CHAPTER 17

LABORATORY APPLICATIONS OF RADIOISOTOPIC TRACERS TO FOLLOW BEACH SEDIMENTS

Norman E. Taney
Chief, Geology Branch, Beach Erosion Board
Department of the Army, Washington, D. C.

For many years coastal scientists and engineers have attempted to label sedimentary particles in order that their movement paths might be determined. Several attempts have been made at the Beach Erosion Board, none of which met with any measure of success. Furthermore, inherent in this system is an extensive sampling program and arduous identification of the labelled particles. Recently, however, the labelling of natural sediments or simulated sediments with radioisotopes as tracers has proved successful and a long sought goal has been achieved.

The utilization of radioactive material as sediment tracers has increased during the approximately 10 years since its inception. Since the initial test in the Thames River(1) in England, the utilization of this technique has spread until it is practically worldwide.(2-8) In the main, the objectives of these tests have been qualitative, the determination of movement path and of sedimentation areas of the tracer material, and thus of the sediments, which are being followed. Labelling techniques have varied widely and involve plating or precipitating a thin film of radioactive material on the natural sediments, the utilization of glass containing a radioactive tracer to simulate the natural sediments, the incorporation of radioactive material within the natural sediments or within simulated sediments, and ion exchange between the natural sediments and tracer material. The means of detection have also varied broadly: Geiger-Mueller systems with one or several GM tubes in gangs, scintillation systems making use of pulse-height spectrometry, and autoradiographic techniques have all been used. The monitoring has varied also as sediment and tracer materials have been monitored in situ or samples have been taken and the monitoring accomplished in the laboratory.

The staff of the Beach Erosion Board has been interested in this new application of radioisotopes since 1955. A literature survey was initiated at that time and is continuing at present. A feasibility study was completed in 1958 which indicated that radioisotopic tracers presented a new technique with which to study sediment transport. The report strongly recommended that studies be planned and executed utilizing this technique. In the Annual Bulletin of the Beach Erosion Board, 1960,(9) several test objectives and procedures were outlined.

EQUIPMENT

About the same time, May 1960, the equipment necessary for such types of tests was acquired. The equipment includes a commercial power supply, a linear amplifier, scaler, and electric timing device, and a single-channel pulse-height analyzer. A 2 x 2 inch sodium-iodide, thallium-activated crystal coupled to a photomultiplier tube form the

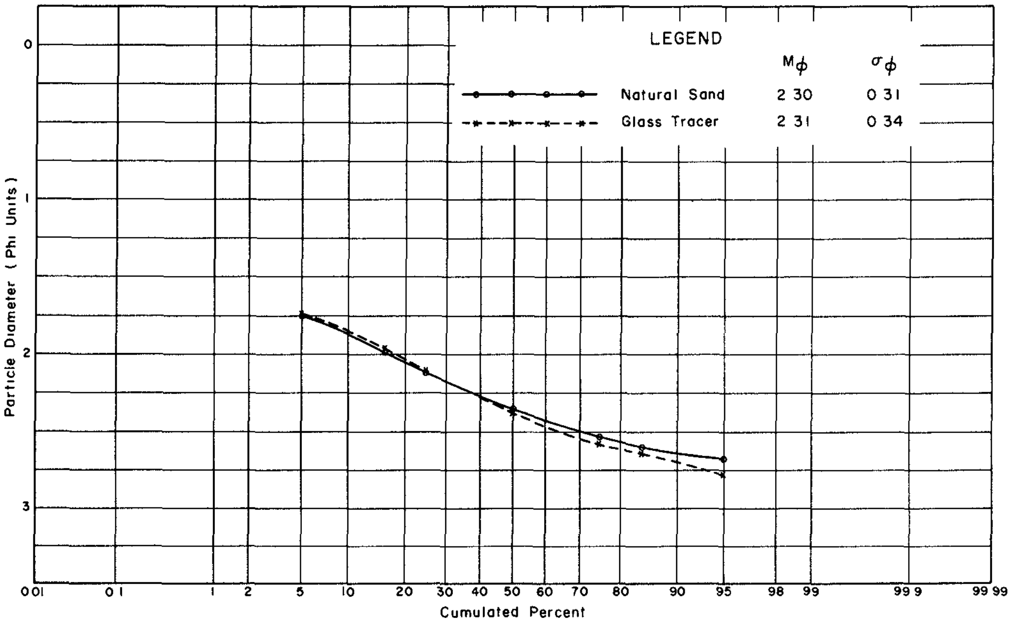

Fig. 1. Cumulated Particle Size Distribution of Natural Sand and Glass Tracer.

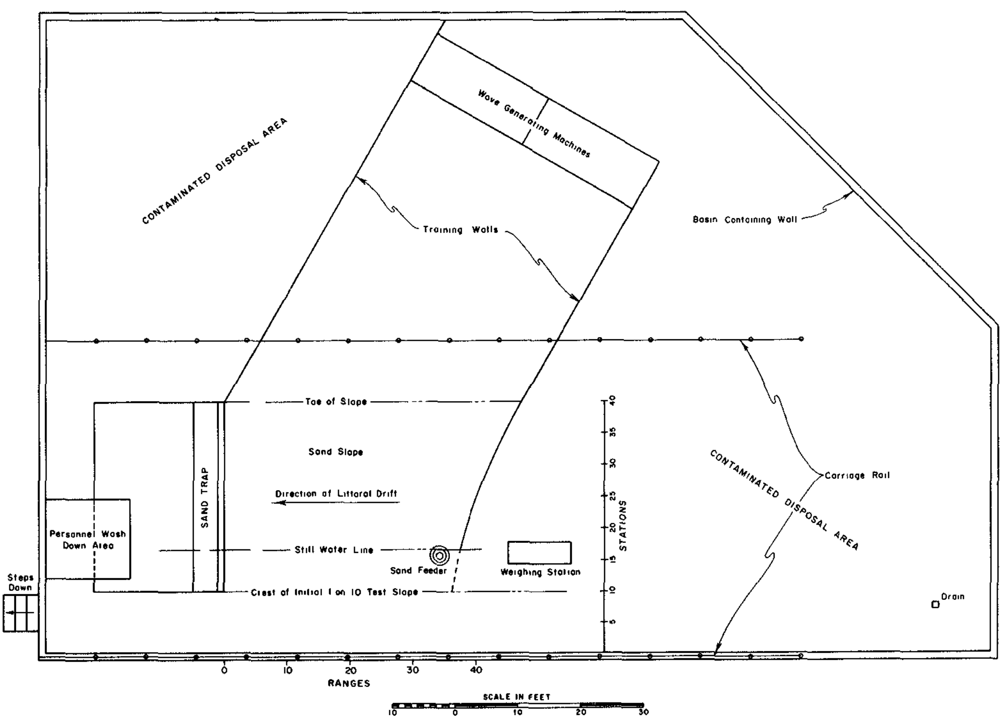

Fig. 2. North Sector Shore Processes Test Basin, Beach Erosion Board.

heart of the detection system. The crystal, photomultiplier and preamplifier are all enclosed within a waterproof aluminum can.

Glass

The the spring of 1962, three special glasses were prepared at the United States National Bureau of Standards. The first glass and one utilized in the test which is the subject of this paper contained aproximately 1.5 percent sodium as the tracer isotope. The density of the sodium glass is 2.656 grams per cubic centimeter. The glass was ground, separated into its size components by sieving, and recombined to make up a cumulated size distribution which is the same as that of the natural sand in the test sector. The glass size distribution was determined hydraulically and compared with the size distribution of the natural sand. Figure 1 shows the final distributions.

Shore Processes Test Basin

The laboratory facility in which the test took place is the north sector of the Shore Processes Test Basin at the Beach Erosion Board. Figure 2 is an illustration of this section of the basin. The test beach is approximately 30 feet long bound on one side by a sand trap and on the other side by an area called the feeder beach on which the sand feeder[10] is placed. The sand feeder is a device which supplie sand to the beach as it is required. Immediately to the right is the weighing station in which the sediments which have been removed from the trap are weighed to determine how much material has been moved in the alongshore direction. Contaminated disposal areas for the sand containing radioactive glass and all other contaminated materials were on eithe side of the test beach. The original slope in the test beach area was 1 on 10, with the toe of the slope at station 40. Still water elevation is 2.33 feet above tank bottom at station 17.6 and the uniform slope continues up to station 10 at elevation 3.0 feet above tank bottom Thence the beach is level to station 0 at the confining wall of this sector of the basin.

TEST CONDITIONS

Wave parameters remained constant during the entire test. The wave amplitude at the generator blade was 0.15 foot and the period was 1.5 seconds. The wave height at the plunge zone was approximately 0.2 foot. Prior to injection of irradiated glass, waves had been generated and had affected the test beach for 9 hours. The surface elevation of the beach had been measured after 1, 2 and 5 hours of wave action, Figure 3 shows the elevation of the beach and nearshore bottom as it was after 5 hours of wave action.

Background activity as determined with the detection system always proved very minor. Background in water decreased from approximately 250 counts per minute on the day of injection to 90 counts per minute during the last day of the test while the background counts in air were 90 and 60 counts per minute from the first to the last day respectively. Background as determined by autoradiographic means proved nonexistent. Because of the low background it was decided arbitrarily to accept as statistically significant all values which were at least twice that of background.

TEST OPERATIONS

INJECTION OF TRACER

Approximately 56 grams of the sodium glass was sent to the United States Oak Ridge National Laboratory for irradiation. After a week of irradiation the glass was received by air freight on Tuesday August 21, 1962 in four shipping containers which contained of the order of 50 millicuries of sodium-24 activity. At the Beach Erosion Board three of the containers holding approximately 50 grams of irradiated glass were opened immediately. Some difficulty was encountered decapping the aluminum irradiation cans because, through an oversight, the proper instrument had not been sent from Oak Ridge. After tops were removed the quartz ampoules containing the glass were placed in a pipe with long-handled tongs, see Figure 4. The ampoules were crushed with a long-handled rammer and the pipe was emptied onto a screening device, placed in the concrete mixer, which permitted the glass particles to pass but retained the larger ampoule particles. Thirty-five pounds of sand and five fluorescent tracers were in the mixer.

After the three ampoules had been emptied into the concrete mixer the screen was shakened to be sure that all of the irradiated glass fell onto the sand. Then the screen, the long-handled rammer, the pipe and the pipe stand were removed to the contaminated disposal area and weighted to remain beneath the water surface in this area.

While the contaminated equipment was being removed brown wrapping paper was being fastened over the mouth of the concrete mixer to prevent loss of radioactive material during the 10 minute mixing period. Ten minutes were required to insure complete dispersal of the irradiated glass grains throughout the 35 pound mass of natural sediment. At the completion of the mixing period the brown wrapping paper was removed to the contaminated disposal area and the sand containing irradiated glass and fluorescent tracers was dumped into an ordinary garden fertilizer spreader mounted on tracks which were fastened to the carriage, see Figure 5. The spreader distributed sand over a 16-inch-wide path centered on range 28. The travel path was limited to 12 feet by two clamps, one being 2 feet landward from still water level at station 15.6 and the other being 10 feet seaward from still water level at station 27.6. Two sheet metal pans, one at each end of the spreader traverse, were placed to prevent an excessive accumulation of radioactive tracer material at each end of the injection area. The spreader gate was opened and the sand, irradiated glass and fluorescent tracers were injected in some eighteen passes over the injection area. When all of the sand had been dispersed including that which had been caught in the sheet metal pans the tracks were swept clean. A fluid to reduce surface tension was sprayed on the water surface to cause those particles which still floated to sink to the bottom in the injection area; however, a very small amount of material did not sink to the bottom but

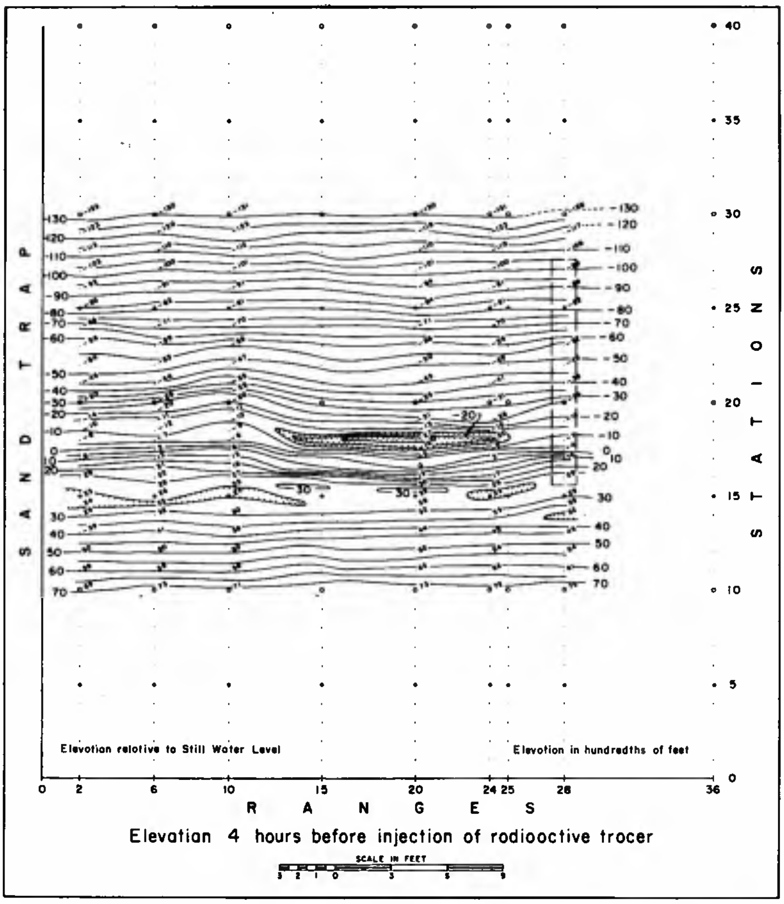

Fig. 3. Elevation 4 Hours Before Injection of Radioactive Tracer.

Fig. 4. Tracer Injection Equipment and Technique.

floated away. At this time the carriage was moved to a hazard-free area. The concrete mixer was removed from the track and placed in the water, the spreaker and all other contaminated gear were removed to the contaminated disposal area.

A thorough check was made at this time to be sure that no contamination remained in any area except the injection area in order to preclude any possible hazard. The carriage was now reestablished over range 28, the center of the injection area, and a radioactive survey was made by monitoring stations at 1 foot intervals. The detection device and monitoring equipment are shown in Figure 6. Three traverses normal to range 28 were also surveyed to define the extent and character of the injection area. Figure 7 shows the activity distribution in and around the injection zone.

OPERATIONS

The carriage was again moved to a hazard-free area and wave action was initiated and continued for 5 minutes. Because the incident waves approached the beach at an angle, sand and tracer materials were moved in the alongshore direction and deposited in the trap at the end of the test beach. During this time as the sediment was deposited in the trap it was removed from the trap through the eductor system and pumped to the weighing station. At the end of the 5-minute period of wave action, the wave generating machines were turned off and the area was surveyed. Ranges 2, 6, 10, 15, 20 and 25 and the injection range 28 were monitored at 1-foot intervals for 30-second counts at each station. This survey was extended sufficiently above and below still water level to stations where activity was not above background. Figure 8 is an isoactivity map corrected to time zero which shows the dispersion of activity as it occurred after 5 minutes of wave action. The decay correction will be discussed later. It is most interesting to note that after 5 minutes of wave action the activity had already reached the trap in very significant amounts. At the completion of the radiological survey, which took approximately 2 hours, samples were taken along ranges 2, 6, 10, 15, 20 and 24 at 1-foot intervals. A thin film of petroleum jelly was smeared on a card over a 1-square inch area. The card was then pressed onto the surface of the beach to secure a surface sample of sediment approximately 1 or 2 grains thick. These samples are for future study to determine the dispersion of the fluorescent tracer materials.

A second 5-minute period of wave action was initiated and upon its completion the same radioactive survey and sampling procedures were executed. At this time one core was secured. The core is approximately 1 3/4 inches in diameter and 6 inches long. It is essentially an undisturbed sample of the sediment with depth. In the laboratory the sediment core was extruded from the plastic coring tube and a sample essentially 1 or 2 grains thick was taken. Samples were secured from the surface and for every 0.01 foot increment to a depth of 0.1 foot. Then samples were secured for each 0.05-foot increment to a depth of 0.4 foot. The samples were dried and placed on standard X-ray film to determine the depth of penetration of irradiated glass particles by autoradiographic means. The exposure time for this technique was determined from

Fig. 5. Tracer Injection Equipment and Technique.

Fig. 6. Tracer Detector and Survey Equipment.

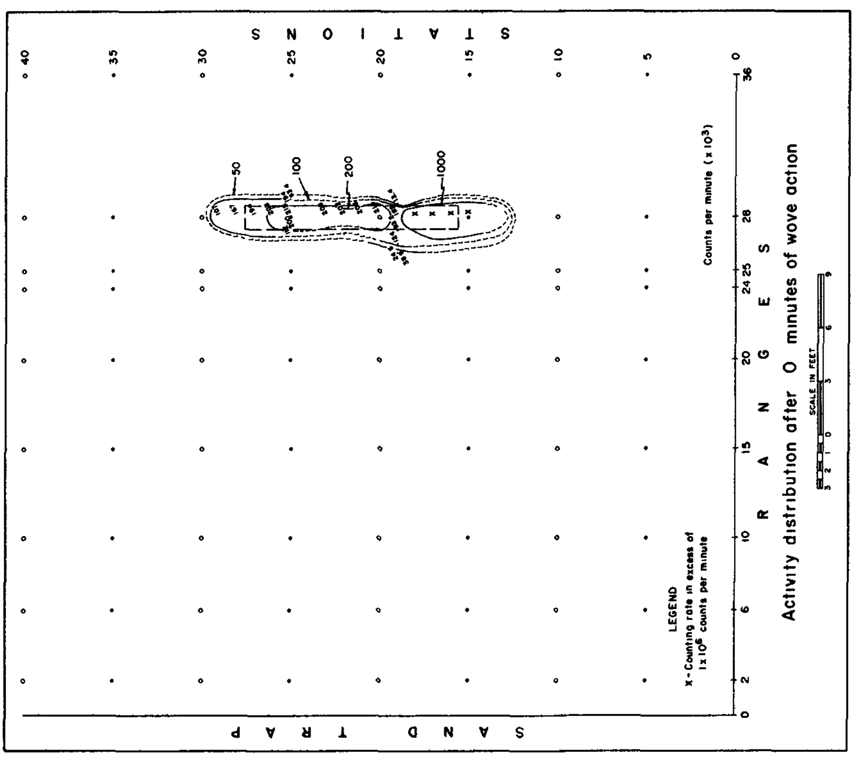

Fig. 7. Activity Distribution After 0 Minute of Wave Action.

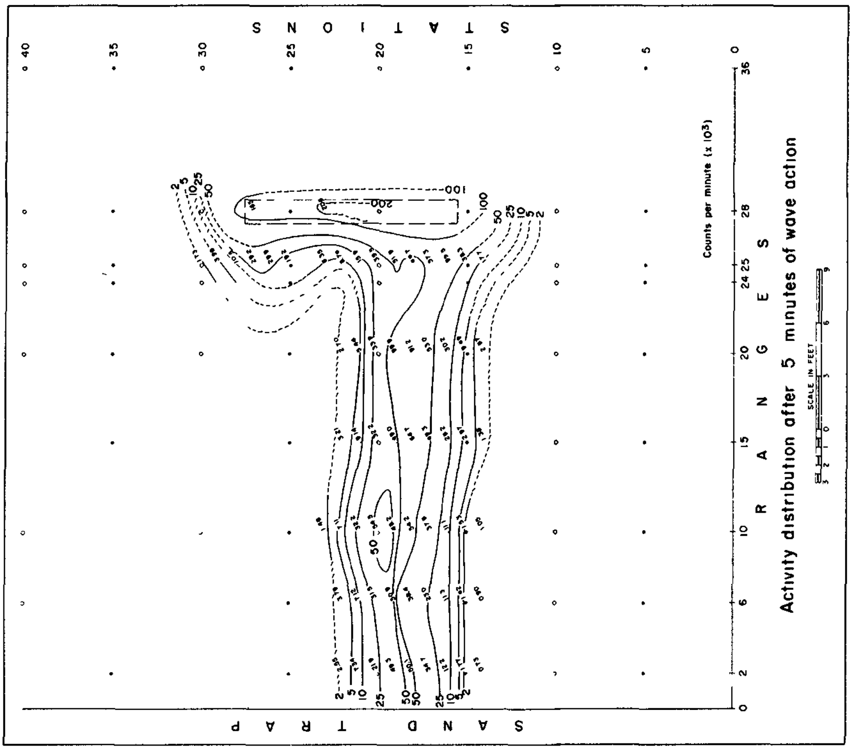

Fig. 8. Activity Distribution After 5 Minutes of Wave Action.

a half-life study of the sodium glass and from a small pilot study utilizing sodium glass unmixed with sand.

Time reference

You will recall that 9 hours of wave action (H+9) had been completed prior to the injection of the tracer materials, the time of injection of the tracer materials is denoted as I+0. During the course of the radioactive tracer portion of the test the following wave action periods were executed; 5 minutes, 5 minutes, 5 minutes, 15 minutes, 30 minutes, and 60 minutes or a total of 2 hours of wave action. By Friday afternoon, the termination of the radioactive tracer portion of the test, the study was at H+11 hours or I+2 hours. After each period of wave action the activity was monitored and surface samples were taken. During the second 5 minutes of wave action it was realized that changes in surface elevation of the test beach might reflect the activity distribution; therefore elevation surveys were made after each period of wave action subsequent to I+5 minutes. Core samples were taken at I+10 minutes, I+15 minutes and I+60 minutes.

RESULTS

The results of the radioactive surveys are presented in Figures 7 through 13 as isoactivity maps. These maps portray the dispersion of the radioactive glass through space and time. All of these maps have been corrected to time zero, I+0. This correction is based upon the half life of the radioactive material which was determined to be approximately 17 hours. Inasmuch as sodium has a 15-hour half life, the longer half life indicated that some material other than sodium was present. Because of this correction each map may be compared directly with any of the others without considering the decrease in activity caused by radioactive decay. Figures 14 through 18 illustrate the elevation changes which occurred to the test beach after each period of wave action.

ACTIVITY DISTRIBUTIONS AND ELEVATIONS

At I+0 minute

Inspection of Figure 7 reveals that the activity distribution immediately after injection was fairly uniform over the portion of the injection area between stations 20 and 27 and that the average activity was determined to be between 200 and 210 thousand counts per minute. From station 18 shoreward to station 15, the shoreward limit of the injection area, the counts were in excess of 1,000,000 counts per minute, but could not be determined accurately because of mechanical limitation of the instruments. Water shielding probably caused the lower counting rates below water level.

At I+5 minutes

The activity distribution after 5 minutes of wave action is shown on Figure 8. By this time, the major dispersal patterns which were to be developed more fully with further wave action were already in

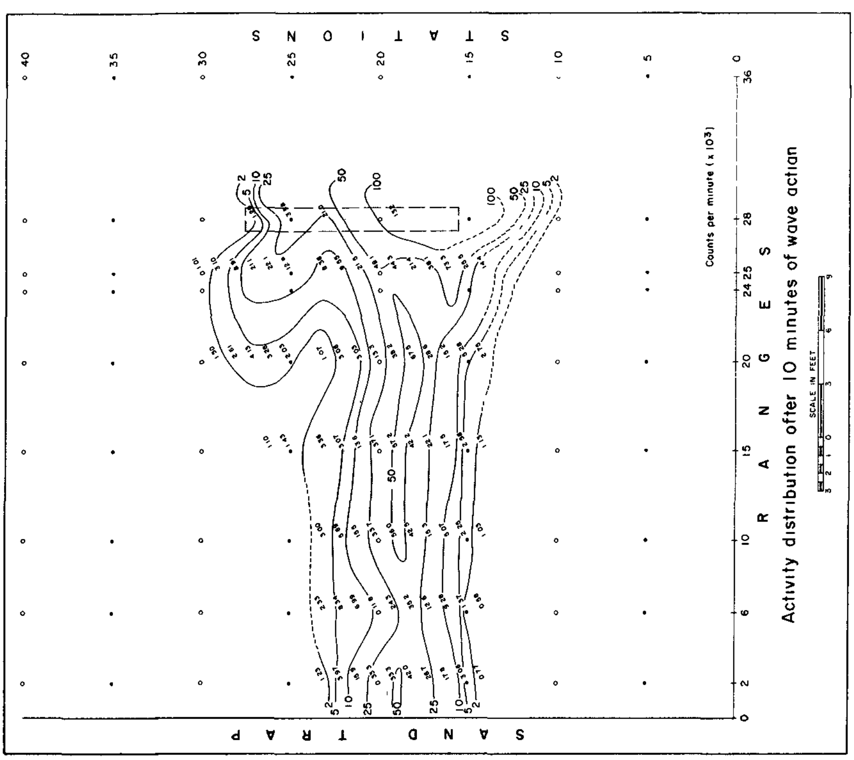

Fig. 9. Activity Distribution After 10 Minutes of Wave Action.

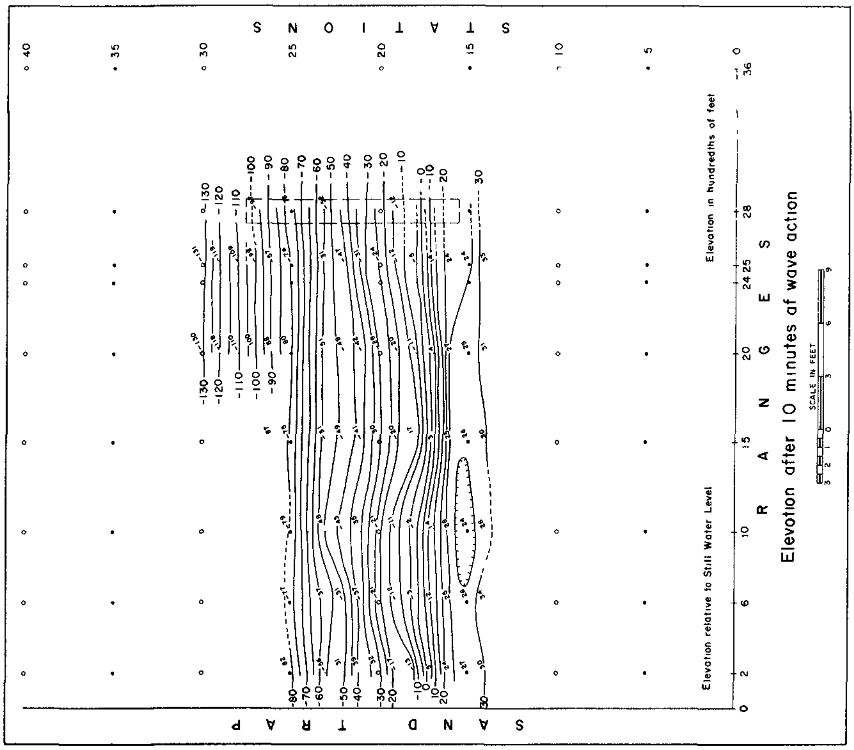

Fig. 14. Elevation After 10 Minutes of Wave Action.

evidence. The major mode of alongshore transport is below or seaward from the still water level and appears to be in the vicinity of the plunge zone. Along range 25 a significant contribution to this major mode appears to come from above or landward from still water level, but by the time the material has reached range 20 much of the transport takes place below still water level. From range 20 to the trap the major alongshore transport mode is in the vicinity of stations 18 and 19. A most interesting mode of transport is shown at range 25 between stations 26 and 27, which appears to indicate a deep alongshore transport region. The counting rates are significantly high at these two stations which are separated from the major transport area by a low at station 22 of the order of one-fourth the counting rate at station 26. It may be coincidental but the deep alongshore transport zone is a little less than one wave length seaward from the plunge zone.

It is most interesting to note that during the first 5-minute period of wave action, significant quantities of activity had already reached the trap. This distance traversed was approximately 28 feet. This indicates that the alongshore transport rate in the vicinity of the plunge zone is in excess of 5 feet per minute. It should be pointed out that time required for the wave-generated littoral current to travel from the injection area to the trap (as determined by fluorescein dye tests) is of the order of 35 seconds.

At I+10 minutes

Figure 9 shows the activity distribution after 10 minutes of wave action. By this time the three zones of alongshore transport were well developed and were (from landward to seaward in direction) at approximately 2 feet above still water level, at the plunge zone, and some 9 or 10 feet seaward from the still water line. The magnitude of activity in these three zones, as determined by counting rates, appears to indicate that the transport above still water is approximately the same as at the plunge zone and that in the deep zone is of the order of one-half to one-third the intensity in the other two. Several most interesting phenomena are illustrated in Figure 9. The zone of alongshore transport above still water levels seem centered at about station 16 (range 25). This area is subject to wave uprush and alongshore transport is expected because of the angle of wave incidence. However by the time the movement reaches range 20, significant indications of a separate and distinct alongshore transport above still water level have disappeared. From range 20 to the trap the isoactivity contours are approximately parallel with still water line. Alongshore transport in the plunge zone is quite interesting in that for the first time this movement appears to be pulsating. A high activity area extends from about range 24 to beyond range 10, is interrupted by narrow neck of lower activity at range 6, and then increases again to the same order of activity magnitude at range 2. Finally, the zone of deep transport is now defined from range 28 to range 20 and appears centered about stations 26 and 27. It is most interesting to note that activities in the injection area are much reduced. There will be further discussion of this point later. Figure 14, the elevation map at this same time, shows a fairly regular surface with several small disturbances similar to the

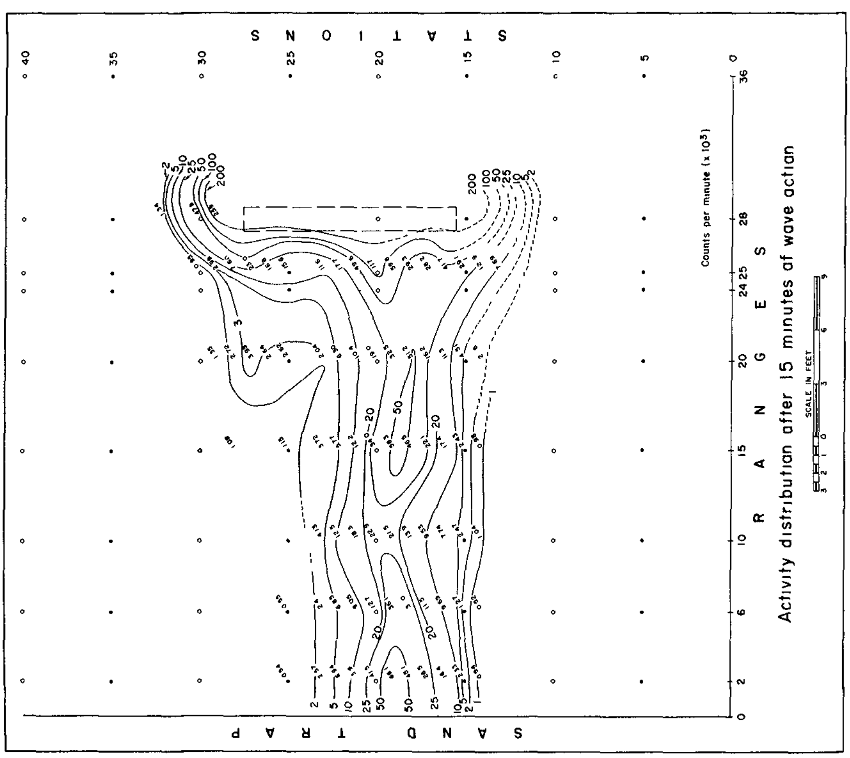

Fig. 10. Activity Distribution After 15 Minutes of Wave Action.

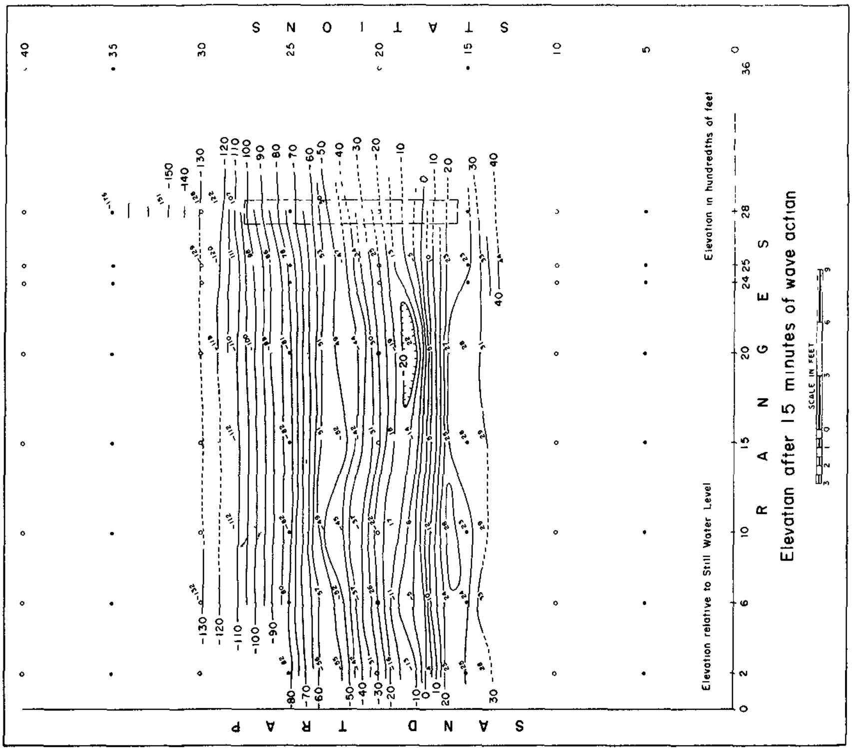

Fig. 15. Elevation After 15 Minutes of Wave Action.

isoactivity map. These disturbances may be noticed at range 25 station 15, an area of high activity above still water level, and at ranges 10 to 6 at stations 23 and 22 respectively where the contour curvature approximates that of the isoactivity line. It is also interesting to note that no indication of the bulb-like protuberance shown on Figure 9 appears on Figure 14.

At I+15 minutes

Figures 10 and 15 portray activity distribution and elevation respectively after 15 minutes of wave action. Once again the alongshore transport is clearly defined in the vicinity of the plunge zone. The pulsating character of this movement is unmistakable and the narrow low-activity neck between the two pulses has been displaced from range 6 (at 10 minutes) to range 10. Also, the lateral extent of the pulse is much smaller. The 20,000-counts-per-minute isoactivity lines have been included to more clearly portray the changes which have occurred. The other two zones of the alongshore transport have been subdued and are not nearly as evident as they were in the previous slide; however in the deep zone of transport the 3,000-counts-per-minutes isoactivity line definitely indicates movement of a lower order of magnitude. It is interesting to note on Figure 15 that a scour area centered about range 20 station 18 corresponds with a high activity pulse in Figure 10. No similar condition is shown along ranges 2 or 6 to indicate the high activity adjacent to the trap.

At I+30 minutes

Figures 11 and 16 portray activity distribution and elevations after 30 minutes of wave action. In Figure 11 the three zones of alongshore movement are again clearly defined. The order of magnitude of each zone is approximately the same as it was earlier as well as are the positions of the three zones. The pulsating character of the movement in the plunge zone is again shown by the presence of a low counting rate area at range 6 station 19. The 15 and 20,000-counts-per-minute isoactivity lines further illustrate this event. A rather interesting deep zone appears for the first time on range 2 station 25 where high activity is approximately opposite the zone of deep alongshore transport which has been recognized as early as I+5 minutes and which is quite clearly defined on this figure at ranges 15, 20 and 25. It is most enlightening to note that there has been enrichment of the activity seaward from station 20 in the injection area and, for instance, at station 23 range 28 this enrichment amounts to of the order of ten times the activity that was present upon injection. Figure 16 is quite regular and gives very little indication of transport as is shown by the isoactivity map.

At I+60 minutes

Figures 12 and 17 and represents conditions at I+60 minutes. Starting at range 28 (Figure 12), the injection area, several interesting points are to be noted. In the transport zone above still water level the counting rate is now at least an order of magnitude below its former value at I+10. At still water level and for some 2 or 3 feet

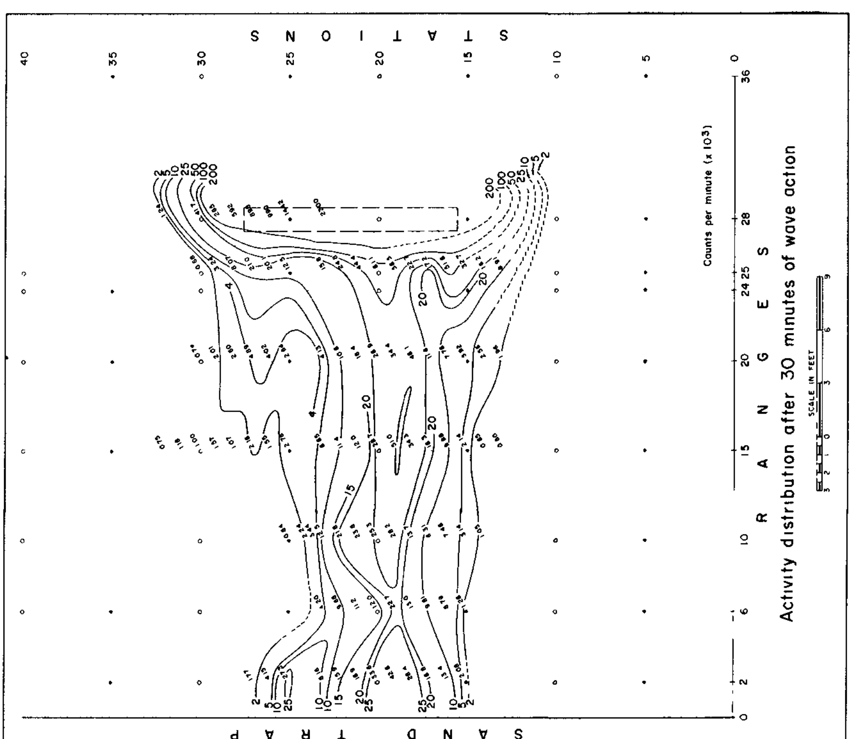

Fig. 11. Activity Distribution After 30 Minutes of Wave Action.

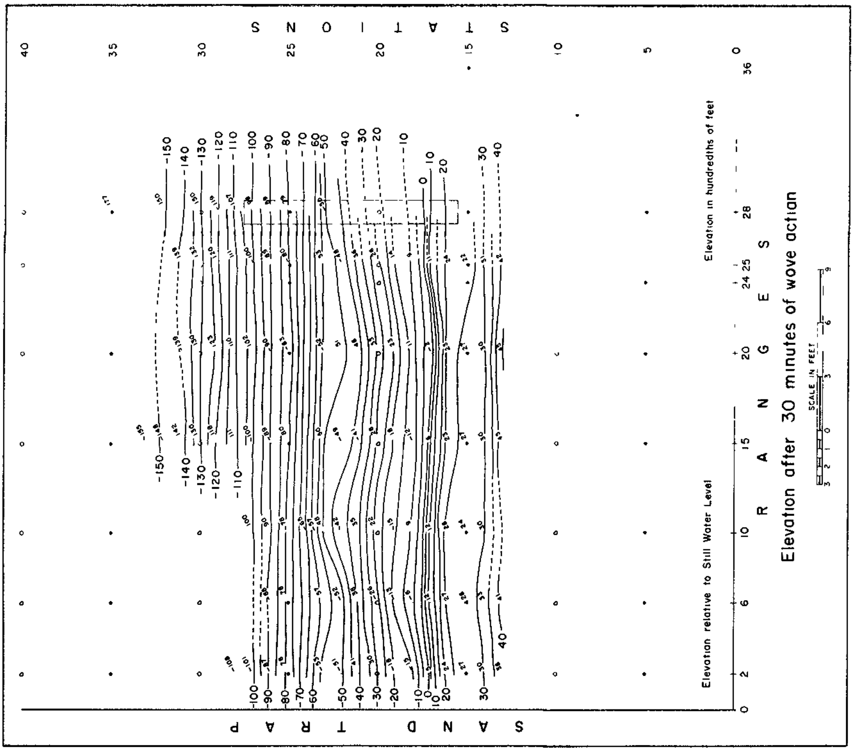

Fig. 16. Elevation After 30 Minutes of Wave Action.

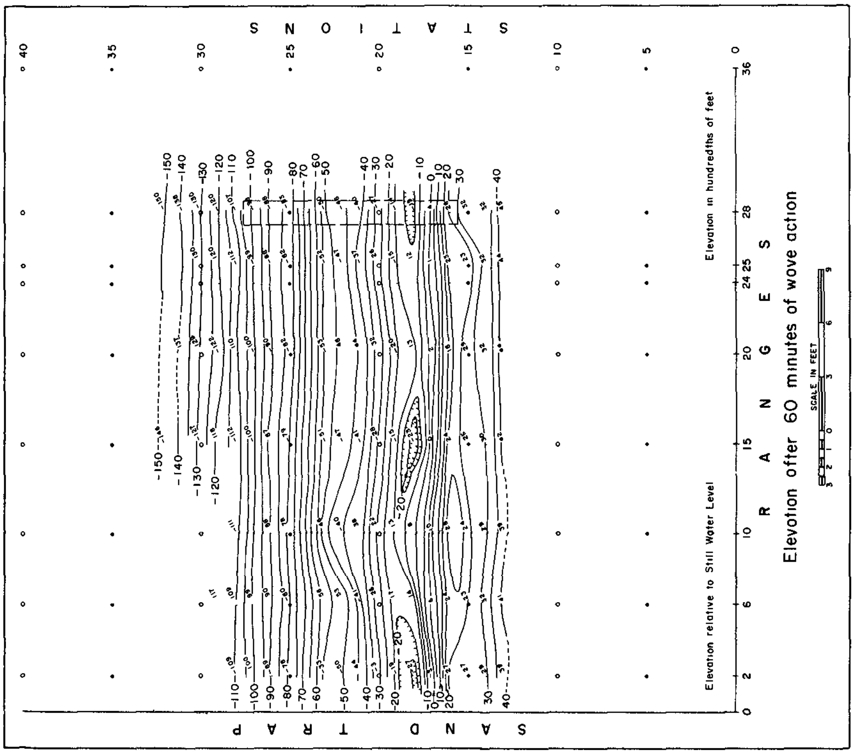

Fig. 17. Elevation After 60 Minutes of Wave Action.

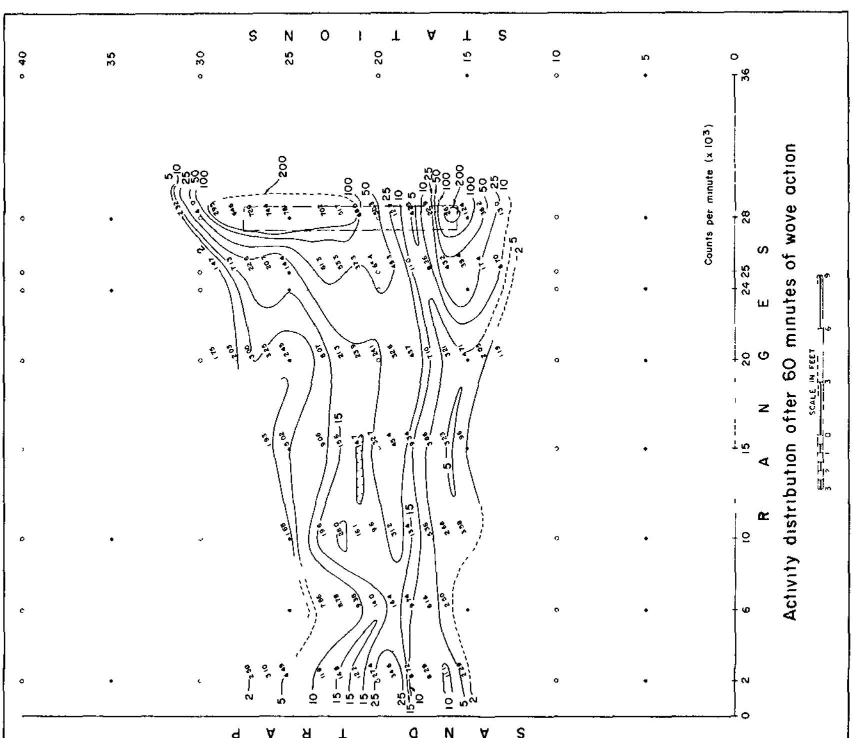

Fig. 12. Activity Distribution After 60 Minutes of Wave Action.

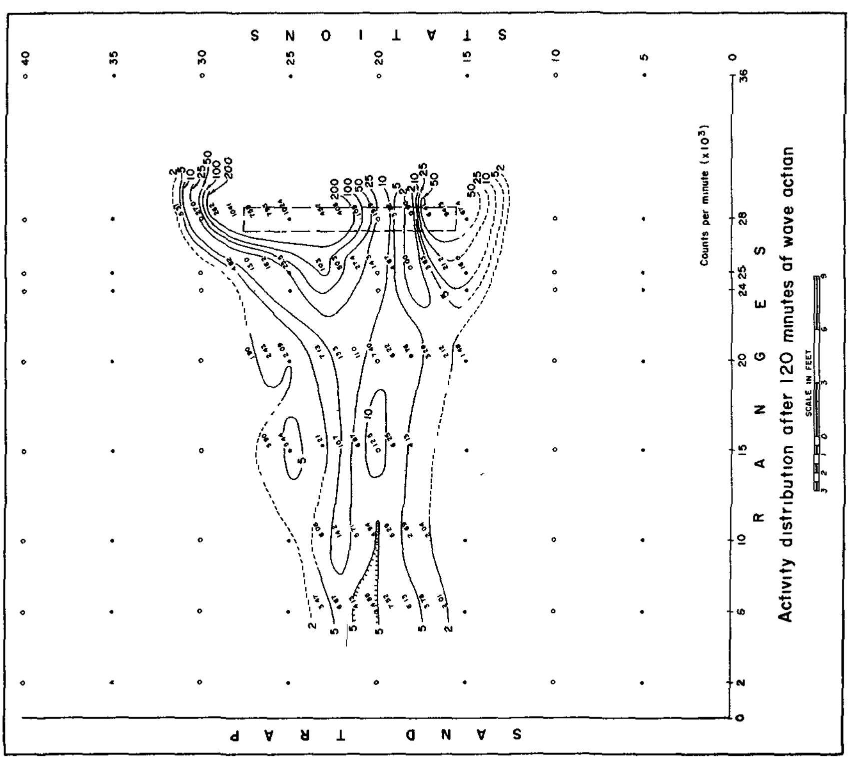

Fig. 13. Activity Distribution After 120 Minutes of Wave Action.

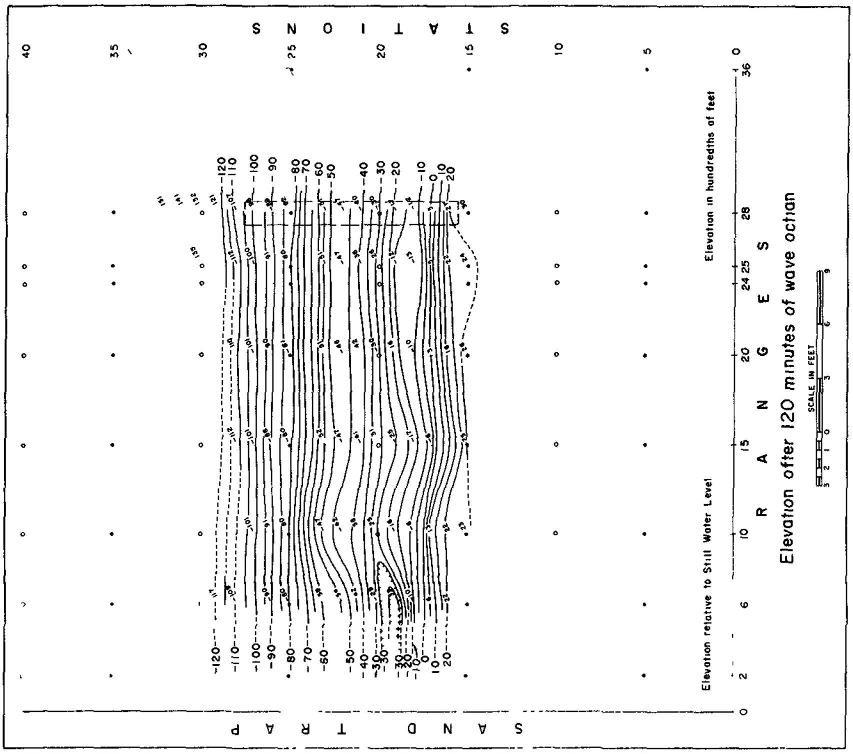

Fig. 18. Elevation After 120 Minutes of Wave Action.

seaward, the counting rate is much lower than it was at injection time. Farther seaward it is some three to four times greater than it was at injection time. At range 25, there is definite indication of an above still water alongshore transport and a broad zone from station 19 to 23 indicates below still water level transport. The deep zone of transport is not as clearly defined along this range although there is a definite high at station 27. At ranges 15 and 20 the three zones of alongshore transport are very evident. Range 6 is once again the region which portrays the pulsating nature of sediment transport in the plunge zone. An erosion area in the injection zone on Figure 17 corresponds with a very low counting rate on Figure 12, and a similar erosion depression on range 2 station 18 corresponds to a low counting rate at that point. There is, however, no indication on Figure 17 of the high counting rate centered between stations 19 and 20 on range 2. Also, there is again no indication of the deep transport area on any of the ranges of Figure 17.

At I+120 minutes

Figures 13 and 18 portray conditions after 2 hours of wave action. There was, unfortunately, insufficient time to complete the surveys and when time was available the activity had completely disappeared. Two most interesting points to be noted on Figure 13 are that in the injection area from station 18 (1-foot seaward from still water line) to station 19 the activity has been completely removed and background counting rates exist. On either side of this zone much greater activities show movement away from still water line. The second point of interest is that the magnitude of the counting rates had diminished greatly by the time 2 hours of wave action had been completed. The elevation map does not reflect the dispersion patterns.

Cores

As was stated earlier, one core was taken after I+10 minutes, five after I+15 minutes and ten after I+60 minutes. All cores were sectioned, as described earlier, and all of the I+10 and I+15-minute samples were exposed to X-ray film. Only one core from the I+60-minute group was sectioned and exposed because of lack of time. Table 1 presents the results of the autoradiographic test. Only a short core was recovered at range 20 station 16 due to the difficulty of coring dry unconsolidated sediments.

ANALYSIS OF DATA

The next series of figures show changes which have occurred between periods of wave action. These figures have been derived as the difference in activity at a given geographic point between two successive survey periods. When the activity at the later time is greater than at the earlier time the value on the change figure is positive and the reverse holds true when the activity at the later time is less than the activity at the earlier time. Only changes in activity distribution are shown as the changes in elevation do not follow any systematic pattern.

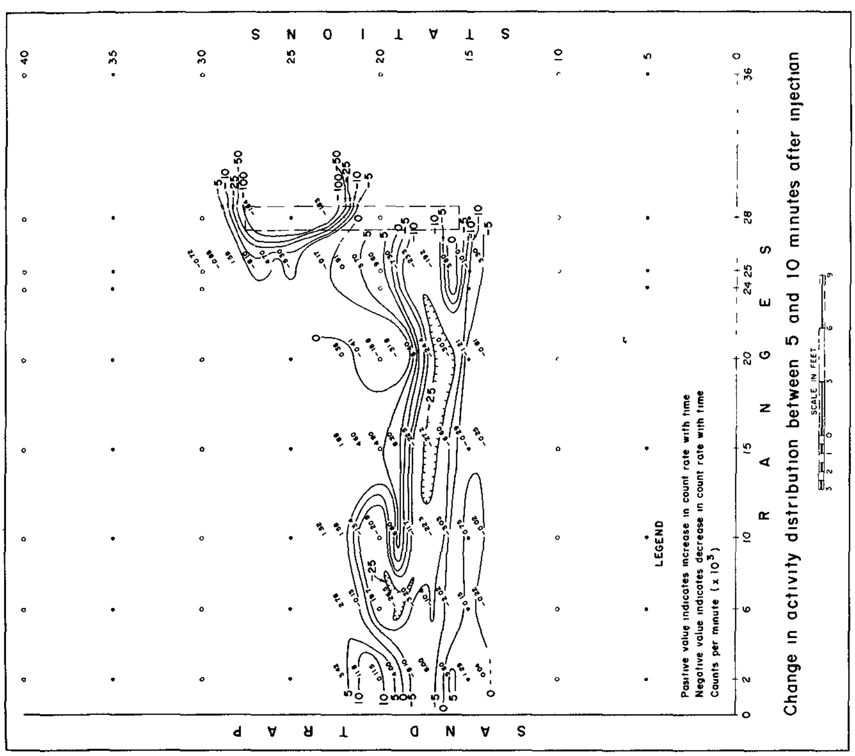

Fig. 19. Change in Activity Distribution Between 5 and 10 Minutes After Injection.

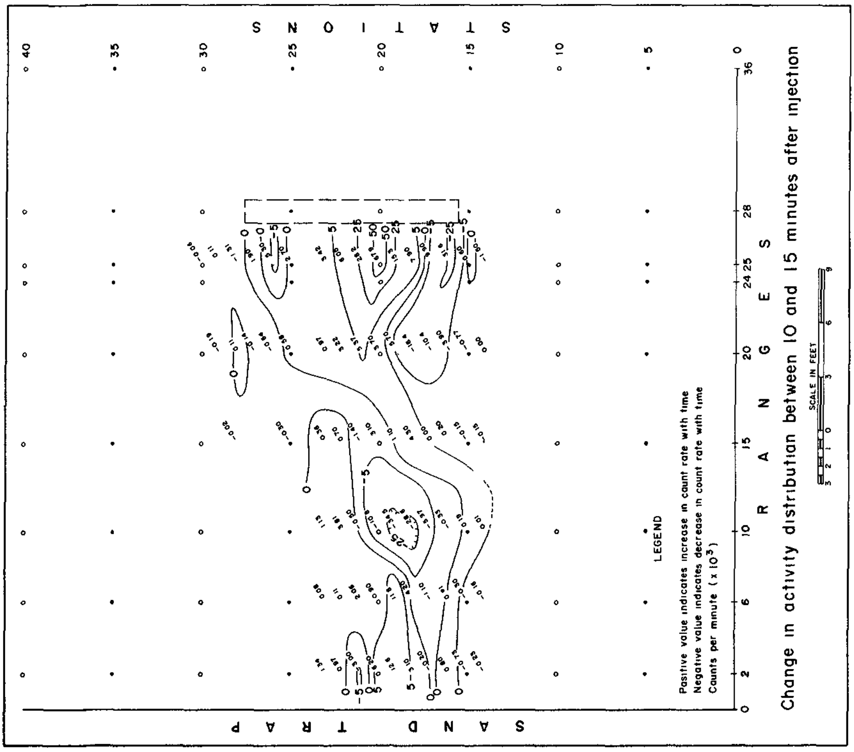

Fig. 20. Change in Activity Distribution Between 10 and 15 Minutes After Injection.

Table 1 - Depth of Penetration of Irradiated Glass Particles

Time (minutes)	I+10	I+15					I+60	
Range and Station	10-19	20-16	20-18	20-20	20-24.5	20-29	28-25	
Depth Below Surface(1)	Number of Radioactive Particles							Remarks
0	2	1	4	2	0	0	~ 70	
1		0	1	1	0	0	~ 50	
2	0	1	2	0	0	0	11	
3		0	3	0	0	0	4	
4	2	0	1	0	0	0	3	
5		0	3	0	0	0	1	
6	4		1	0	0	0	0	
7			2	0	1*	0	0	*Identifi-
8	2		3	0	0	0	0	cation
9			4	0	0	0	1	question-
10	0		2	0	0	0	0	able
15	0		0	0	0	0	0	
20	0		0	0	0	0	0	
25	0		0	0	0		0	
30	0		0	0	0		0	
35			0	0	0			
40				0	0			

(1) Depth measured in hundredths of a foot

CHANGES IN ACTIVITY DISTRIBUTION

Figure 19 portrays the change in activity between I+5 and I+10 minutes. The first point of importance lies within the injection area seaward from still water line. After 10 minutes of wave action the activity seemed to disappear in that the counting rate had decreased by an order of magnitude, 200,000 compared to 20,000. This decrease in activity could have been caused by the removal of the activity from the area or the covering of the activity by a movement of uncontaminated sand from some other area.

The negative lobe extending from the injection area in the vicinity of stations 25 and 26 clearly correlates with the deep zone of alongshore transport shown earlier in Figures 8 and 9. Above still water level in the vicinity of range 25 station 16, a small positive area indicates an above still water movement of activity from the injection area toward the trap. This small area continues to about midway between ranges 20 and 25. The zone of greatest movement, which is at the same location as the plunge zone, is indicated by a long narrow positive stringer stretching from the injection area to midway between ranges 6 and 10. Extending from range 6 toward range 10 is a small negative, Y-shaped area which points to the pulsating nature of the transport. Movement of activity into the trap is indicated at range 2 stations 17 and 18 while a build up of activity is indicated at stations

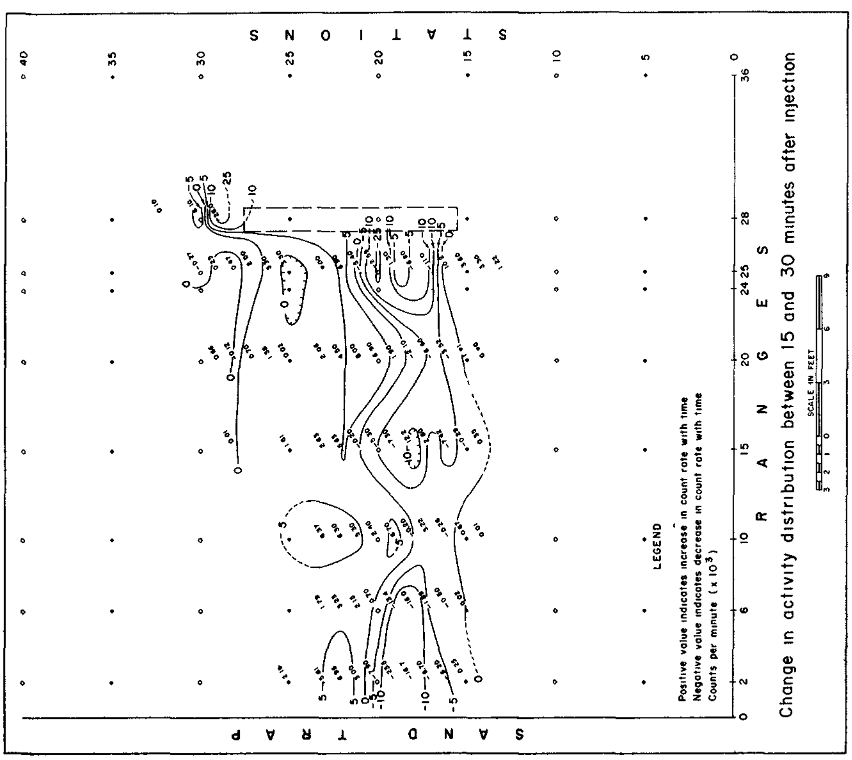

Fig. 21. Change in Activity Distribution Between 15 and 30 Minutes After Injection.

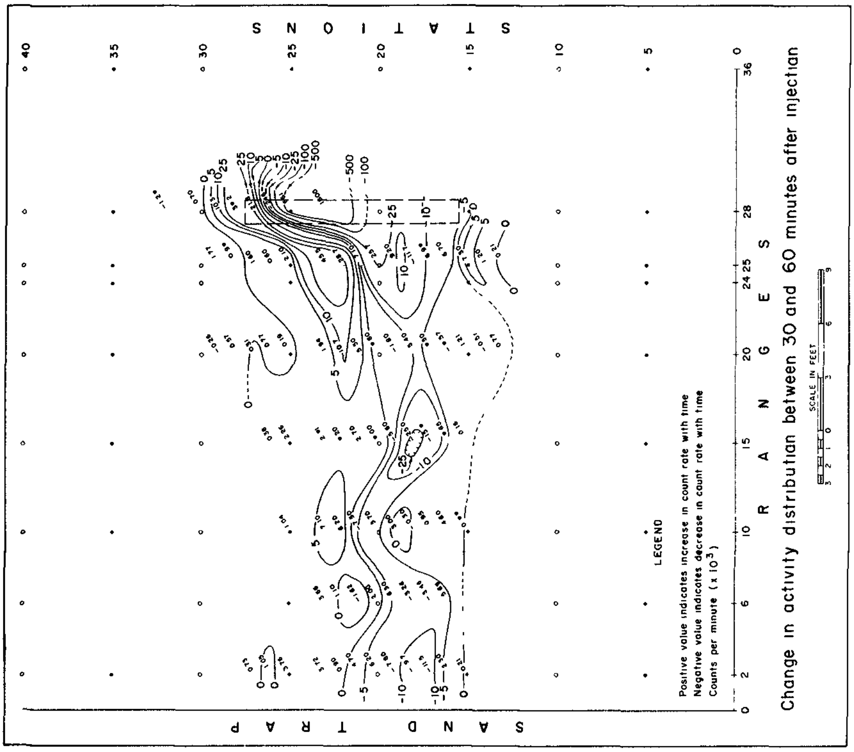

Fig. 22. Change in Activity Distribution Between 30 and 60 Minutes After Injection.

20 and 21. The large negative area shown along ranges 15 and 20 appears to indicate movement not only in the alongshore direction but also toward the offshore where it joins with the transport along the plunge zone.

Figure 20 is quite different in character from Figure 19. The alongshore sediment transport zone above still water level and the deep trend are both negative indicating movement away from the injection area. In the wave plunge zone the formation of a new pulse of sediment moving from the injection area is denoted by a positive area in the vicinity of station 20 range 25. The negative values near station 30 range 25 indicate that the irradiated particles have either been removed from the area or that they have been covered by uncontaminated sediments. The negative area in the vicinity of stations 19 and 18 range 10 appears to be a break between the pulse which is just starting from the injection area and the pulse which is leaving the test area and being deposited in the trap.

Figure 21 portrays the changes in activity which occurred between 15 and 30 minutes after injection. Except in the vicinity of ranges 10, 20 and 25 all values above still water level are negative. Along range 20 at station 15, and range 25 at stations 16 through 14 the positive values appear to be the beginning of a movement of a new pulse or slug of material from the injection area. The very small positive value at station 15 range 10 indicates the placement by wave uprush of a small amount of activity near the berm. The negative values along range 25 from station 17 through station 21 reflect the removal of activity from this zone as a slug of material moves away from the injection area toward the trap. Further movement along the wave plunge zone is not clearly defined except in the vicinity of station 19 range 10 where a small positive area indicates the movement of a pulse of material. Between ranges 2 and 6 at stations 18 and 19 the negative values portray the removal of material. The general increase in activity in the offshore direction confirms offshore transport and deposition in deeper water.

It is important to understand that this Figure 21 and the two which follow do not clearly show the pulsating nature of the sediment transport. The reason is that the time between measurements for this and the two figures which follow is probably in excess of that required for a slug to form and be moved. As a consequence, only indications of pulses may be defined by the differences in activity illustrated by these figures.

Figure 22 shows the changes in activity distribution between 30 and 60 minutes of wave action after injection. The values below still water level in the injection area are highly negative, probably due to the interposition of uncontaminated sediment between the tracer particles and the detector. This fact is borne out in Figure 12 which shows counting rates of the order of three or four times in excess of those which were found immediately after injection. The positive tongue shown at station 15 range 25 probably correlates with the tongue of material moving above the still water level on Figure 12. The positive boot-shaped area extending from station 28 in the injection area to

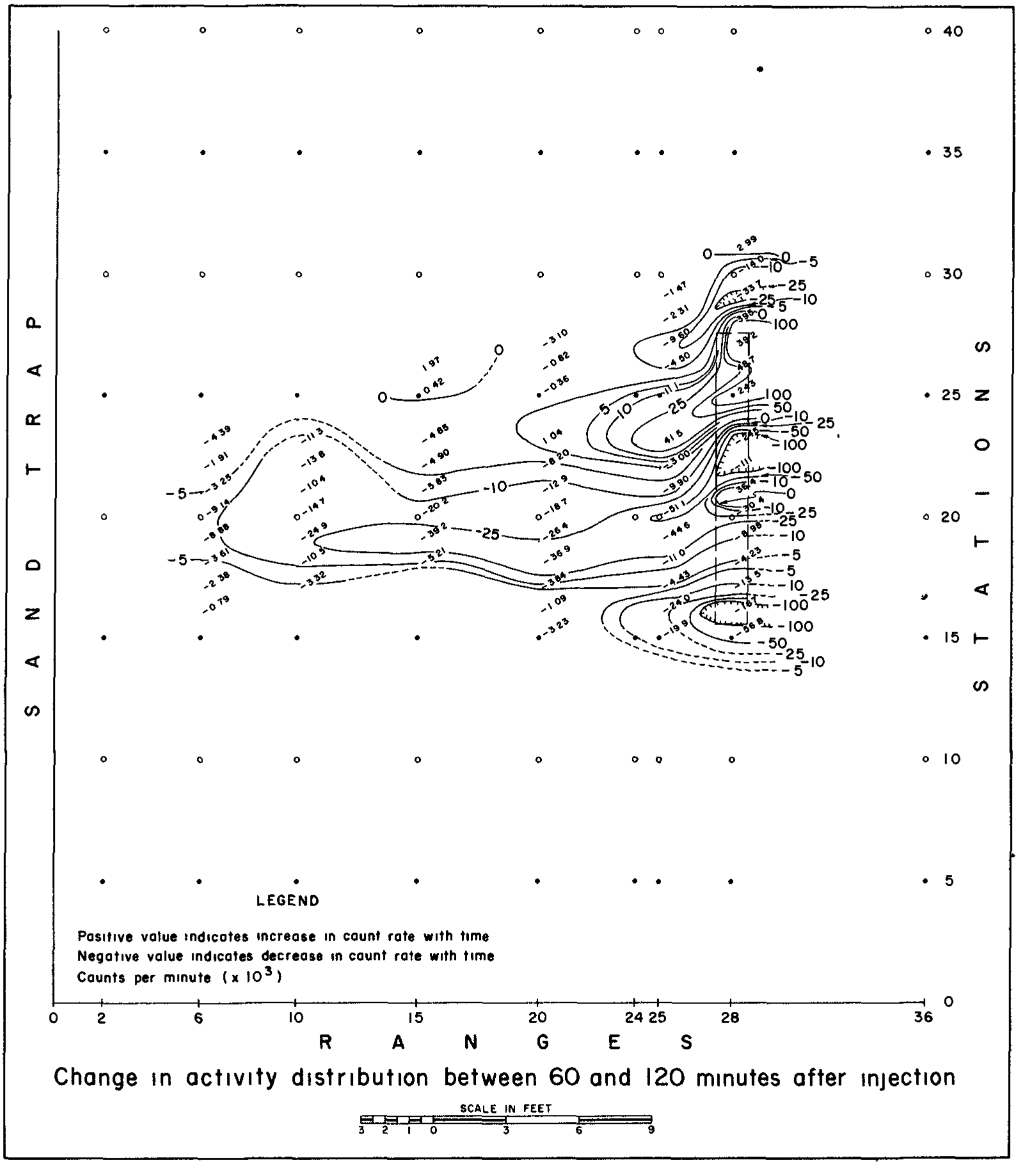

Fig. 23. Change in Activity Distribution Between 60 and 120 Minutes After Injection.

station 22 on range 20 indicates alongshore drift with a separate pulse probably indicated at a positive area in the vicinity of stations 22 and 23 on range 10. The negative areas at station 18 range 15 and stations 17 and 18 range 2 suggest pulsating transport of sediments with the center of the slug at station 19 range 10.

Figure 23 shows a general decrease in activity in practically all areas except the deep zone of the injection area. In this deep zone, stations 25 through 28 and 31, seaward or offshore movement of sediments is strongly indicated. The long narrow negative tongue which extends from range 10 to the injection area correlates with the removal of activity from in the vicinity of still water level to the plunge zone.

Seaward movement of activity is shown by all of the change in activity figures. Activities in excess of ten times background are found as deep as $1\frac{1}{2}$ feet below still water level at stations 32 and 33, some 5 or 6 feet seaward from the limit of injection. This offshore movement has clearly been defined from range 28 to range 15.

The data developed by autoradiographic means and presented in Table 1 were to be used to describe the thickness of the sediment zone disturbed by wave action. However the paucity of data makes the analysis inconclusive. The deepest irradiated particle was found 0.1 foot beneath the surface at range 20 station 18, the greatest depth in the trough in front of the bar crest present at station 19. This depth was corroborated in two other cores. It is interesting to note that the activity distribution with depth is random. The thickness at the landward limit (station 16) of the zone is 0.02 foot and at the seaward limit (station 24.5) is 0.01-foot. The 0.09-foot depth at station 25 range 28 is attributed to gradual deposition caused by seaward movement of the sediments.

Unfortunately the period of initial wave action was too long, so that significant quantities of activity had traversed the 28 feet between the injection area and the trap during the 5 minutes of initial wave action. For this reason it is impossible to make a definitive statement concerning the velocity of particle movement; however, the negative aspect of these data also furnishes information that the sedimentary particles are moving at velocities in excess of 5 feet per minute. The wave induced littoral current moves at a velocity which is approximately 45 to 50 feet per minute and the sedimentary particle at some slower velocity but greater than 5 feet per minute.

The results shown in Figures 7 through 23 seem to indicate several mechanisms which had not formerly been detected. The first of these is a changing movement in the onshore-offshore direction. An example of this movement is given by the increase in activity in the injection area in the vicinity of station 25 and deeper. While there has been an enrichment of the activity by a seaward movement of sediment and tracer material, there are also periods of low activity or low counting rate (an example is after 10 minutes of wave action). Seaward moving uncontaminated sediments could cover the activity and lower the count rate. However, the uncovering of the isotopic tracer as evidenced by the high rates (at for instance 15 minutes and 30 minutes after injection) negates such reasoning and points toward an oscillatory motion, onshore-offshore. Analysis of the elevation data fail to clarify this problem as the phenomenon is not recognized in those data. A second mechanism of somewhat similar nature has been discussed as the pulsating transport of sediments in the alongshore direction. It appears quite clear that slugs of activity move in the alongshore direction. These slugs are separated from each other by areas of low activity and appear to form and move independently from each other. Again, no indication of this type of movement is shown by the elevation maps. Finally the deep alongshore movement had not been determined before by elevation measurements although it was known to exist from earlier experimental work. It may be that this deep movement, in water depths of approximately 1 foot, is quite significant in that the magnitude of activity appears to be of the order of one-half that of the material moving in the zone of wave swash and one-fourth or less of that moving along the zone of wave plunge.

Future plans involve further analysis of the data which resulted from the test which has been discussed and from a second test which was completed approximately a month ago. As a result of this first test, it is recognized that the use of sodium with its very short half life (15 hours) presents severe limitations which could be overcome by using an isotope with a longer half life, such as lanthunum ($T\frac{1}{2} \doteq 40$ hours) which was used in the second test. Also, as a result of this test, it would appear that measurements might well be taken at much shorter time intervals than formerly. Units of time such as 5 minutes would not prove excessively long.

In the over all it is considered that this first radioactive tracer test was eminently successful. Procedural techniques for this type of testing were gained. Limitations of the use of isotopes such as sodium were realized and data heretofore unavailable were measured and became available for analysis.

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