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DISTRIBUTION OF TAR BALLS ON THE BEACHES OF GRAND BAHAMA ISLAND, BAHAMAS

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DISTRIBUTION OF TAR BALLS ON THE BEACHES OF GRAND BAHAMA ISLAND, BAHAMAS

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August 1976

ABSTRACT

Tar balls, or stranded lumps of weathered petroleum residues, have been found on beaches along the south shore of Grand Bahama Island in the Bahamas. The quantities measured average 24 g/m^2 at the High Water Mark. The distribution of tar balls along the shore shows a high degree of variability which is apparently not directly related to selected beach parameters, geographic location, or proximity to crude oil transshipment facilities.

"DISTRIBUTION DE NODULES DE GOUDRON SUR LES PLAGES DE LA GRANDE BAHAMA, AUX BAHAMAS"

J. P. Coakley

RESUME

On a trouvé le long de la côte sud de la Grande Bahama, aux Bahamas, des nodules de goudron ou des concrétions de résidus de pétrole désintégrées laissées sur la plage. Les quantités mesurées à la laisse de haute mer étaient en moyenne de 24 g/m^2. La distribution des nodules de goudron le long de la côte indique une grande variété qui ne semble pas directement reliée à certains paramètres des plages, à l'emplacement géographique ou à la proximité des installations de transbordement du pétrole brut.

INTRODUCTION

Particulate components derived from cultural and industrial activities are not uncommon in modern sediments, but they have, until recently, been largely ignored in sediment studies. Prominent examples of such antropogenic inputs to sediments are coal particles and clinkers in Great Lakes sediments, contributed by steam-ship and smelting operations; and taconite and asbestos fibres from mineral processing and waste disposal in Lake Superior sediments. Although the latter have had considerable ecological impact, neither are of global importance mainly because the sources are confined to a limited area or involve small amounts.

On the contrary, "tar balls", or rounded masses of semi-solid petroleum residue, (Figure 2) stranded on beaches and coasts, are being recognized as a global phenomenon and as alarming indicators of world-wide pollution of the oceans and coastal waters by petroleum discharges of various types. Furthermore, their impact on tourist-amenity beaches in the tropical regions is considerable, and with the expected rise in petroleum movements by sea, this impact on shoreline recreational and aesthetic resources will undoubtedly increase.

However, up to now, the occurrence of such particles on shorelines has not been widely studied, and very few data on their occurrence exist in the literature. For studies of the phenomenon along the coasts of Bermuda and that of the eastern United States, refer to Butler and others (1973) and Dennis (1959, 1974), respectively. The purpose of this report is, therefore, to quantify the phenomenon at one locality, Grand Bahama Island, in the Bahamas archipelago, and to attempt to uncover relationships between various physical beach parameters and the incidence of these tar balls.

STUDY AREA

The carbonate sand beaches of the Bahamas are among the finest in the world, and together with the ideal climate, are the main assets of local tourist industry. Grand Bahama Island, the northernmost island in the archipelago, is located approximately 100 km east of West Palm Beach, Florida (Figure 1), and extends in an east-west direction for some 120 km. The northern coast borders on the shallow, protected waters of the Little Bahama Bank and is composed almost entirely of low-lying mangrove tidal flats, while the southern coast comprises extensive, high-use sand beaches, with occasional beach-rock and mangrove stretches (Figure 1). For this reason, the present study was restricted to the southern shore.

The south shore of Grand Bahama faces the Northwest Providence Channel, one of the deep (1500 m) passages between the islands. This channel connects to the east with the Atlantic Ocean south of Abaco Island. Net current is westward, parallel to the shoreline and joins the north-flowing Florida current off the west end of the island.

SAMPLING PROCEDURE

17 sample sites were selected at intervals of approximately 8 km or where accessibility to the shoreline permitted (Figure 1).

At each site, 3 samples, approximately 50 m apart, were collected at the high water mark (HWM), usually indicated by a linear deposit of stranded sargassum and turtle grass. An effort was made to avoid sampling beaches that were regularly cleaned, or beaches in close proximity to groynes or other shoreline obstructions.

The sampler consisted of a square wooden box (25cm x 25cm), 5 cm deep, the bottom of which was covered by a heavy-duty screen (mesh size - 6.4 mm or 0.25 in) as shown in Figure 2. By placing this box at random at a site on the HWM, pressing it into the sand up to the screen, and forcing a flat plate through the sand to close off the open end, a sample of about 3 litres in volume and 0.25 m^2 in area was taken.

After sieving the sample through the screen bottom to remove sand and small debris, the tar balls retained on the mesh (diameter > 6.4 mm) were counted and stored in labelled plastic bags. Other parameters measured at the site were beach slope (to the low water mark), beach width or distance between HWM and base of beach slope (corrected for tidal stage), and an estimation of mean particle size in phi units* (by visual comparison with a set of standards). A description of the tar balls themselves was also recorded, in particular their general size characteristics, shape, and maximum dimension. Colour, firmness, and association with aquatic weed deposits were also recorded. In addition, qualitative observations on the abundance of stranded sea-weed, morphology of the beach zone,

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* Phi number = $-\log_2$ (diameter in mm)

including the back beach, and the presence or absence of beach rock, were recorded. In all, a total of 48 samples were collected. Later, each sample was cleaned of loose sand and weighed to 2 decimal places.

RESULTS

Description of tar balls.

In general, the tar balls collected were in the form of rounded, oblate, discoidal or ellipsoidal masses, most likely a combined effect of rolling and resting on the sand surface. The next class in terms of frequency of occurrence were those that were irregular in shape, and are presumed to have been at one time attached to floating sargassum or debris. This is very likely, in view of the marked affinity noted between sargassum masses at the HWM and tar balls. Maximum axial length recorded was 7 cm although some up to 12 cm were observed in places. However, the great majority of diameter values fell between 1 and 3 cm. No attempt was made to determine a size frequency distribution as the smaller particles passing through the screen were not measured. Usually, the larger balls were soft to medium-firm in texture, although a few crumbly individuals were noted. In colour, these larger balls ranged from jet-black to grayish to rusty-brown. The latter colour was more common in buried specimens. The smaller particles were usually harder and more variable in colour.

Quantitative results.

Table 1 shows the tabulated results for each location, reduced to Root-Mean-Square (RMS) averages of each 3-sample set per square metre of beach at the HWM. This reduction was necessary because of the high variability in amounts recorded, even within a single sample set. Similar results for the distribution of tar balls with respect to sample location are presented in Figure 3.

RMS averages ranged from a low of 1.3 g/m^2 at High Rock to a high of 128.9 g/m^2 some 8 km to the east of this lowest value. This fact indicates clearly the high variability of the data. It is also noteworthy that both of these locations are just down-current from a large crude oil trans-shipment facility. Other high values were located at location 8a (also very close to a very low value), and at Hanna Hill, immediately down-current from another refinery trans-shipment complex.

In spite of the irregular nature of the distribution of tar balls along the south coast of Grand Bahama, we can arrive at a useable average figure for the shoreline by applying a weighting factor based on the spacing between locations, assuming that the values are representative of the section of shore extending one-half the interval between adjacent locations. This weighting gives a figure of 50 tar balls per m^2 or 24 grams per m^2 for the entire south coast.

In order to examine the relationship between the amount of tar material at a location and the physical parameters of the beach sampled, a table of correlation coefficients were calculated (Table 2). It is admitted that the number of samples was somewhat small for such an analysis, but it was felt that such an exercise would be useful in indicating possible avenues for future experiment designs. Table 2 shows that with the exception of obviously correlated variables, such a number of tar balls vs. weight of tar balls, and beach slope vs. beach width, none of the beach parameters were significantly related to the incidence of tar balls.

In addition, an analysis of variance was carried out to test whether samples from different reaches of the shoreline were significantly different. This was done by dividing the shoreline into three sections of varying orientation: an eastern section which included locations 15 to 12, a central section - 11 to 6, and a western section - locations 4 to 1. It was hoped that such a division would permit inferences to be made on the effect on tar ball frequency of shoreline orientation and of location of the section with respect to the two crude oil handling operations.

The result of the analysis of variance (Table 3), indicates that although the mean value was higher in the central area, there was no basis for the hypothesis that samples from the three sections of coast were different, at the level of confidence chosen. This confirms the impression gained from visual examination of Figure 2.

DISCUSSION

The above results indicate that the beaches along the south shore of Grand Bahama Island are all contaminated to varying degrees by tar balls. These tar balls vary greatly in size and physical appearance and give no direct indication of their source and age. What seems clear is that they are deposited on the beach by wave and tidal surges, and are most frequent above the High Water Mark. What remains unclear are the factors which control their distribution. Although the physical character of the beach itself is certainly of some importance in this regard, it must be concluded that this factor either was not a decisive one here, since no significant correlation was found between tar incidence and beach parameters, or was unresolvable at the sampling intervals used.

Assuming that the original source of the tar balls was tanker discharges in the Sargasso Sea area of the Atlantic Ocean, down-current (east) of Grand Bahama, one might expect some trend in tar ball incidence as one proceeds westward along the coast, i.e. higher values in the eastern sections (closer to source) than in the western sections. The evidence of Figure 2 and Table 3 appear to negate this expectation. Also, there appears to be little relationship, except in a strictly local sense, between tar ball incidence and location with respect to the two shoreline installations that receive regular cargoes of crude oil.

There remains then, three possible explanations for the distributions found. The first is that the experimental design used here (in particular, the number of samples taken) was inadequate to resolve the above trends. The second is that the sources of these tar balls might be randomly distributed along the entire coast instead of being confined to the Atlantic Ocean to the east. If this latter is the case, then one must also conclude either that oil discharges are taking place in the shipping lanes relatively close to the shoreline, or that tar balls are uniformly distributed by natural processes in the waters offshore. Studies by Butler and others, 1973, support this uniform distribution concept and also, the obviously well-weathered particles noted would not be compatible with local discharges as a source. The third possibility is that the notion of purely east-west current drift along the shore of Grand Bahama Island might be a serious oversimplification, and there might exist significant departures from the pattern related to the local bathymetry and wave regime.

While the resolution of these possibilities is beyond the scope of this paper, it is hoped that the present study will prove to be of benefit to subsequent surveys and investigations into this phenomenon.

REFERENCES CITED

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Dennis, J.V., 1959. Oil Pollution Survey of the United States Atlantic coast. Am. Petr. Inst. Publ. no. 4054, 75 pp.

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TABLE 1. SUMMARY OF SAMPLE DATA

Sample no. and location		Beach slope	Beach width	Grain size	No. tar balls > 6 mm *	Wt. tar balls (gm) *
1.	West End	0.20	8 m	1.0	45.6	17.3
2.	Bootle Bay	0.09	15	1.5	42.4	13.7
3.	Silver Beach	0.20	6	1.25	27.2	4.0
4.	Hanna Hill	0.06	16	1.0	177.2	62.4
5.	Hunters	No sample taken (shore rocky or disturbed (fill))				
6.	Caravel Beach	0.11	15	2.0	27.0	15.6
7.	Mather Town	0.09	22	2.25	11.8	4.8
8.	Barbary Beach	0.06	30	2.25	13.3	2.9
9.	Old Freetown	0.07	20	2.5	43.9	35.8
10.	Gold Rock	0.13	7	2.25	30.9	21.7
11.	High Rock	0.13	5	2.25	6.9	1.3
12.	Lit. Pelican	0.12	10	2.5	32.3	14.9
13.	Pelican Pt.	0.13	10	2.5	24.2	10.3
14.	8 km east	0.15	8	2.75	40.5	22.5
15.	Deepwater Cay	0.16	10	2.75	62.2	23.0
16.	Sweetings Cay	No sample taken; site inaccessible				
17.	8 km S.E.	No sample taken; site inaccessible				
8a.	3 km E of (8)	0.14	10	0.50	90.24	63.7
11a.	8 km E of (11)	0.09	10	2.0	193.66	128.9

* Sample RMS averages multiplied by 4 to obtain values per m^2.

TABLE 2. TABLE OF CORRELATION COEFFICIENTS

	No. of particles	Wt. of particles	Beach slope	Grain size	Beach width
No. of particles	1	0.92*	-0.23	-0.25	-0.09
Wt. of particles		1	-0.21	-0.28	-0.11
Beach slope			1	-0.19	-0.77*
Grain size				1	0.13
Beach width					1

* Significant at .995 confidence level

TABLE 3. ANALYSIS OF VARIANCE (single factor model) (using weight of tar balls)

	AREAS		
Samples	Western	Central	Eastern
1	17.3	15.6	14.9
2	13.7	4.8	10.3
3	4.0	2.9	22.5
4	62.4	35.8	23.0
5		21.7	
6		1.3	
7		63.7	
8		128.9	
Totals	97.4	274.7	70.7
$\bar{X}$	24.35	34.34	17.68
Std. Dev.	25.98	43.54	6.16

Source	Sum of Squares	D.F.	Mean S.S.	F-ratio	
Main effect (between areas)	799.33	2	399.67	0.34	NS*
Deviations (within areas)	15,408.20	13	1,185.25		
Total	16,207.53	15	-		

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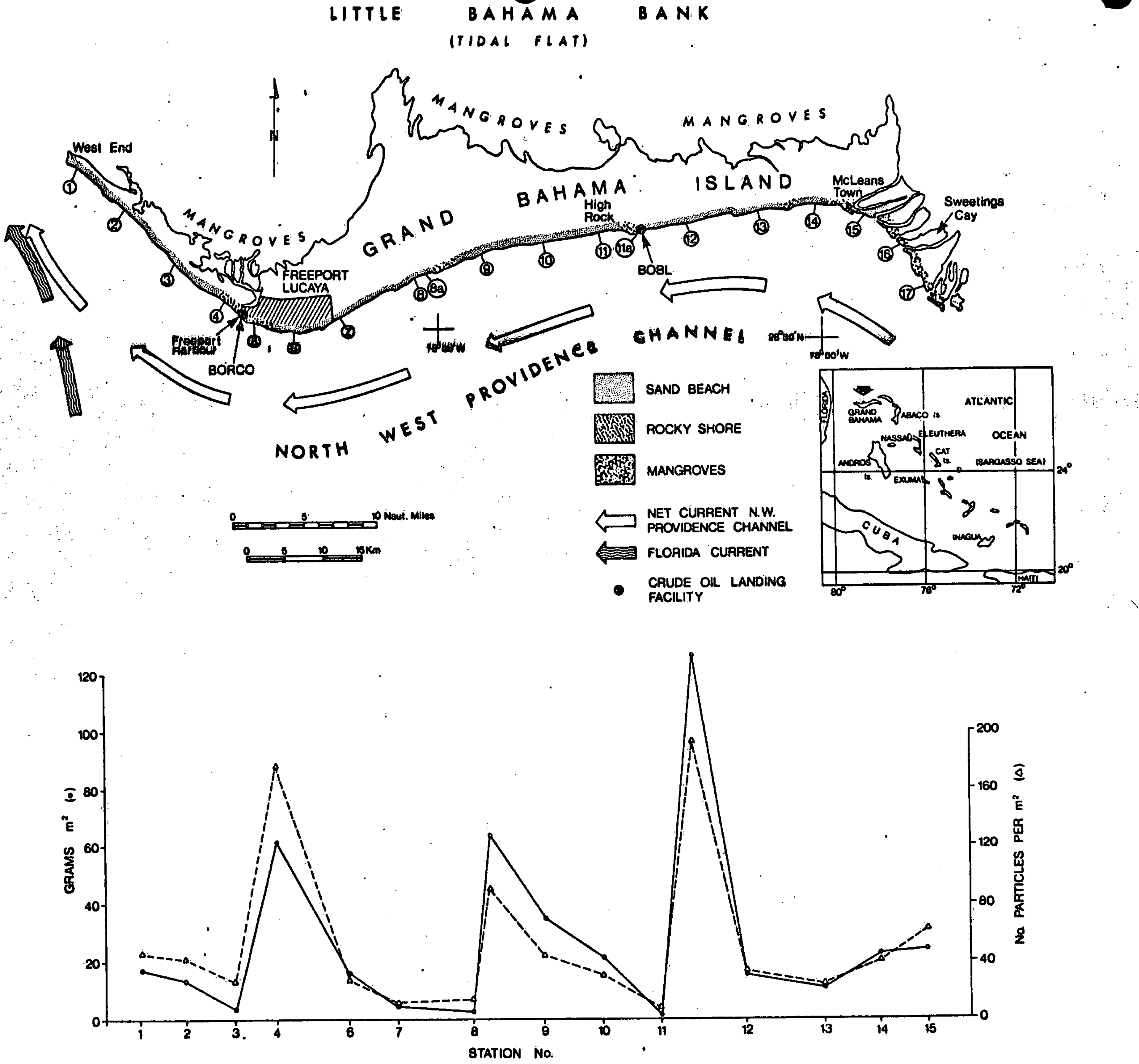
* Not significant

DISTRIBUTION OF TAR BALLS ON BAHAMIAN BEACHES

Figure Captions

Figure 1.	Location of sample sites for beach survey on Grand Bahama Island. The graph below the location map shows the distribution of tar ball counts at each sample site, both in gram/m^2 and number of particles per m^2.
Figure 2.	Sampling apparatus used for the survey. A - Screened box; B - Masonite sliding lid for collecting the box sample; C - Examples of tar balls collected.



LITTLE BAHAMA BANK
(TIDAL FLAT)
MANGROVES
MANGROVES
MANGROVES
N
West End
GRAND BAHAMA ISLAND
FREEPORT LUCAYA
Freeport Harbour
BORCO
High Rock
BOBL
McLeans Town
Sweetings Cay
1
2
3
4
5
6
7
8
8a
9
10
11
11a
12
13
14
15
16
17
NORTH WEST PROVIDENCE CHANNEL
78°30'W
26°30'N
77°30'W
SAND BEACH
ROCKY SHORE
MANGROVES
NET CURRENT N.W. PROVIDENCE CHANNEL
FLORIDA CURRENT
CRUDE OIL LANDING FACILITY
0 5 10 Naut. Miles
0 5 10 15 Km
FLORIDA
GRAND BAHAMA
ABACO Is.
ATLANTIC
OCEAN
(SARGASSO SEA)
NASSAU
ELEUTHERA
CAT Is.
ANDROS Is.
EXUMA
CUBA
INAGUA
HAITI
24°
20°
80°
76°
72°
GRAMS m² (•)
No. PARTICLES PER m² (Δ)
STATION No.
0
20
40
60
80
100
120
0
40
80
120
160
200
1
2
3
4
6
7
8
9
10
11
12
13
14
15

Figure 1

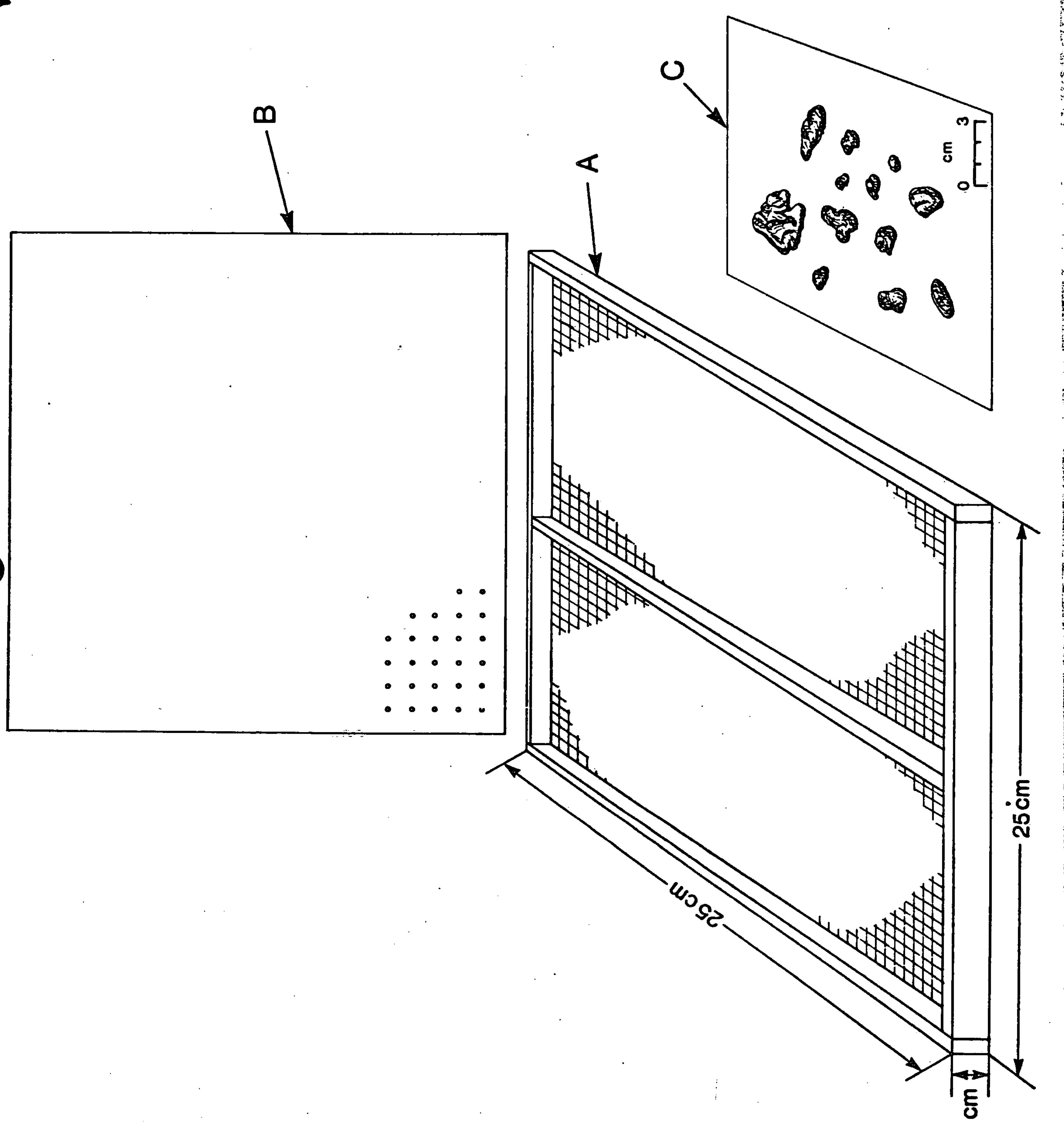


Figure 2