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FOREWARD

The following study was funded by Contract No. AT-(40-1)-2789 with the U.S. Atomic Energy Commission. The work was completed in December 1967. The material presented here was extracted from the final report. It essentially constitutes a reprint of that material to enhance its availability to others.

Since 1967, many aspects of sediment mixing by invertebrates have been investigated. The results of this study, however, contain information and techniques not described by later investigators and should prove useful for comparison with other data and for planning of future investigations.

The use of ^{85}Kr as labeling agent for sediments has not been reported in more recent investigations. The horizontal distribution of surface sediments caused by the activity of Loimia medusa is considered a significant factor in selective concentration of sediment particles, and of radioactive materials, over the sediment surface.

We gratefully acknowledge the assistance of Mr. Ernest Warinner of the staff of VIMS in the use of radiological equipment and other aspects related to use of radioisotopes.

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INTRODUCTION

In the event radionuclides are accidentally introduced into an estuary, many isotopes would become adsorbed on suspended particles of clay or silt; others would be incorporated into living cellular material (Caritt and Goodgal, 1954; Rice and Willis, 1959). Oysters and other filter feeders in these estuaries are capable of filtering from suspension large quantities of the suspended solids, as well as the larger living cellular material (Haven and Morales-Alamo, 1966a). Ingested material along with the associated radionuclides would be voided as compacted fecal strings or pellets (biodeposits). Many of these fecal pellets may be alternately suspended in the water mass or deposited on the bottom during a single tidal cycle (Haven and Morales-Alamo, 1968).

The present paper investigates how particles in the sand or clay size range, along with adsorbed radionuclides, may be mixed into subsurface deposits.

Investigations on sediment mixing by benthic marine invertebrates include studies by Shafer (1952), Rhodes (1963, 1967), Mangum (1964), Rhoads and Stanley (1965), Gordon (1966), and others. Techniques discussed by these authors include measurements of volume or weight of

sediments ingested or transported. Quantitative data on levels to which surface deposits are mixed into bottom deposits are not described.

Studies were begun in 1962 at the Virginia Institute of Marine Science in which fecal pellets from oysters were tagged with fluorescent particles and placed on the surface of marine sediments. Subsequent mixing was followed by taking cores and identifying particles under ultraviolet light (Haven and Morales-Alamo, 1966b). This technique demonstrated that biodeposits were incorporated into deeper layers in the field, but particle counts required an excessive amount of time. Later studies were conducted in the laboratory with clay sediments labeled with ^{144}Ce. The results showed that surface particles similar to those occurring in fecal pellets and similar to those suspended in the water mass were mixed to a depth of 8 to 10 cm by various invertebrates (Progress Reports, 1964, 1965). However, possible chemical incorporation of ^{144}Ce into animal tissue or substances in the sediment made results difficult to interpret.

Techniques developed by hydrologists for studying movement of sand grains in marine areas, as summarized by Kato et al. (1963), were investigated for possible application to our problem. In these studies glass containing ^{60}Co or a similar isotope is manufactured and then ground to sizes similar to sand grains. These grains are placed on the surface of sediments and subsequent transport followed with suitable radiological detecting apparatus. These techniques, while

adequate for simulating sand size particles, could not be used to simulate clay particles with their unique lattice structure.

A new technique was used in this study for labeling both sand and clay particles and involves the adsorption of ^{85}Kr on particles of sand and clay. The process for incorporating Kryptonates®* onto a wide variety of solids is described by Chleck et al. (1963). Trial shipments of kaolinite clay and sand grains obtained from the Gloucester Point area showed that the process was applicable to both sand and clay particles.

METHODS

Six studies were completed during 1965 and 1966. Details, including species investigated, concentration of ^{85}Kr, types of substrate and number of aquaria, are shown in Table 1. The general design of all studies was similar. Various species of invertebrates were introduced into sediments held in circular, acrylic plastic aquaria 30 cm in diameter and 10 cm high. Sediments were obtained from a depth of 10 feet of water at Gloucester Point, Virginia, and were screened prior to use through 0.5 or 1.0 mm screens to remove larger animals. Sediment size composition in all studies was approximately 85% sand and 15% silt and clay.

From two to five aquaria were held inside a square 100 cm^2 acrylic plastic aquarium 10 cm high; this was placed inside a second slightly larger, epoxy-coated wood container. River water flowed into

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* Registered trademark

each circular aquarium through a horizontal baffle at the surface of the water at 1.4 liter/min. This resulted in a slow, even flow which did not disturb surface sediments. Each aquarium overflowed into the square, acrylic plastic aquarium which discharged through a small overflow.

Animals were allowed to acclimate and establish burrows or tubes in the circular aquaria for about one week. After acclimatization, water flows were shut off and kryptonated sand or clay was scattered over the water surface and allowed to settle for 24 hours. After settling was completed, water from the square tank was recycled over the animals. A pump raised water from the square tank into an aerating column 80 cm tall in the center of the tank. Water was conducted from the column through tygon tubes to the aquaria where it overflowed back into the large tank.

Recycling continued for a week, and during this period, the water was monitored for presence of radioactive particles. One-liter samples of the water were filtered daily through a 0.45μ membrane filter to remove suspended solids; filter and solids were analyzed for the presence of radioactive ^{85}Kr using a Beckman scintillation counter at the photopeak maximum. If the filtrate showed no activity, recycling was discontinued and a flow of 0.25 liter/min was trickled into the top of the aerating column from which it flowed to the aquaria. Overflow from the holding tank was monitored daily for activity.

Controls consisted of aquaria set up in a similar manner to those containing animals except that dilute formalin or dilute sodium hypochlorite solution was added weekly to kill animals introduced by the inflowing water.

At the end of each study, flows were shut off, and samples of sediment from test and control tanks were obtained with a 5 cm diameter plastic core tube. Cores were centered around the entrance of an animal's burrow or in the center of conical piles of sand rejected by animals. Later, contents of each core were extruded with a plunger and the sides cut away to prevent contamination of the interior with ^{85}Kr adhering to the sides of the core. Cubes of sediment 0.5 cm^2 from the center of the core from various depths were placed in separate small, plastic counting tubes. Interval between samples was 0.5 cm in the upper 2 cm and 1.0 cm below this level. Cores were taken in the control tanks in a similar manner. In certain instances, cores taken in tanks containing animals where no animal activity was indicated were also used as controls. In experiments with Loimia medusa, a smaller core tube 1.0 cm in diameter was used to collect sediment samples from the upper 1.0 cm. In presenting analysis of cores, the midpoint of each interval is shown. For example, depth of a sample taken in the 2.0 to 3.0 cm zone was designated as 2.5 cm.

Samples of sediment were dried at 85°C and activity determined with a scintillation counter as previously outlined. Results are tabulated as total counts/gram/minute (c/g/m) for each core or as

percent of total activity at each level. Counts within 10% of the background counts are shown as 0.0 or (B).

Water temperatures were essentially the same for each study and varied from about 18 to 24°C; salinities ranged from about 18 to 22 ppt.

Animals investigated had a wide range of habitats and were selected as representative of commonly occurring groups in the lower York River, Virginia. During early studies, several species were placed in each tank; beginning 10 June 1966, each tank contained only one species (Table 1).

Four separate lots of kryptonated clays or sand were prepared: sand 62 to 74 μ in grain size and treated to give a specific activity of 0.97 mc/g; sand sieved to range from 62 to 120 μ and treated to give a specific actitity of 0.75 cm/g; kaolinite clay (#7 Dixie Rubber Pit) with a specific activity of 0.83 mc/g; kaolinite clay with an activity of 1.5 mc/g. The activated clays and sands were diluted with sands or clays of similar grain size before their introduction into an aquarium. Total activity added to each tank varied from 0.022 to 0.726 mc for clay and from 0.080 to 0.304 for sand (Table 1).

Loss of activity from the clay or sand activated with ^{85}Kr was measured under conditions which might be encountered in the marine environment; subsamples of each lot of kryptonated sediments were held dry in small shell vials, in sea water, and under wet anaerobic silts. Activity was measured at intervals over a 67-day period.

RESULTS

Loss of Activity From Sand and Clay

Loss of ^{85}Kr gas from sand or clay stored dry over a 67-day period was 6 and 4%, respectively, of their initial activity. When activated sands or clays were stored for the same period in sea water (25 ppt), sand lost 29% of its activity, while clay lost only 10%. When stored under anaerobic sediments, sand lost 35% of its initial activity, while clay lost only 9%. Under the conditions of the study surface sediments in each tank were aerobic; those below 1 to 2 cm were usually anaerobic. Consequently, differences in loss of ^{85}Kr between these two levels during any single study would be slight and not exceed 6%; differences for clay would be about 1%.

Sediment Mixing in Controls

An analysis of 12 control cores for ^{85}Kr activated clay and ^{85}Kr activated sand gave similar results (Table 2). In 11 out of 12 cores, no activity was detected below 0.75 cm. The single exception showed only 2.1% of the total activity at 1.25 cm. These data indicate little vertical sediment mixing in control tanks due to water currents or other physical causes. Consequently, mixing in tanks containing animals below the 0.75 cm zone will be attributed to activity of benthic animals.

Sediment Mixing by Species

Mya arenaria. Adults of this lamellibranch may reach a length of about 8 or 10 cm and may bury as deep as 30 cm into the substrate with

their siphons extending upward to the sediment-water interface. Siphons may be completely withdrawn, leaving a hole up to 4 or 5 mm in diameter. Vertical mixing of sediments associated with this species is caused by extension or withdrawal of the siphon in the substrate or by surface particles falling into open burrows.

Six separate experiments were made with animals 1 to 2 cm long which buried at depths ranging from 2 to 6 cm (Table 3). All cores were taken with the siphon hole in its center. Two of these studies illustrate typical mixing. One experiment began 12 May 1967 and lasted 21 days. Four separate cores taken in one aquarium showed that from 22 to 55% of the ^{85}Kr activated clay, originally at the surface, was below 0.75 cm at the end of the study. Activity was distributed to 4.5-5.5 cm zone, depths which coincided with the posterior ends of the clams (Table 3).

Similar results were obtained with ^{85}Kr activated sand. In a study extending from 24 August to 7 September 1967, 25 to 33% of all activity was below 0.75 cm at the end of the experiment (Table 3). In cores I and II the anterior ends of the clams were at 4.5 and 3.5 cm, respectively, and all activity was distributed in the siphon holes above these levels.

In core III the base of the animal was at 3.5 cm; most of the activity was above this point but a trace existed below the animal.

Pectinaria gouldi. This animal constructs a cone-shaped tube of sand and buries in the substrate in an oblique position. The larger

anterior end may be as deep as 6 cm while the smaller posterior end projects just above the sediment-water interface. Materials ingested from the subsurface are voided forcibly from the posterior end into the water where they settle, covering existing surface sediments with shallow conical hills up to 2 cm high. The animal is capable of limited horizontal movement and may move about 1 cm during 24 hours. Subsurface cavities resulting from feeding may collapse, forming shallow depressions 0.5 to 2.0 cm deep adjacent to the piles. Estimates of quantities of sediments ingested range from 6 grams daily (Gordon, 1966) to 400 ml yearly (Rhodes, 1967).

Three separate studies were made with this animal (Table 4). The first began 18 February 1966, extended for 37 days, and used ^{85}Kr activated sand. Cores I and II, taken in the center of the conical refuse piles, showed from 67 to 76% of the original activity below 0.75 cm. Mixing occurred along the vertical distance (5.5 cm) occupied by the animals. Core I shows a typical increase in activity with depth which shows covering of the original surface with material from deeper layers.

The third study, using sediments labeled with ^{85}Kr activated clay, began 10 June 1966 and lasted 30 days. Results were similar to those with sand. In cores I and II 52 to 57% of the original surface activity was below 0.75 cm. Core III showed 37% below 0.75 cm with mixing to 7.5 cm. Cores IV, V, VI and VII were taken in an area where P. gouldi had been active a week or two prior to taking the core. Three out of four showed typical mixing to as deep as 4.5 cm.

Clymenella torquata. This annelid inhabits a vertical sand-encrusted membranous tube 2 to 3 mm in diameter which in mature animals may be about 15 cm long. Sediments are ingested at the bottom of the tube and voided forcibly into the water where they fall back, forming a conical pile around the tube entrance. Quantity of sediment voided may be as high as 1 mg/day (Mangum, 1964). Particles may be selectively ingested, leading to biogenetic grading (Rhodes and Stanley, 1966). In this process the animal ingests only fine-grained sediments which may lead to a concentration of very fine particles at the sediment-water interface with coarser particles just below the surface.

There were two studies with this animal (Table 5). In the first, beginning 2 May 1966 and lasting 22 days, from 69 to 70% of the ^{85}Kr activated sand originally at the surface was found below 0.75 cm at the end of the study. In each core the upper 0.5 cm showed almost no activity. This shows the deposition of sediments which originated in the lower end of the burrow. Below 0.75 cm there was a zone 2.0 to 2.5 cm deep where activated ^{85}Kr sand was concentrated. In each core there was no detectable activity at the bottom of the membranous tube. Almost identical results were obtained utilizing labeled clay in the second study, beginning 24 August 1967 and lasting 14 days. In this study 100% of the original activity was below 0.75 cm; activity was concentrated in a 2.0 cm zone below this level. No activity was detected at the bottom of the animal's tube located at 6.5 cm.

Leptosynapta tenuis. This common worm-like echinoderm has no permanent tube, but burrows in the substrate voiding large volumes of sediment in its path. In many instances the animal maintained contact with the surface with a burrow entrance 2 or 3 mm in diameter. Animals usually feed and void sediments below the surface. Surface feeding was occasionally observed.

Four separate studies were made with this species which typically inhabits a clay-sand bottom (Table 6). The first began on 3 May 1966. With one exception there was little mixing below 1.5 cm. The reason for this is not apparent.

The study beginning 24 August 1967 using clay labeled with ^{85}Kr was typical of the three remaining experiments. From 6 to 63% of the total activity in 6 cores occurred below 0.75 cm in irregularly spaced pockets. The maximum depth at which activated clay was observed was 7.5 cm.

Mulinia lateralis. This small bivalve mollusc attains a length of about 1.0 cm and lives just below the substrate surface (Table 5). Visual observations showed it capable of moving horizontally 1 to 2 cm daily. The limited mixing of surface sediments occurred to a depth of 2.0 cm and appeared to be associated with a plowing action of the animal as it moved through the bottom.

Phoronis architecta. Phoronids live in membranous tubes up to 20 cm long and about 1.5 mm in diameter (Table 5). Food is obtained by filtering the overlying water. Mixing of surface sediments to a

depth of 4.0 cm was associated with this animal. The mechanism of mixing, however, was not apparent.

Loimia medusa. This terebellid inhabits a membranous U-shaped burrow 15 to 20 cm long and feeds on surface detritus by means of long slender tentacles which may extend up 15 to 30 cm from the burrow entrance. Tentacles are withdrawn at intervals and adhering sand and detritus particles drawn into the burrow. At intervals ingested sediments are voided back into the water where they settle to form a low pile around the entrance to the tunnel.

A large number of cores 1 cm in diameter and 1 cm deep were collected near the center of the Loimia burrows and at varying distances away. Also, 5 cm deep cores were taken in two locations.

Two studies were completed with this animal. The first began 16 November 1966 and lasted 34 days. In this study surface activity of ^{85}Kr activated clay was measured as counts/minute/gram in the center of shallow piles of sediment at the entrances at seven burrows and at varying distances away (Fig. 1). In every instance, activity around the burrow entrance was many times higher than in the surrounding areas which were swept by the tentacles. In contrast, surface distribution in the control tank showed a relatively even distribution (Fig. 2). Vertical distribution of sediments was not appreciably influenced by the activity of this animal since two cores taken at the entrances to burrows showed little mixing below 0.75 cm (Table 7).

Identical results were obtained during the second experiment which began 12 May 1967 and lasted 21 days. This study also used ^{85}K

activated clay. Surface activity was many times greater around the shallow piles of sediment at the burrow entrances than it was in the surrounding areas (Fig. 3). With a single exception, cores taken in aquaria without animals showed an even distribution of surface activity (Fig. 4).

DISCUSSION

The preceding study has demonstrated that radioactive particles in the clay to sand grain size, originally deposited on the water-surface interface, may be mixed into deeper layers by benthic organisms to depths of 6 to 7 cm in a few weeks. Methods and depths of mixing may depend on the species of benthic animal as shown below.

1) Surface deposits may be covered with sediments ingested at lower levels and deposited on the surface later by annelids such as Pectinaria gouldi and Clymenella torquata. 2) Surface deposits may be ingested at the surface and transported to lower levels as exemplified by the feeding habits of the echinoderm Leptosynapta tenuis. 3) Mixing may be partly mechanical, as in molluscs; Mya arenaria may mix sediments by extending or withdrawing its siphon; mixing associated with Mulinia lateralis may be caused by the "plowing" action of the animal as it moves horizontally or vertically. 4) Mixing may be wholly physical and may be caused by surface particles falling into holes created by animals. In addition to vertical mixing, animals may be the direct cause of a horizontal concentration of surface particles into certain areas as was shown by Loimia medusa.

Mixing by annelids, echinoderms and molluscs may take place in the estuary in a manner similar to that shown in the laboratory. However, in this latter area the basic action of animals will be modified by hydrographic features such as currents or waves. The interrelation of the biological and physical is undoubtedly complex and no attempt was made to evaluate their interrelation.

Ecologically, mixing by benthic animals may be of major importance in mixing surface sediments high in carbon, phosphorus, or organic matter into deeper layers. Of more importance is the possible mixing of radionuclides accidentally introduced into an estuary into bottom deposits. The original deposition of isotopes may occur by physical means or by the action of animals filtering solids from suspension (Haven and Morales-Alamo, 1966a). It is evident that if these surface deposits were accidentally contaminated with radioactive isotopes, they would within a period of days or a few weeks be mixed by the action of invertebrates into deeper layers.

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TABLE 1

Summary of studies utilizing clay (Kaolinite) or sand labeled with ^{85}Kr, Gloucester Point, Virginia.

Date	mc ^{85}Kr Added	Vehicle	Size Range	Aquarium	Number Cores	Species
2/18/66-3/22/66	.080	sand	62-74	A	2	Pectinaria gouldi
	.080	sand	62-74	A	1	Mya arenaria
	.080	sand	62-74	B	3*	control
5/3/66-5/25/66	.242	sand	62-74	A	4	Leptosynapta tenuis
	.242	sand	62-74	B	2	Clymenella torquata
	.242	sand	62-74	B	1	Mulinia lateralis
	.242	sand	62-74	B	1t	control
	.242	sand	62-74	C	1	Phoronis architecta
	.242	sand	62-74	C	3	Mya arenaria
	.242	sand	62-74	C	2	Pectinaria gouldi
6/10/66-7/10/66	.244	clay	62-74	A	6	Leptosynapta tenuis
	.244	clay	62-74	B	7	Pectinaria gouldi
	.244	clay	62-74	C	3	Mya arenaria
	.244	clay	62-74	C	2t	control
11/16/66-12/20/66	.726	clay	1-5	A	29	Loimia medusa
	.726	clay	1-5	B	14	control
	.066	sand	62-120	C	3*	control
5/12/67-6/2/67	.080	clay	1-5	A	36	Loimia medusa
	.080	clay	1-5	B	15	control
	.080	clay	1-5	C	4	Mya arenaria
	.080	clay	1-5	D	6	Leptosynapta tenuis
	.080	clay	1-5	E	2*	control
8/24/67-9/7/67	.026	clay	1-5	A	3	Mya arenaria
	.026	clay	1-5	A	1t	control
	.304	sand	62-120	B	3	Mya arenaria
	.304	sand		B	2t	control
	.022	clay	1-5	C	1	Clymenella torquata
	.022	clay	1-5	C	1t	control
	.022	clay	1-5	D	6	Leptosynapta tenuis

* In separate aquarium.

t In same tank as animals.

TABLE 2

CONTROL CORES

Percent of total activity at different depths in sediment cores collected from laboratory aquaria at the end of sediment-reworking studies using sand or clay labeled with ^{85}Kr. Counts of less than 10% of background are presented as 0.0. Data listed under the same dates represent cores taken from the same aquarium.

	Sand* 2/18/66 to 3/22/66			Sand† 5/3/66 to 5/25/66	Clay† 6/10/66 to 7/10/77		Clay* 11/16/66 to 12/20/66		Clay* 3/12/67 to 6/2/67		Clay† 8/24/67 to 9/7/67	Sand†
Depth	I	II	III	I	I	II	I	II	I	II	I	II
0.0-0.5	100.0	97.3	97.9	100.0	98.0	100.0	95.1	100.0	100.0	100.0	100.0	100.0
0.5-1.0	0.0	2.7	0.0	0.0	2.0	0.0	4.9	0.0	0.0	0.0	0.0	0.0
1.0-1.5	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.5-2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.0-3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.0-4.0		0.0		0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.0-5.0							0.0	0.0	0.0	0.0	0.0	0.0
5.0-6.0												
6.0-7.0												
Total c/g/m	996	2447	177	99	130	224	283	122	3108	11,218	504	430

* In separate aquaria.

† Core taken in aquaria with animals but where no activity seen.

TABLE 3

Mya arenaria

Percent of total activity at different depths in sediment cores collected from laboratory aquaria at the end of sediment-reworking studies using sand or clay labeled with ^{85}Kr. Counts of less than 10% of background are presented as 0.0. Data listed under the same dates represent cores taken from the same aquarium.

	Sand 2/18/66 to 3/22/66	Sand 5/3/66 to 5/25/66			Clay 6/10/66 to 7/10/66			Clay 5/12/67 to 6/2/67			
Depth	I	I	II	III	I	II	III	I	II	III	IV
0.0-0.5	72.1	87.2	56.2	0.0	73.2	80.9	91.6	72.9	53.2	20.3	59.3
0.5-1.0	22.9	6.8	20.3	12.3	14.7	0.0	6.1	3.3	7.2	25.0	18.2
1.0-1.5	0.9*	1.4	8.3	11.0	12.1	3.4	0.0	5.0	13.3	15.9	12.9
1.5-2.0	1.6*	0.0*	6.8	3.7	0.0	3.4	0.0	7.8	12.7	28.1	6.5
2.0-3.0	0.0*	4.7*	6.2	33.5	0.0	7.3	0.0	4.2	5.2	6.1	0.0
3.0-4.0	1.9	0.0	1.8	23.9*	0.0*	0.0*	0.0	4.7	4.9*	0.0*	0.0*
4.0-5.0	0.6		0.2	11.8*	0.0*	0.0*	1.2*	0.1*	3.4*	4.4*	0.0*
5.0-6.0				2.1*	0.0*	0.0*	0.0*	0.0*			2.9*
6.0-7.0				1.7	0.0	0.0	0.0				
7.0-8.0						4.9	1.1				
Total c/g/m	436	192	1444	76	68	237	195	846	849	295	1757

* Zone occupied by shell of M. arenaria.

TABLE 3. (concluded)

Depth	Clay 8/24/67 to 9/7/67 I	II	III	Sand 8/24/67 to 9/7/67 I	II	III
0.0-0.5	84.0	91.4	67.9	64.9	0.0	63.2
0.5-1.0	2.3	2.1	5.0	2.3	74.7	7.5
1.0-1.5	2.7	3.7	22.1	6.7	21.5	7.4
1.5-2.0	0.7	2.4*	3.5	10.4	3.0*	18.8
2.0-3.0	1.7	0.3*	1.5*	9.5*	0.7	2.4*
3.0-4.0	3.1	0.0	0.0*	6.2	0.0*	0.4*
4.0-5.0	0.8*	0.1	0.0	0.0*	0.0	0.0
5.0-6.0	4.8*	0.1	0.0			0.2
6.0-7.0		0.0				
7.0-8.0						
Total c/g/m/	1145	1650	461	2998	1980	2059

* Zone occupied by shell of M. arenaria.

TABLE 4

Pectinaria gouldi

Percent of total activity at different depths in sediment cores collected from laboratory aquaria at the end of sediment-reworking studies using sand or clay labeled with ^{85}Kr. Counts of less than 10% of background are presented as 0.0. Data listed under the same dates represent cores taken from the same aquarium.

	Sand 2/18/66 to 3/22/66		Sand 5/3/66 to 5/25/66		Clay 6/10/66 to 7/10/66						
Depth	Hill		Hill		Hill			No Mound Seen			
Depth	I	II	I	II	I	II	III	I	II	III	IV
0.0-0.5	16.2*	12.5*	11.9*	33.4*	2.6*	21.2*	63.1*	98.2	70.6	73.0	65.2
0.5-1.0	16.4	11.1	10.7	9.4	45.8	22.2	0.0	1.8	4.0	0.0	9.8
1.0-1.5	12.2	60.2	20.4	9.5	40.2	20.4	19.6	0.0	2.3	0.0	0.0
1.5-2.0	14.6	0.6	35.7	2.2	4.3	21.5	6.8*	0.0	0.0	0.0	0.0
2.0-3.0	25.9	0.5	18.1	12.5	1.9	8.0*	0.0	0.0	23.0	0.0	25.0
3.0-4.0	5.0	3.9	0.0	3.2	1.9*	6.6	0.0		0.0	6.5	
4.0-5.0	0.0	0.5	3.3*	8.5*	3.2	0.0	8.1		0.0	20.5	
5.0-6.0	9.7*	10.6*	0.0	21.2	0.0	0.0	0.0		0.0	0.0	
6.0-7.0					0.0	0.0	0.0		0.0	0.0	
7.0-8.0						0.0	2.3		0.0		
8.0-9.0									0.0		
Total c/g/m	382	1789	411	511	345	203	94	168	199	43	49

* Zone occupied by Pectinaria gouldi.

TABLE 5

Percent of total activity at different depths in sediment cores collected from laboratory aquaria at the end of sediment-reworking studies using sand or clay labeled with ^{85}Kr. Counts of less than 10% of background are presented as 0.0. Data listed under the same dates represent cores taken from the same aquaria.

	Clymenella torquata			*Mulinia lateralis*	*Phoronis architecta*
	Sand 5/3/66 to 5/25/66		Clay 8/24/67 to 9/7/67	Sand 5/3/66 to 9/7/67	Sand 5/3/66 to 5/25/66
Depth	I	II	I	I	I
0.0-1.5	0.3*	0.2*	0.0*	42.3*	33.7*
0.5-1.0	30.7*	29.9*	0.0*	51.7*	22.5*
1.0-1.5	10.4*	55.4*	37.7*	0.9	17.3*
1.5-2.0	21.2*	13.6*	56.1*	5.1	11.2*
2.0-3.0	28.5*	0.9*	4.1*	0.0	13.2*
3.0-4.0	8.8*	0.0*	2.1*	0.0	2.0*
4.0-5.0	0.0*	0.0*	0.0*	0.0	
5.0-6.0		0.0*	0.0*		
6.0-7.0			0.0*		
7.0-8.0					
Total c/g/m	296	413	292	378	947

* Zone occupied by animal.

TABLE 6

Leptosynapta tenuis

Percent of total activity at different depths in sediment cores collected from laboratory aquaria at the end of sediment-reworking studies using sand or clay labeled with ^{85}Kr. Counts of less than 10% of background are presented as 0.0. Data listed under the same dates represent cores taken from the same aquarium.

	Sand 5/3/66 to 5/25/66				Clay 6/10/66 to 7/10/66					
Depth	Hill I	Hole II	Hill III	Plain IV	Hill I	Hill II	Hole III	Hole IV	Hill V	Hill VI
0.0-0.5	18.5	83.5	97.5	94.5	86.2	45.7	47.4	38.7	91.6	93.0
0.5-1.0	21.5	16.5	2.5	4.1	13.8	35.7	46.2	31.7	4.9	4.3
1.0-1.5	28.5	0.0	0.0	1.3	0.0	5.2	6.4	11.3	0.0	0.7
1.5-2.0	31.5	0.0	0.0	0.0	0.0	8.7	0.0	13.9	0.0	0.0
2.0-3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	0.0	0.0
3.0-4.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.7
4.0-5.0	0.0				0.0	0.0	0.0	0.8	0.0	0.0
5.0-6.0	0.0				0.0	2.4	0.0	0.0	0.0	1.3
6.0-7.0					0.0	0.0	0.0	0.0	0.0	
7.0-8.0					0.0	0.0	0.0	0.0	3.5	
8.0-9.0					0.0	0.0	0.0	0.9		
Total c/g/m	576	241	413	165	39	126	236	449	74	346

TABLE 6. (concluded)

	Clay 5/12/67 to 6/2/67						Clay 8/24/67 to 9/7/67					
	Hole I	Hole II	Hole III	Hill IV	Hill V	Hill VI	I	II	III	IV	V	VI
0.0-0.5	50.9	96.3	30.3	63.9	30.3	34.7	93.5	32.1	35.9	40.1	17.3	46.7
0.5-1.0	22.9	1.8	8.5	7.9	69.7	31.4	0.0	25.9	33.4	31.1	19.9	32.6
1.0-1.5	8.8	0.0	19.0	19.5	0.0	25.8	6.5	30.2	3.9	9.2	12.0	2.2
1.5-2.0	14.4	0.0	8.8	3.5	0.0	4.8	0.0	9.5	4.5	15.2	16.8	16.3
2.0-3.0	2.9	0.0	31.6	0.0	0.0	1.9	0.0	2.3	3.6	3.8	23.3	0.0
3.0-4.0	0.0	0.0	0.0	5.2	0.0	2.1	0.0	0.0	4.7	0.4	7.3	1.5
4.0-5.0	0.0	0.2	0.0	0.0	0.0	0.6	0.0	0.0	12.0	0.2	2.0	0.0
5.0-6.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	1.9	0.0	1.5	0.0
6.0-7.0	0.0	1.6	1.6	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
7.0-8.0		0.0				1.2	0.0		0.0		0.0	0.7
8.0-9.0												
Total c/g/m	359	768	179	543	165	461	153	305	359	838	800	135

TABLE 7

Cores taken in the center of *Loimia medusa* burrows; experiment conducted 5/12/67 to 6/2/67.

Depth	Clay Percent of Total Activity	
0.0-0.5	53.0	52.6
1.5-1.0	45.5	46.3
1.0-1.5	1.4	0.5
1.5-2.0	0.0	0.5
2.0-3.0	0.0	0.0
3.0-4.0	0.0	0.0
4.0-5.0	0.0	0.0
5.0-6.0		
Total c/g/m	1700	5793

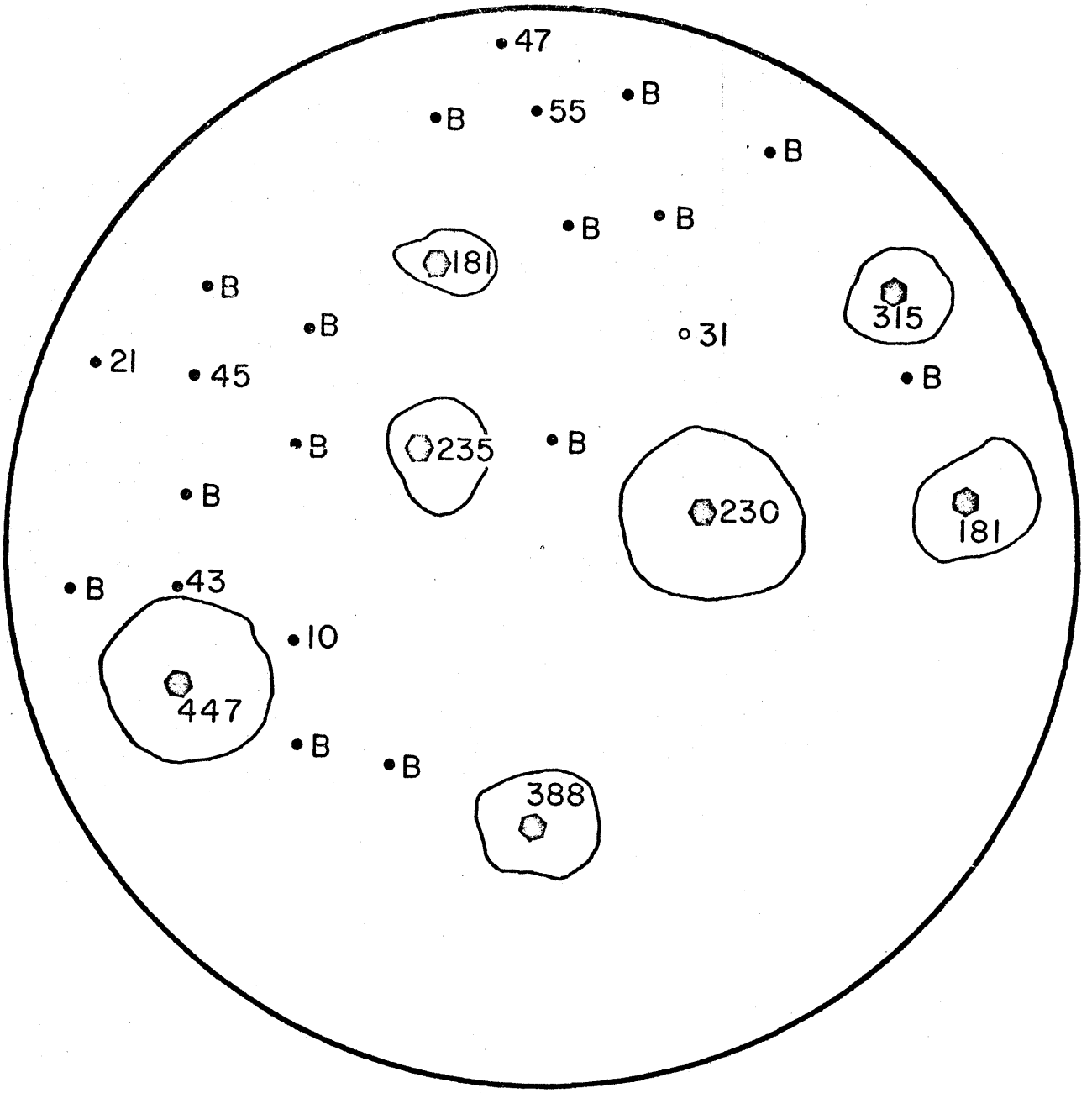

Fig. 1. Activity in counts/gram/minute of surface sediments in tank holding individuals of Loimia medusa in ^{85}Kr-activated clay from 16 November to 20 December 1966. Hexagons indicate entrance to burrow. B = Background Counts.

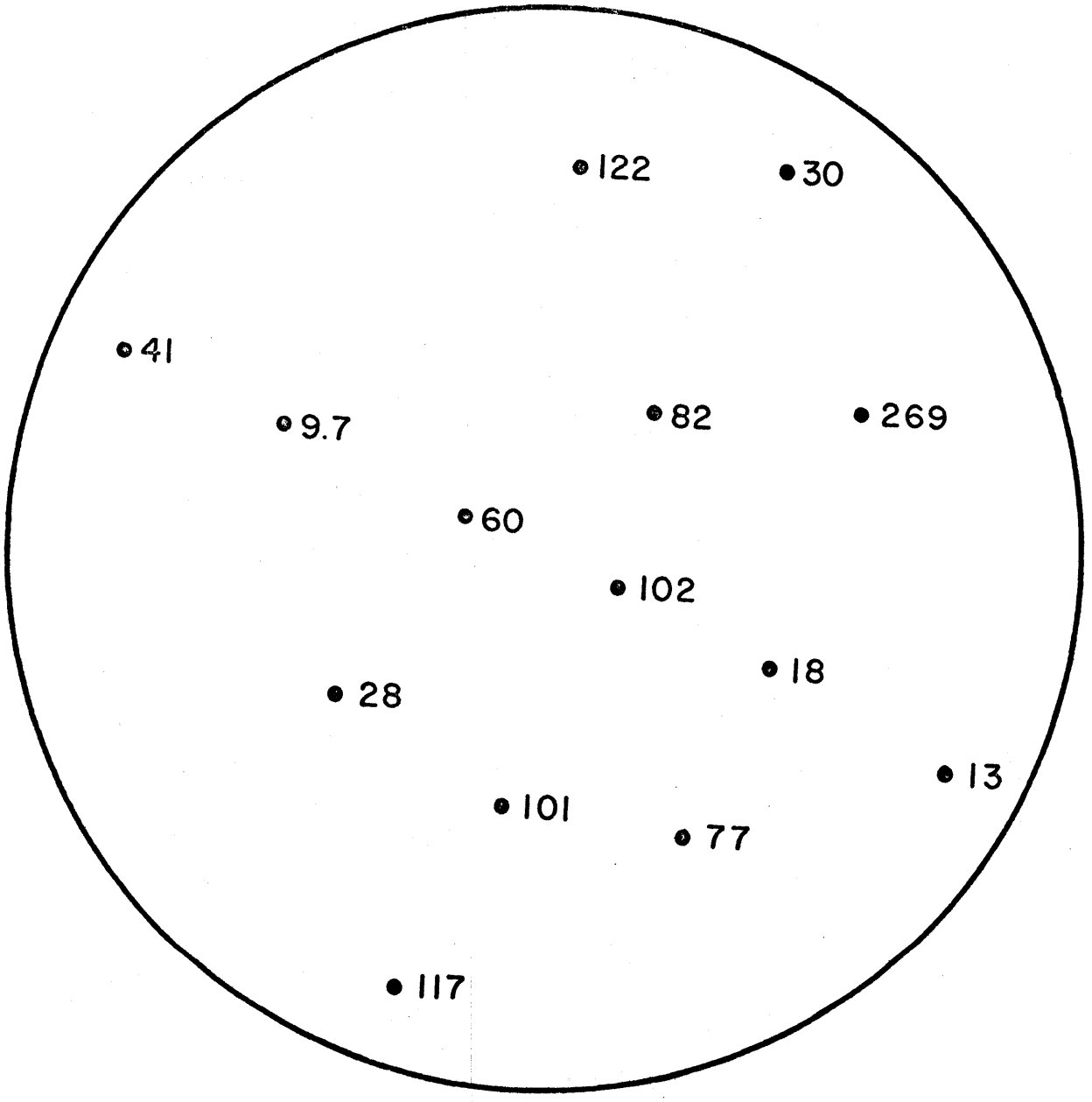

Fig. 2. Activity in counts/gram/minute of surface sediments in control tank in ^{85}Kr-activated clay from 16 November to 20 December 1966.

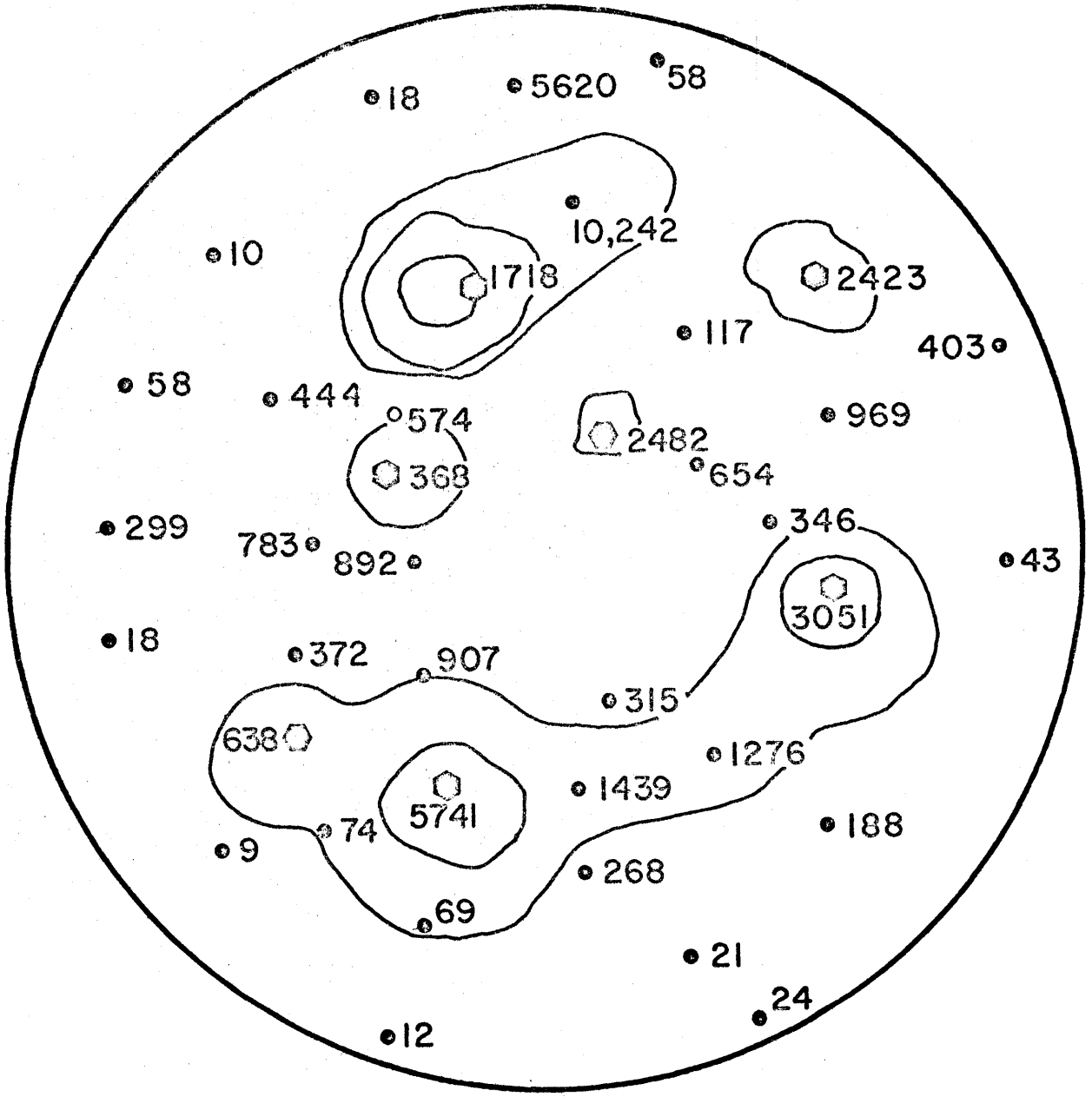

Fig. 3. Activity in counts/gram/minute of surface sediments of Lioma macutata in ^{85}Kr-activated clay from 12 May to 2 June 1967. Hexagons indicate entrance to burrows. B = Background Counts.

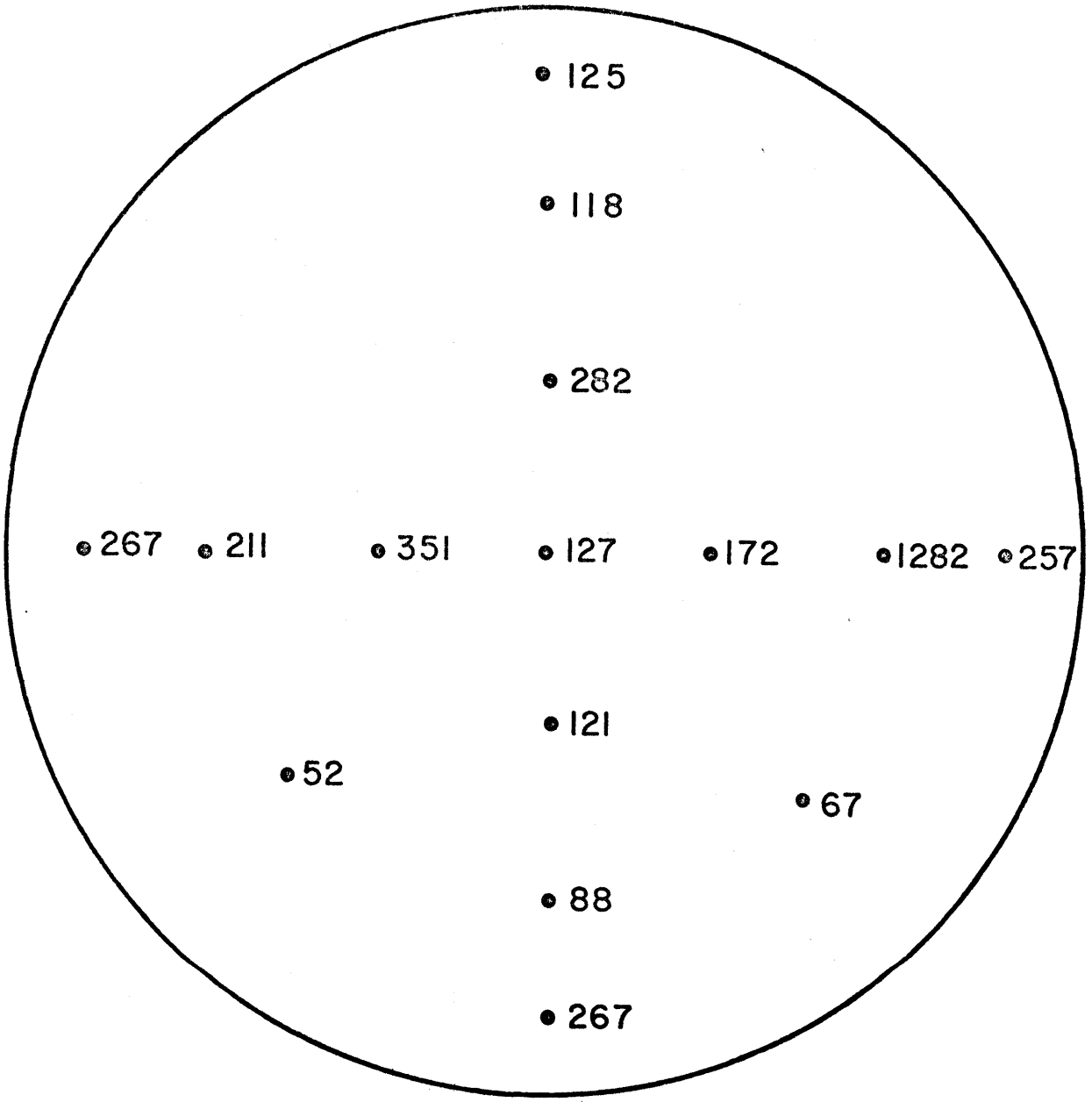

Fig. 4. Activity in counts/gram/minute of surface sediments in control tank in ^{85}Kr-activated clay from 12 May to 2 June 1967.