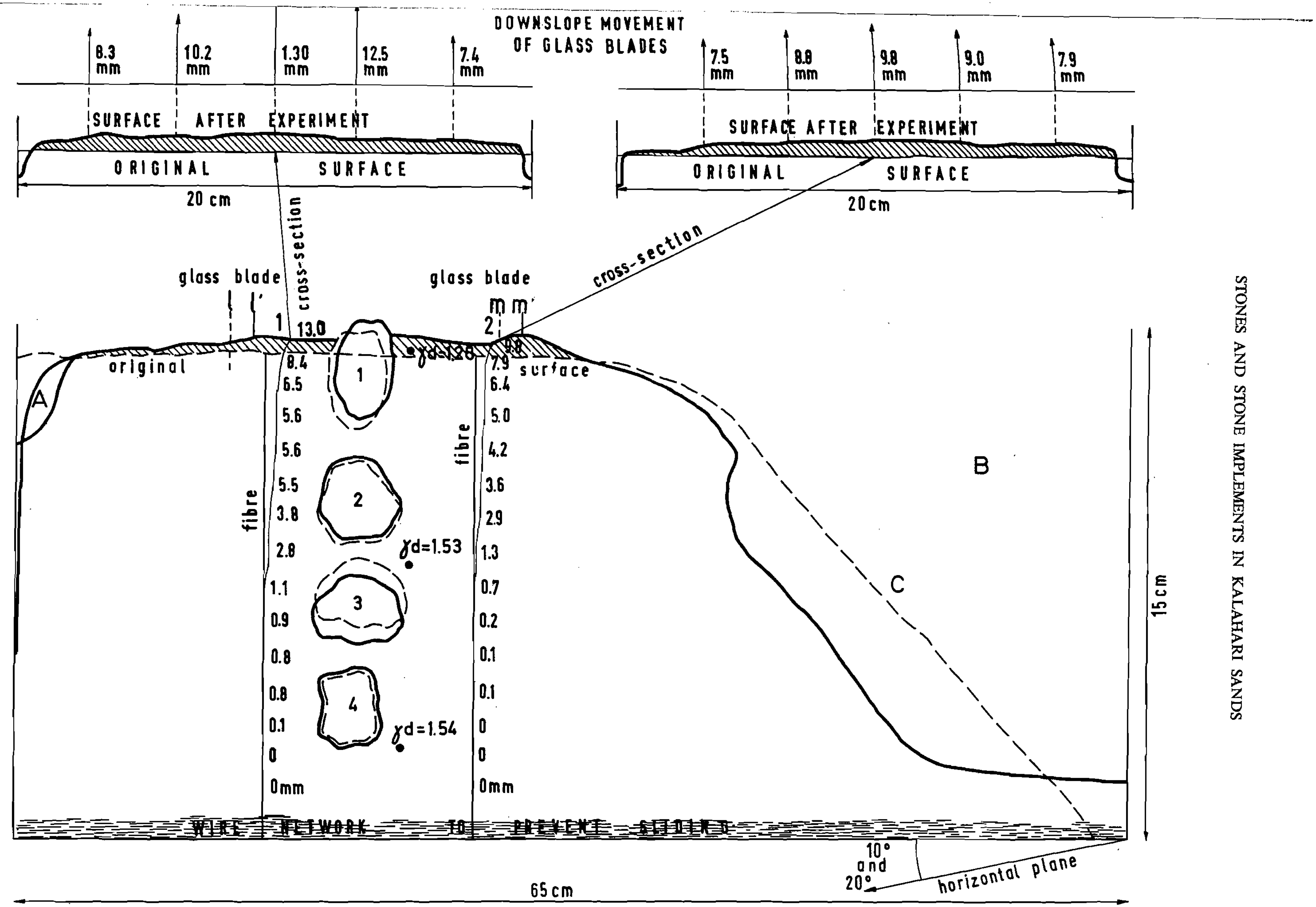


Figure 6. Graphical synopsis of the creep experiment; position of stones, fibres, glass blades (l and m) and top of sediment indicated before (dotted line) and after the experiment (full line); indicated dry unit weights were taken after the experiment

Table IV. Vertical displacement of quartz pebbles after creep experiment

Pebble	Top of pebble before experiment	Vertical displacement after experiment
1	0·53 cm above top of sediment	0·35 cm upward
2	3·45 cm below top of sediment	0·04 cm upward
3	6·31 cm below top of sediment	0·50 cm downward
4	9·48 cm below top of sediment	0·01 cm downward

Drying went on in sunlight or by means of a radiation lamp.

The box was inclined over 10° at the start of the experiment. After 10 cycles, the slope inclination was increased to 20°.

Results

The creep mechanism. The vertical displacements of the 4 quartz pebbles as recorded after the experiment can be better understood after discussion of the creep movement. Figure 7 shows the amount of creep recorded after each cycle by measuring the position of the middle glass blade of the two glass blades lines. It shows that creep was faster on the 20° slope. On the 10° slope, as well as on the 20° slope, the creep rate seems to be linear rather with the logarithm of the number of cycles than with the number of cycles. In fact, the slope inclination was raised to 20° because the creep movement died out at 10°. The idea that this dying out is due to an adaptation of structure and settlement of the sediment to a given slope is corroborated by the following observations.

First, there appeared in the sediment, after the experiment, a very clear lamination (Figure 8), which must be parallel to the isolines of expansion during the wetting phases. As such a structure has never been seen in the other experimental boxes, it must be typical for creep.

Second, it was observed that after the experiment the sediment had undergone a slight vertical expansion, which was most accentuated in the centre of the box where the total creep movement was highest (Figure 6).

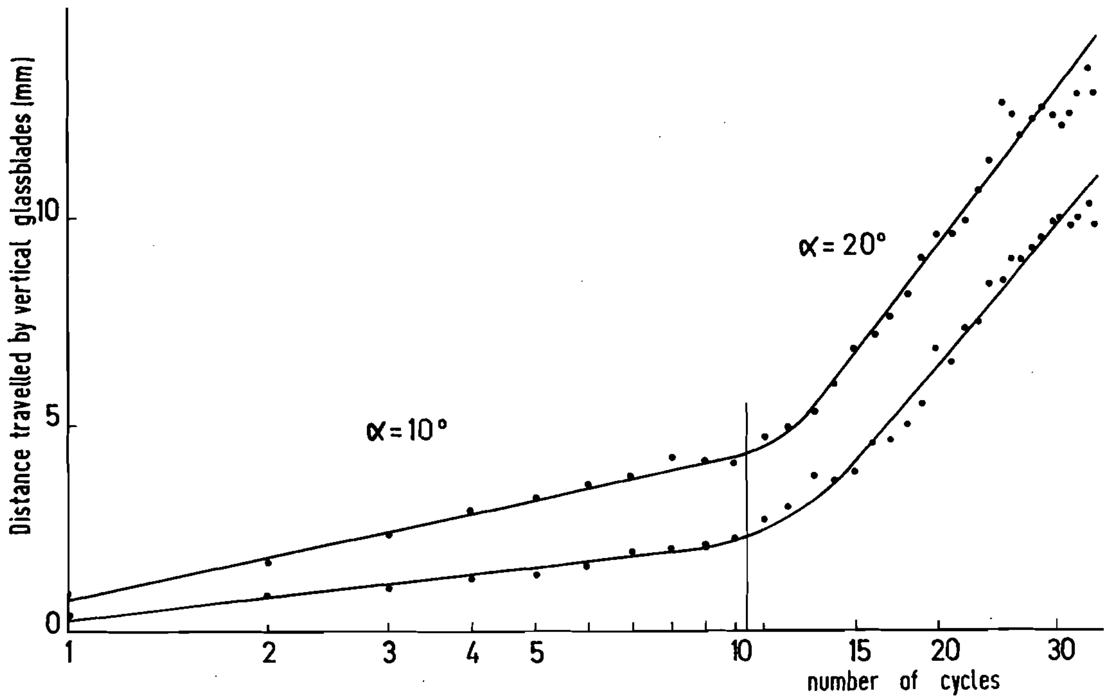


Figure 7. Net amount of creep movement, recorded by the position of the middle glass blade of the two lines l and m on Figure 6; at 20° slope inclination, the creep movement is much more pronounced

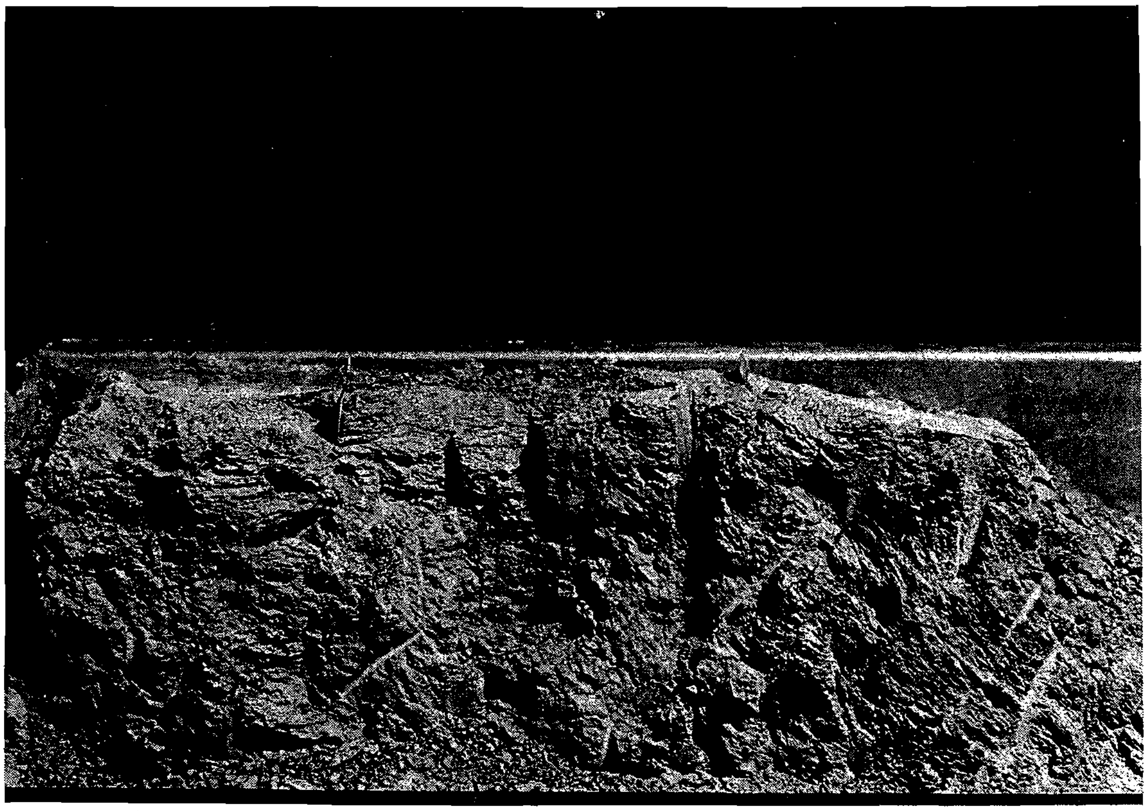


Figure 8. Longitudinal section through the Kalahari Sands block, used in the creep experiment; less than 1 mm-thick micro-laminae, more or less parallel to the block surface, are formed in the before the experiment homogeneous sediment. The distance between the two glass blades lines equals 16 cm

Finally, there was a relation in depth between the amount of movement measured by the fibres position and the dry unit weight (Figure 6). In the upper part of the box with a mean displacement of the fibres of 10 mm, the dry volume was decreased to 1·28 g/cm^3; in the centre of the box, with a mean displacement of ± 2 mm, the dry unit weight was increased to 1·53 g/cm^3; near the bottom, where no displacement was recorded, the dry unit weight attained 1·54 g/cm^3. These data suggest that the sediment has undergone, during the experiment, a vertical contraction in its lower part and a vertical expansion in its upper part, strongly accentuated near the top.

Recorded movements of the quartz pebbles. The difference between the vertical position of the buried quartz pebbles before and after the experiment is given in Table IV. In fact, the pebbles followed more or less the vertical contraction and expansion of the sediment as indicated under *The creep mechanism.*

GENERAL RESULTS AND INTERPRETATIONS

Facts, evidenced by the experiments

First, stones do not sink, by their own weight, through a mantle of reworked Kalahari Sands, wetted and dried alternately. At best they can penetrate into the top of the mantle over a distance of a few centimetres. This distance depends on the weight of the stones.

Second, undeformable objects, buried in a non-consolidated mantle of reworked Kalahari Sands, do not strictly accompany the vertical movement of the enclosing sediment during the consolidation of the soil column. Depending on size, form and orientation of the object, and on the water content of the sediment, the objects penetrate, during their absolute descent, into sediments originally situated above or below them.

Finally, the structure and settlement of the sediment changed during the creep experiment. These changes were reflected by a vertical expansion of the upper part and a vertical contraction of the lower part of the sediment layer. The vertical movements of the pebbles were partly due to these expansion and contraction movements. The creep movement died out as a result of the structural reorganization of the sediment during the experiment.

This should not be in contradiction with experiments described by other authors where living fauna was included in the soil sample (Young (1963)) or where only a few wetting/drying cycles were applied, (Kirkby (1967)) and where material other than reworked Kalahari Sands was used.

A possible explanation for the vertical distribution of artefacts at Gombe

The experiments show that vertical dispersion of artefacts can be expected in a consolidating, and maybe in a creeping, mantle. However, it is evident that the high degree of vertical dispersion of artefacts, as recorded at Gombe, can only be explained by a high number of reiterations: in other words, consolidation and destruction of structures should have occurred repeatedly at Gombe.

It is thought that the activity of termites and worms can bring about such a recurrence. The activity of this type of faunal life is well known—soil particles are brought up to the surface from the inner part of the mantle. Authors such as Grasse (1950), Nye (1955), Boyer (1958) and De Ploey (1964) explained the descent of stones into the soil by means of this type of biogenic process. It is generally accepted that this activity finally leads to total obliteration of the original structures in the sediment.

It is also strongly suggested here that the activity of termites and worms can lead to recurrent or maybe continuous consolidation of the mantle. Indeed, galleries, holes and burrows are partly the result of the biogenic removal of particles from the inner part of the mantle. Continuation of this removal will cause an ever-densifying pattern of this type of structure. Their consecutive collapse finally will transform the soil, which was consolidated before, into a loose mantle, ready to reconsolidate under the weight of the overburden. As biogenic activity continues also during the stage of reconsolidation, a mantle, provided by new, not yet collapsed, biogenic structures and characterized by a 'too low' dry unit weight, is likely to be found. This seems to be the actual situation of the mantle of reworked Kalahari Sands at Gombe. Supposing a homogeneously spread biogenic activity, the mantle at Gombe can be considered as consolidating permanently in reaction to the ever-continuing biogenic activity.

In the case of a non-creeping mantle, the significance of the differences in vertical movement indices becomes very important, because every lowering of a certain level in the soil profile should not be due to the removal of the particles itself, but to the collapse of the biogenic structures and to the reconsolidation afterwards. Taking the example of Table III, object 1, in wet sediment, this means that object 1, point up, will descend over 116 cm in the same time as it should descend over 86 cm, with the point directed downward. Taking into account the high variability of forms within an artefact population, the high changes in water content in the mantle in space and in time, and a non-homogeneously spread biogenic activity, all elements are present for obtaining high dispersion of artefacts during their descent. This is shown schematically in Figure 9.

In case of a creeping mantle, the biogenic activity, as described above, must be considered as the factor which enables the continuation of creep by wetting and drying. Therefore the stones, buried in a creeping mantle, will probably undergo, besides an eventual supplementary vertical dispersion described in the creep experiment, a movement of differential descent as described for a non-creeping mantle.

Final remarks

The process described above is thought to have more than local importance. Indeed, the site of Gombe has the ecological and stratigraphical context of most of the open-air sites situated in the immense Central African Kalahari Sands belt where termite activity is of exceptional importance. It is therefore believed that the process of vertical redistribution of stone objects has a general repercussion on archaeological, pedological and geomorphological investigations in Central Africa and maybe in other parts of the world.

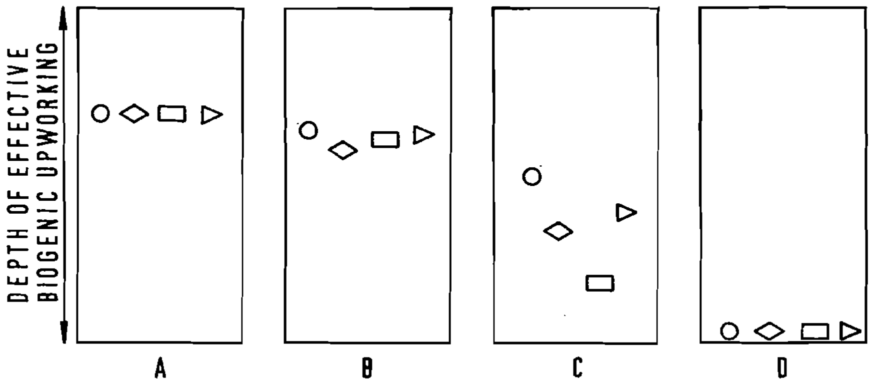


Figure 9. Dispersion of stones during different phases of biogenic upworking of material, as evidenced by the experiments. A: original position. B and C: vertical dispersion of stone implements during their descent. D: concentration of stones upon the bedrock. Equal time intervals between A, B, C and D are not implied

The theoretical consequences of the vertical mixing up of stones during their descent can be summarized as follows. First, the original succession of artefact concentration will be obliterated. In this way living floors become indistinguishable and the separation of different industries becomes difficult. It should be stressed that artefacts, being dispersed in a vertical way, cannot be considered as *in situ.*

Second, charcoal samples, dated by the C^{14} method, have no clear relation to artefacts found at the same depth. They certainly do not date all artefacts from the same level, because these artefacts can be of very different age.

Finally, the phenomenon of differential vertical descent of stones has importance for archaeological, pedological and geomorphological interpretations. This is especially the case in places where the stratigraphy consists of a loose mantle, overlying a solid bedrock. Here the effect of biogenic activity is often restricted to the overlying mantle, the top of the bedrock being undeformable even if perforated by the soil fauna. This means that artefacts and/or stones will concentrate upon the bedrock, at the base of the mantle. Archaeologists could be misled in their interpretations by the presence of this concentration, as it is difficult to know if it encloses one or more industries. Pedologists and geomorphologists could interpret such a 'stone-line', as residual material, resting on an erosion surface, possibly polygenetic (De Heinzelin (1965), Marchesseau (1965), Tricart and Cailleux (1966)) and eventually due to slope pedimentation (Humbel (1968), Segalien (1969), Folster (1969), Rohdenburg (1969)). Although such an explanation will be valid in many cases, one should keep in mind the possibility, as formulated above, that coarse stone elements making up the stone-line could be originally dispersed in the overlying layer of loose sediments. Only the presence of sedimentation structures in the overlying mantle can entirely exclude this possibility.

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