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An Experimental Examination of Trampling Effects on the Lateral Movement of Surface Artifacts

Richard Wayne Stoops Jr.
University of Tennessee, Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Richard Wayne Stoops Jr. entitled "An Experimental Examination of Trampling Effects on the Lateral Movement of Surface Artifacts." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

Jan F. Simek, Major Professor

We have read this thesis and recommend its acceptance:

Walter E. Klippel, Paul W. Parmalee

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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AN EXPERIMENTAL EXAMINATION OF TRAMPLING EFFECTS ON THE LATERAL MOVEMENT OF SURFACE ARTIFACTS

A Thesis

Presented for the

Master of Arts

Degree

The University of Tennessee, Knoxville

Richard Wayne Stoops Jr.

August 1989

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Date May 26, 1989

This thesis is dedicated to

My friends, who each have been generous in their love and support throughout this process.

ACKNOWLEDGEMENTS

. . .being a bear of Very Little Brain . . .
-A. A. Milne (House at Pooh Corner, 1928)

Although only one name is listed on this work, it is the product of numerous individuals. The number of people who assisted, in one form or another, in the completion of this study are almost too extensive to mention; but I am going to try.

These experiments were conducted on land made available by the University of Tennessee Agriculture Experiment Station. Dr. John Hodges III, Superintendent of Farms, was extremely helpful in selecting a site and making equipment available to prepare the ground surface. Bill Morrison at Holston Farms gave us access to the field every morning and saw to the mechanical preparations of the surface. Dr. John Foss, Head of the Plant and Soil Science Department, made many valuable suggestions about treating the soil and quantifying the relevant soil properties.

The execution of the experimental phase of this project was a meticulous and time consuming task. For their patience and hard work in raking, rolling, and setting up the experimental plots, I wish to thank Lee Ann Wilson, Joanne Juchniewicz, Sue T. Myster, Hank McKelway, James Myster, Charlie Hall, Darcy Morey and Mark Guilbeau. Mapping the plots was a time consuming task, which was not made easier by the small artifact numbers and sweltering sun. For their impeccable job of recording tile locations, I wish to thank Sue T. Myster, Lee Ann Wilson, James Myster, Rick Cummins, Lee Meadows, Peer Moore-Jansen, Carole Tucker and Rick Richardson. Walking over 2,796 tiles required a horde of tramplers during the course of the experiment. For their tireless, burlap covered feet, I am indebted to Peer Moore-Jansen, Dave Hunt, Lee Ann Wilson, Rick

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Once the tiles were mapped, this left the task of digitizing over 600 unit maps. While the digitizing tablet made this job infinitely easier, it was still a repetitious chore requiring two diligent individuals at a time. For their patience and good humor, I am indebted to Patricia Fay, Lee Ann Wilson, Hank McKelway and Zada Law. I wish to thank Alice Beauchene at the University of Tennessee Computer Center (UTCC) for always being receptive to frantic calls about untangling the vagaries of computer graphics. All of the graphs included herein and the digitizing program were created using UTCC's graphic capabilities. Mike Morris graciously agreed to analyze the soil samples from the test plots. Lee Ann Wilson provided numerous helpful editorial comments on an earlier draft of this thesis. Kurt Hess designed the cover for the distribution version.

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ABSTRACT

An often cited but little understood archaeological disturbance process is the effect of a site's occupants walking across the surface. Human foot traffic will move and alter archaeological materials, artifacts, in characteristic ways. How surface items will respond to trampling is dependent on a variety of factors. These factors will determine the extent and dimensions available for movement. By controlling for some of the relevant variables, the effects of other variables can be examined.

In this thesis, experiments are described that identify each of the variables that influence or may possibly influence how surface artifacts respond to foot traffic. The application of the experimental method allows most of these to be controlled so that the effects of other factors can be studied. These factors, trampling pattern, artifact distribution, artifact size and trampling duration, were each determined to have a significant impact on the movement of surface items.

Ceramic tiles of three size grades were placed in a regular pattern at known locations. These were laid on a prepared soil surface. The surface was constructed to accentuate lateral and decrease vertical displacement. The sediment exhibited a high clay content. The surface was flat, dry and compact with no extant vegetation or detritus. Each test consisted of four individuals walking across the surface in a proscribed pattern. After each test, tile locations were mapped and the test was repeated. This yielded beginning and ending Cartesian coordinates for each item for each bout.

A model of artifact displacement as a function of trampling disturbance was

generated based on the significant factors. This allowed for the determination of the impact of each of these factors. Most displacement will occur soon after deposition. A non-restricted walking pattern will move materials more that if the pattern is constrained. Material high density areas are more resistant to trampling disturbance than low density areas. Larger artifacts are more liable to move, but they will not move as far as small artifacts. This model, while accounting for only some of the relevant variables, serves as solid baseline for further research.

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CHAPTER I

INTRODUCTION

Step by step / The longest march / Can be won . . .
-John McCutcheon (Traditional Folk Song)

The ultimate concern of anthropologists is the study of humans and their culture. Archaeologists extend that study into the past. This opens the opportunity for a diachronic perspective of living systems, and alternate perspectives on extant ones. This unique perspective allows a greater breadth of understanding of the function, form, and evolution of human culture.

However, the nature of the information source, the archaeological record, limits the types of questions which can be posed. Only those aspects of human adaptation that have material consequences may be dealt with. Although allowing for a tremendous range of inquiry, this ultimate boundary still exists.

Archaeologists are challenged to gain knowledge about the evolution of human culture using only the available material consequences. Traditionally, archaeologists had a tendency to "leapfrog"; to skip over some of the basic building blocks in order to make cultural inferences (Tringham 1978:172-175). The step that was often ignored or incompletely treated is today called middle range theory. Middle range theory is a way of explaining and making generalizations about the way in which materials are incorporated into systems, what aspects of cultural systems can be reflected in materials, and how these materials continue be affected by the environment (cf. Clarke 1973:98-100, 1978:13-23; Gifford 1977:203-205;

Hodder 1981). Middle range theory is "middle range" because it serves to bridge the gap between data and general theory. Ideally, it is this general theory which will in turn serve to explain past human behavior (Raab and Goodyear 1984, cf. Binford 1977a:6-7, 1981b:21-30, 1982c:128-130; Merton 1968:38).

Environmental factors that alter archaeological materials are grouped under the rubric of formation processes. Formation processes are those forces which act to change the context and character of archaeological traces over time (Binford 1977b, 1978a, 1978b, 1979, 1980; Schiffer 1983, 1987; Wood and Johnson 1978). Middle range theory is composed of explanations and generalizations about the behavior of these processes. Studies which investigate the character, form and function of formation processes, middle range research, involve attempts to develop "'Rosetta Stones' that permit the accurate conversion from observation on statics to statements about dynamics" (Binford 1981b:25).

Formation processes introduce patterning in the condition and context of artifacts. The challenge presented by these processes is not so much one of correcting distortions (cf. Binford 1981a, 1981b) but of recognizing how cultural materials have been created and changed since deposition. Recognition of the impacts of trampling and other processes has begun to influence the interpretations that are made regarding archaeological materials (cf. Stein 1987).

The phenomena under consideration have important implications for the study of the spatial distribution of artifacts. Numerous variables, (cultural ones such as a group's settlement system, subsistence system or procurement strategy, and natural ones such as water, root action, animal burrowing, frost heaving, forest fires or tree falls) are involved in the formation of the archaeological record. These variables differ in magnitude as well as duration. Some have a greater effect at a given stage of development than others. The effect of occupational disturbance is a unique process in that it functions between the time of primary disposal and either site abandonment or artifact burial. Therefore, trampling falls into a unique category as an essentially physical process (a formation process) with a human causal agent.

Trampling as a Formation Process

This study makes an empirical assessment of human occupational disturbance or trampling as a formation process. As humans walk across a surface, trampling is the interaction that occurs between their feet and whatever materials lie on that surface. Many different parameters influence how an artifact responds to being trampled.

At present these parameters, the diagnostic characteristics of a trampled assemblage and the variables influencing the context of deposits, are unquantified. Thus, the horizontal spatial relationships of artifacts change in an unknown manner. This study addresses the question: "What effect does trampling have on the horizontal spatial distributions of artifacts?" In order to approach this problem, a series of controlled experiments were created. Each of the variables influencing the movement of artifacts exposed to human foot traffic was identified and controlled by measuring, holding as constant, or randomizing them. The variables of interest were set up in a factorial arrangement designed to quantify their effects and interactions. Through these experiments, the nature of trampling is described and defined.

Since conscious interaction is presumed to be absent between the site occupants and surface materials, artifact trampling is treated as a physical process. This experiment was designed to reduce this process to its essential elements. Since the effects of these variables were quantified, subsequent experimentation can add other variables to bring the experimental situation out of the realm of the abstract and closer to that of archaeological reality.

Using the data generated from this study (that is, direction of movement and distance traveled by each surface artifact from bout to bout) quantitative analysis was used to produce a model. Analysis resulted in a formal mathematical model of artifact movement as a function of human trampling. This model has a high degree of predictability of the variability evident in the observed values. Generalizations were then made from the models produced.

This model will ultimately provide a tool to investigators making assessments of spatial integrity within archaeological deposits. Eventually, this will assist in unraveling the genesis of the spatial relations found in the archaeological record. With other formation processes controlled, these spatial relationships may then be understood in terms of factors conditioning the disposal of such remains; that is, how artifacts and their associations came to be.

This question is approached by first classifying those processes that may have affected the condition and context of archaeological materials in the Eastern Woodlands. Each is defined and categorized. The development and current status of experimental archaeology is addressed in Chapter III. Definitions for and examples of experimentation as it is used in archaeological research are presented. In Chapter IV, the results of previous research into trampling are itemized and critiqued. Chapter V identifies the relevant variables affecting artifacts responding to human foot traffic and defines the variables studied. The methods used to conduct these trampling experiments are addressed. Qualitative descriptions and plots of results along with a quantitative analysis of results are presented in Chapter VI. Chapter VII includes a first approximation of a generalized model of trampling, followed by summaries and conclusions.

CHAPTER II

FORMATION PROCESSES

> Look at their fields, and imagine what they write, if ever they should put pen to paper. Or what have they not written on the face of the earth already, clearing and burning, and scratching, and harrowing, and plowing, and subsoiling, in and in, and out and out, and over and over, again and again, erasing what they had already written for want of parchment.
> -Henry David Thoreau (A Week on the Concord and Merrimack Rivers 1849)

Developments in archaeology have pointed out the importance of contextual dynamics. Attention has been focused on these dynamics, referred to as formation processes, to determine how they alter archaeological deposits. Traditionally, investigators have assumed that deposits have suffered insignificant amounts of disturbance, or that the disturbing factors, random in nature and over time, would cancel each other out (Schiffer 1983, 1987). A variety of experimental studies (e.g. Gifford-Gonzalez et al. 1985; Lewarch 1979; Rudolph 1977; Villa and Courtin 1983) and ethnographic observations (e.g. Heider 1967; Lee 1966; Yellen 1977) present a series of "cautionary tales" which support the idea that past behaviors or events will seldom be mirrored in material deposits. There are very few "Pompeiis" (cf. Binford 1981a). In fact, deposits demonstrably undisturbed by natural processes are rare if they occur at all.

From the moment of their initial deposition, a variety of forces affect the character and context of cultural byproducts. Factors such as site location, local climatic conditions and geomorphological history of the area will alter archaeological deposits with varying intensities (Foley 1981; Rowlett and Robbins 1980). Of interest here are those factors which affect the ***context***, as opposed to the condition, of archaeological deposits. Processes such as bioturbation, frost heaving, freeze/thaw, plowing, soil creep, stream action and flooding alter deposits in characteristic ways (Schiffer 1987:10-11).

The combined effect of these formation processes is movement of archaeological materials through the soil matrix. These processes can be grouped according to their principle migration dimension. Some tend to move materials vertically through this matrix while others tend toward more horizontal displacement. A third group moves material independently of these vectors (Table 1). Each of these methods may be defined by their distinctive attributes, and some leave behind unique traces which betray their influence on archaeological context.

Table 1. Some processes potentially affecting archaeological sites in the Eastern Woodlands.

Vertical	Horizontal	3-D
Deflation	Eolian Transport	Argilliturbation
Fauna	Fluvial Transport	Plowing
Freeze/Thaw	Mass Wasting	Treefall
Root Action	Ice Wedging	
Trampling	Solifluction	
Wetting & Drying	Trampling	

Trampling. Trampling fits into two categories as it exhibits two separate components. First, in sandy sediments, human trampling tends to cause a vertical migration of artifacts (Villa and Courtin 1983). The smaller size grade of any artifact class is most vulnerable to this disturbance (Stockton 1973; Villa and Courtin 1983). Second, more compacted or clayey substrata are conducive to horizontal displacement of artifacts. The larger size grades ***may*** be more susceptible to this mode. Materials which are pushed into the substrate are impervious to horizontal displacement.

Vertical Movement

Formation processes which move materials primarily perpendicular to the land surface are classified as vertical. This does not mean that the ***only*** direction of movement is vertical. Some horizontal dislocation may occur, but this is largely outweighed by the vertical component.

Deflation. Wind may cause the downward migration (vertical displacement) of artifacts by the process of deflation. Finer grained particles are sorted out from the coarser ones. In extreme cases, this can remove the soil matrix, causing archaeological deposits to become overlapping (e.g. Davis 1975). As wind velocity increases, there may be a horizontal component as well.

Faunal. Faunal disturbance can be fairly pronounced and pervasive throughout a deposit. Ants, worms, groundhogs, squirrels, and gophers can move artifacts upward and downward over great vertical distances (e.g. Bocek 1986; Erlandson 1984; Ohel 1987; Rolfsen 1980; Stein 1983). Wood and Johnson (1978) give some indications of the magnitude that this process can attain. The presence of animal burrows are good indicators that the deposits have been subjected to burrowing activities. However, these burrows are only visible when they have been refilled with soil of a different color than the matrix. Detecting the presence of such activities can also be discerned by comparing burrow distribution with material distribution (Erlandson 1984), or size sorting of materials (Bocek 1986).

Freeze/Thaw. Freeze/thaw cycles, although not as pronounced in the Eastern Woodlands as they are in permafrost zones and the northern latitudes (ice wedges, patterned ground, etc.), have the potential to gradually dislocate materials upward. This is particularly true of materials of lower thermal conductivity such as stone (Rolfsen 1980; Wood and Johnson 1978).

Root. Root action may produce some lateral dislocation, but the majority of materials affected by this process will percolate downward. In clayey soils, holes may be left by decaying roots (root casts) which can give materials the opportunity to drop several centimeters in an instant (Whyte 1985). These influences are separated from treefalls which are covered below.

Wetting and Drying. The simple wetting and drying of sediments found in a fluctuating water table has the potential to bring courser materials to the surface (Moeyersons 1978).

Horizontal Movement

Processes in which the primary direction of impact is parallel to the land surface are classified as horizontal. Some vertical motion may occur, but the principal vector is lateral.

Eolian Transport. Wind can move artifacts horizontally across a site surface. As the breeze strength increases, so does the size of materials moved. Eolian transport has a vertical component as it is often accompanied by deflation.

Mass Wasting. Mass wasting leaves some very distinctive traces. Determining whether this process has been at work on the deposits at hand can be fairly straightforward (Rick 1976); trees with their lower trunks perpendicular to slopes, leaning fence posts, cracking pavements, and large rock slabs thrusting out of the matrix downslope (soil creep) can indicate this type of activity (Bloom 1978).

Fluvial. Fluvial processes may leave distinctive traces such as sorted grains and patterned artifacts. The strike and dip of artifacts can show patterning diagnostic to fluvial transport of disturbance (Behrensmeyer 1982).

Ice Needles. Ice needles can raise artifacts vertically several centimeters above the substrate and redeposit then in slightly different positions as the needles thaw and collapse. Artifacts directly beneath the surface can be raised above the surface and moved in this manner. Movement is minimal, although it may be cumulative (Rigaud and Simek 1987; Tricart 1970).

Three Dimensional Movement

Finally, there are those processes which have no primary vector of movement. These forces can move materials in any direction within the soil matrix. Some, earthquakes and treefalls, do this catastrophically. Others are more gradual.

Argilliturbation. Argilliturbation is caused by the wetting and drying of sediments with an unusually high clay content. This shrinking and swelling of a clayey soil is typical only in Vertisols and some Rendzinas. The turbulence in these soils is so severe that trees cannot grow on them (Duffield 1970; Wood and Johnson 1978).

Earthquake. Earthquakes cause vertical and lateral displacement of deposits. However, since there are often notable geological faults or refilled wedges associated with these occurrences, they are generally easily detectable.

Plowing. Plowing can cause artifacts to move three dimensionally through the substrate within the reach of the plow. The vertical component of this movement has been largely ignored (cf. Reynolds 1982; Simek and Dunnell 1989). Ammerman (1985) contends that artifacts in plowzones will oscillate within a small range and, once they have hit an equilibrium, will not venture any further from it (cf. Frink 1984; Lewarch 1979; Rudolph 1977).

Treefall. Lastly, treefalls can rip large sections of the soil matrix up and redeposit it. In forested areas, particularly those with shallow bedrock or an impenetrable clay substrate, large portions of the land surface can be worked over in a short period of time (Gifford 1978; Reid and Gallison 1989). Treefalls also tend to leave distinctive soil patterning which has often been confused with pit houses (Gifford 1978).

Summary

Archaeological materials reside in a dynamic context which continually alters their morphology and associations. A combination of environmental conditions will move materials in different directions, depending upon the nature of the process. Each of these processes leaves behind a distinctive trace or traces which can be detected to discern what affect it has had. By separating these forces and examining them individually, one may be able to discover their distinctive signatures. This in turn may help to unravel how they, separately and in tandem, have produced the archaeological record.

Experimentation offers a means for examining the different aspects of these forces. Although this a technique allows for control of all the relevant variables involved, it has been applied with mixed results in archaeology.

CHAPTER III

EXPERIMENTAL ARCHAEOLOGY

> Scientific research is necessarily long-term, tedious, lonely, and often boring. Patience and imagination are necessary to see the worth of such labors.
> -Ruth Tringham (Experimentation, Ethnoarchaeology, and the Leapfrogs in Archaeological Methodology, 1978).

Since the archaeological record is influenced by a variety of processes, a study of these processes would be difficult if not impossible simply by examining their effects on materials at the time of recovery alone. This is where the technique of experimentation becomes useful. Through controlled experiments, not only can different processes be studied individually, but the different elements making up a process can also be distinguished. The effects of these elements can be studied individually and in tandem.

Experimentation is not new to archaeology. There is a long history of performing experiments in lithic studies in order to examine the techniques necessary for stone tool production and determine their response to use stress (e.g. Evans 1897; Tringham et al. 1974). The application of experimental methods to archaeological problems has been dependent on the researcher's definition of experimental archaeology.

Definitions

The first attempt at classifying experimental archaeology was offered by Ascher (1961), who defined it as that ". . . category of experiments . . . in which matter is shaped, or matter is shaped and used, in a manner simulative of the past" (Ascher 1961:793); that is, strictly replication. Experiments are for ". . . testing beliefs about past cultural behavior . . . the imitative experiment is the keystone of experimental archaeology" (Ascher 1961:793). According to this perspective, archaeological experiments are primarily imitative or replicative. A majority of the studies conducted until that time, and for several years thereafter, were of this type. Ascher's examples included cave painting (Johnson 1957), "charmstones" (Treganza and Valdivia 1955), notched scapula and ribs (Morris and Burgh 1954), arrow shaft straightening (Cosner 1951), and Old World copper smelting (Coghlan 1940).

While many imitative studies have concentrated on lithic reproductions from Evans (1897) to Newcomer (1971), other artifacts and archaeological traces have been duplicated as well (e.g. Crabtree 1966; Flenniken 1978; Greene 1981; Johnson 1981; Newcomer and Sieveking 1980). Using materials and hypothesized methods of prehistoric peoples, these investigators attempted to reproduce the form of observed archaeological remains. By attempting presumed methods, they attempted to determine what was possible.

Subsequent investigators found Ascher's definition somewhat restrictive and sought to encompass a larger range of activities. Saraydar and Shimada (1973) modified this definition by asserting that the testable hypotheses for these experiments needed to become more complex. Model building can proceed after enough "basic data" have been compiled.

Initially, Coles (1973) also classified all experimental archaeology as replication. According to Coles (1973:13) ". . . experimental archaeology is a convenient way of describing the collection of facts, theories and fictions that has been assembled through a century of interest in the reconstruction and function of ancient remains." However, he later divided experimental archaeology into three levels (Coles 1979). The first, or lowest level, is the recreation of prehistoric materials or structures where the goal is the end product. In these simulations, modern techniques are used to facilitate construction. These are mainly useful for display purposes. The second level is Ascher's replication, using technology and raw materials available prehistorically (e.g. Callende 1976; Erasmus 1977). This allows for the measure of such parameters as length of time and amount of energy expended by a modern technician to construct a similar artifact. The third level is functional; that is, how an artifact performs under use. This would include microwear studies (Keeley and Newcomer 1977; Odell and Odell-Vereecken 1980), stone versus steel axe comparisons (Saraydar and Shimada 1971), Iron Age storage pits (Reynolds 1974), Norwegian hide boats (Marstrander 1976; Christen and Morrison 1976), butchering a goat with stone tools (Jones 1980), the Pamunkey project (Callahan 1976) , and the *Kon-Tiki* voyages (Heyerdahl 1971).

Ingersoll and his colleagues define experimental archaeology ". . . as a systematic approach to the explication of data. Operationally this definition encompasses tests of hypothesis, replication of activities, duplication of conditions, construction of explanatory models, manipulation of methodological variables, and simulation of data-based observations" (Ingersoll et al. 1977:ix). They present a classification scheme which consists of four categories. The first and second classes are replicative studies and tests of method, respectively, as defined by Ascher

(1961). The third category consists of studies of site formation processes and taphonomy (e.g. Ascher 1970; Gifford and Behrensmeyer 1977; Jewell and Dimbleby 1977; Whyte 1985; Wildesen 1982). Fourth is ethnoarchaeology (e.g. Binford 1977, 1978a, 1978b, 1979, 1980, 1982a; Binford, ed. 1978; Bonnichsen 1973; Gifford 1977, 1978; Gould 1978; White and Thomas 1972; Yellen 1977).

Some of the aforementioned definitions are limited to replication studies, and thus may be too restrictive to be useful as a goal for experimentation. Replication itself is of limited utility. An exception is the last definition, which enumerates the various elements of experimental archaeology. A more intuitively satisfying definition is offered by Tringham who states:

> 'Experimental archaeology' -- that is, experiments as part of archaeological investigations -- . . . comprises a series of observations on behavior that is artificially induced. [This] may involve more or less rigorously controlled conditions and recorded results [Tringham 1978:170].

She divides Ascher's one class (imitative experiments) into two basic categories. The first are lower level, "by-products of human behavior," encompassing the contact between materials and activities, and how these change over time. These include material taphonomy, formation processes, and a basic-level investigation of the nature of artifacts. The second are higher level, "behavioral experimentation," comprised of propositions about activities which leave no direct archaeological traces.

Within this classification scheme, trampling would be classified in the by-product category. It is a "contact trace," a human modification of materials on the surface during and after deposition. In essence, it is a "natural" phenomena with a human motive force.

Archaeological Experiment vs. Scientific Experiment

These aforementioned definitions have guided in the goals and results of archaeological experiments. Replicative tests recreate observed archaeological phenomena and use materials and presumed methods that would have been available aboriginally (Ascher 1961). A method of manufacture is proposed and the results of the test support or detract from it. This proposition can not be completely ruled out, nor can it conclusively be proven to be the method used. At worst a new hypothesis is added, at best an alternative one can not be eliminated. Thus, replication differs from a true "scientific method" (cf. Wilson 1952).

Nonetheless, it has been asserted that "archeology is a science . . . [it] is concerned with the systematic study of the relationships between human behavior and its material correlates . . ." (Ingersoll et al. 1977:xi). However, "systematic study" is apparently applied loosely in that Ingersoll and his colleagues define an experiment merely as a "systematic approach" to explaining data. Their application of testing techniques is further broadened by not imposing a rigorous control on all of the relevant variables (Ingersoll et al. 1977:ix). How is it possible to be systematic without controlling for all relevant variables? It is not necessary to conduct an experiment in a laboratory in order to apply controls, although it helps. Taking into account all of the factors that relate, or potentially relate, to the phenomena under study is ". . . long-term, tedious, lonely, and often boring" (Tringham 1978:175). However, controlling the relevant factors is something that needs to be addressed if the results are to yield a valid conclusion.

Tringham (1978:178-179) observes that most experimenters seem to have adapted Ascher's (1961:108) argument that these rules need not be followed rigorously, since their subject of study is cultural behavior and not natural phenomena. Their primary goal is to make a positive inference; trying to prove that a specific trace could possibly be created by a specific technique. This is the reverse of the scientific method which involves falsification and must be able to reject the proposed hypotheses (Wisdom 1952; Wilson 1952). Positive inferences ***increase*** the number of possible solutions (equifinality), generating more questions than answers (Salmon 1975). The progress of knowledge comes when one refutes an hypothesis (Popper 1968).

It is possible to conduct a replicable, controlled, useful experiment by following a few simple rules. Briefly these may be outlined as follows (Wilson 1952).

1. It is necessary to have a basic understanding of the nature of the problem and the relevant theory. The experiment should be cast in its simplest form.
2. Define the type of event to be studied and the identity and nature of the controlling variables.
3. Make measurements on a relative scale. These are generally the most useful as it is usually a comparison which is of interest. Link these observations to an absolute scale if possible, to make comparisons with different observers.
4. Define the population to be studied and design a sampling strategy which will be representative.
5. Subject similar test specimens to the same treatment as the object of the experiment except for the change in the analysis variable. These controls

can help to correct for the effect of variables which can be changed in an unknown or uncontrollable way. The establishment of a standard is a control which can be reproduced by others.

6. Incorporate randomization into the design for any decisions which may introduce experimenter, subject or instrument bias.

7. Repeat the experiment to check the result and gain an estimate of precision.

8. Exactly the same conditions should not be carried out for replicate observations. Ideally, one should have a factorial design which can examine different treatment levels and their interactions.

9. Change an irrelevant variable between replications. Irrelevant variables are those that the experimenter believes will have no effect on the outcome.

10. Variables which change in an unknown way or have unknown effects should be randomized.

11. Choose a level of statistical significance that is based on prior knowledge and gives an acceptable balance between Type I and Type II errors.

12. In the case of factorial experiments with several levels, the number of interactions, and thus the number of experimental conditions, can be reduced by eliminating those that from prior knowledge are known to be insignificant (fractional replication).

13. In testing for rare events, a multiple search, or screening, system may be necessary.

Obviously, not all of these are applicable to every experiment, but this system should be followed as closely as possible in order to produce definitive results (Wilson 1952:36-67).

The application of this technique can assist in untangling the complexities of trampling. Since there are several factors that control the movement of surface materials when trampled, an attempt to determine the effects of all of them simultaneously would be fruitless. If too many factors are permitted to vary, any resultant artifact movement would be unassignable to cause. In the controlled environment of an experiment, most of the contributing factors can be measured or held constant while the effects of others are studied. This research does this by defining all of those elements that do or may potentially contribute to how trampled artifacts respond. Most of these are controlled so that the effects of only a few can be examined.

As may be seen from the examples cited above, an experimental approach has long been established within archaeology, and a more rigorous application of experimental techniques is becoming more common. It is within the framework of the experimental method and its application to archaeological phenomena that this study is conducted.

Summary

While a variety of definitions have been offered for experimentation in archaeology, most of these have centered around replication. An alternative classification elucidates the interactions between humans, materials and environment, and cultural systems.

Replication is useful, but is of limited utility when one is attempting to make a definitive statement about past cultural systems. A more fruitful approach is the application of traditional scientific methods to the design and execution of archaeological tests. Experimentation has been used to make positive statements about the creation and formation of the archaeological record. It is a means of explaining the effects of the different components of a process.

Since a variety of forces influence how artifacts respond to being trampled, experimentation provides a means for separating these factors out and examining their effects. Previous investigators have applied experimentation to trampling with mixed results. An experimental checklist may be used to critique the utility of these earlier investigations. While experimentation has proven useful, this has not been the only approach to the problem. Other lines of evidence have been investigated.

CHAPTER IV

PREVIOUS INVESTIGATIONS

> . . . for it is the habit of the errant Seri to roam spryly and swiftly on soundless tiptoes.
> -McGee 1896

This thesis examines the process of trampling as an example of what Matthews (1965) calls human occupational disturbance. Previous investigations into trampling have used different lines of evidence to detect trampling effects. Most have dealt with the taphonomic effects of trampling with many concentrating on modifications to bone. While various means to investigate movement have been used, the majority of these studies have focused upon vertical, rather than horizontal displacement.

Archaeological Evidence

Suspecting that some bone tools may be produced by natural rather than cultural processes Meyers et al. (1980) looked at six paleontological sites from Western Nebraska. These ranged in age from 0.5 to 17 million years. Restricting themselves to the tibia and humerus of camel (*Camelops* sp.) and horse (*Equus caballus*), they looked for longitudinal, transverse and spiral fractures, abrasion and chipping. Numerous examples of spiral fractures were present at all sites. Their presumed causes for the creation of these pseudo-tools were trampling, weathering and trampling, and soil compression.

Haynes and Stanford (1984) compared *Camelops* finds to an ideal condition. That is, remains in good associations with cultural remains and modifications that are not attributable to natural processes. They suggest that natural breakage occurs around waterholes at an estimated rate of 30%, largely due to trampling (Haynes 1983b). Surface modification were due to soil movement, gnawing (Haynes 1983a), weathering and trampling (Haynes 1981) .

Archaeological evidence was used by Hughes and Lampert (1977) to compare two rockshelters in Australia. Both sites displayed a change through the deposit from one assemblage type to another. However, one, an inland occupation site, exhibited a gradual change between these assemblages while the other, a coastal site, revealed a sharp transition. By examining the radiocarbon dates and the nature of the sediment at the two sites, the authors concluded that the deposit in the first rockshelter had been subject to extensive vertical displacement of artifacts by trampling.

Working with material from Terra Amata, Villa (1982) relied upon refitting of lithic debris to establish that vertical displacement had occurred. Trampling was proposed as a possible means for this displacement (1982:279).

In another refitting study, Hofman (1986) traced the vertical movements of materials though alluvial deposits at the Cave Spring site. This site is situated on the Duck River in Tennessee's Nashville Basin. Lithics recovered from a 2 m x 3 m excavation area were refitted over a broad area and up to 40 cm vertically. One of the factors suspected as responsible for the observed displacement was trampling.

Ethnographic Observations

In the course of setting up a bone weathering experiment, Brain (1967) collected bones from around a waterhole of the Ossewater Hottentot village, Namib Desert, Pretoria. He found numerous "bone tools." By interviewing the villagers to determine the uses of these tools, he discerned that they had not been used at all. Brain inferred that these pseudo-tools had been trampled by goats around the waterhole. Further examples of pseudo-tools were discovered in similar circumstances.

To see how modern systems deposit bones and thereby gain insights into how paleontological deposits were generated, Behrensmeyer and Boaz (1980) perused and recorded bone elements in a series of transects. These transects were defined in different geographical settings within the Amboseli Basin, Kenya. Bones were aged, identified, and their condition was noted. Certain elements were more likely to be buried than others; limb elements, podials and phalanges. By observing the activities of live animals, they determined that the primary process responsible for these burials was trampling. Buried crania and mandibles were fragments; maxillae, frontlets, mandible fragments and a few teeth. Compact bones were selectively buried (see also Behrensmeyer 1978).

In a study of gnaw and fracture patterns, Haynes (1983b) inspected bone locales in Isle Royale National Park (U.S.), Wood Buffalo National Park, and Superior National Park (Canada). He observed animal activities at a series of sites and made collections. He surmised that bones were more likely to break when trampled if they had been gnawed first. He asserted that kicked bones which moved several centimeters were less likely to break if they were fresh. Bison herds on the move can shift bone by several meters.

Andrews and Cook (1985) charted the disarticulation of a cow (*Bos taurus*) skeleton discovered near Draycott, Somerset, England. The elements were mapped annually as they were dispersed downslope and buried. Since the bones occurred along a cow path, trampling was implicated as being the primary motivating force. Only about a third of the expected elements were recovered after five years. The pelvis showed little modification, while the cranium was fragmented. Numerous scrapes and striations appeared on the other elements. Marks along the shafts and diaphyses were shallow and had no particular orientation.

Yellen (1977) excavated a series of sites that had been recently occupied by the !Kung of Western Botswana. He intended to check spatial patterning of elements and their preservation. Overall, elements that were trampled into the loose, sandy substrate showed better preservation. He determined that certain kinds of bone, shaft fragments and anything buried, are more likely to be preserved.

Gifford (1977, 1980; Gifford and Behrensmeyer 1977) observed behaviors of the Dassanetch of Lake Turkana, Kenya, on a single occupation site. After four days of occupation, all visible bone refuse on the surface was plotted. She excavated this site the following year. Substantially more bones were recovered (1,954) than had been originally plotted (200). Some of this was due to fragmentation, but many others had not been previously recorded. It was presumed that these pieces had been trampled into the loose, sandy sediment. Buried pieces were no greater than 3 to 5 cm in maximum dimension. Based on these observations, Gifford suggests that trampling will create "zones", or strata, of similarly sized items. The amount of migration depends on the nature of the substrate and the intensity of trampling. Bones in a given zone will be less than or equal to the upper size range, in their maximum dimension, for this zone (see also Gifford 1978).

Also working in Lake Turkana, northern Kenya, Hill (1979) charted the disarticulation of a topi (*Damaliscus korrigum*) as it decomposed. He point plotted the bones and recorded the sequence of disarticulation of various elements. The causes of scattering were "apparent." He postulated that the movement caused by carnivores, scavengers and water action was random. The primary "random" processes cited was trampling by these animals.

Students in a fieldwork methods class looked at vacant lots in Tucson, Arizona to study formation processes (Wilk and Schiffer 1979). They observed the results of cultural uses: travel, refuse disposal, storage, parking, access to spare car parts, children and adult play, and camping by transients. They also observed the effects of natural processes; wind, water, and trampling. It was determined that trampling fragments, crushes, and abrades objects and moves them to marginal areas, that is, out of pathways. This process may potentially cause artificial artifact clusters. Some items may penetrate the soil, depending on the artifact size and nature of the substrate.

Experimental Studies

Flenniken and Haggarty (1979) conducted an experiment to examine surface modifications and breakage that occurred as a result of trampling. They constructed a 3 m x 0.6 m box and divided it into 55 cm^2 compartments and filled the first with a loess matrix of silt loam, the second with a medium to coarse alluvial sand, the third with mixed clay through gravel, and the fourth with basalt gravel. These were then hand tamped and an obsidian core was reduced over each. No mixing was permitted between cells and the materials were not reoriented after deposition. Three walkers made 1000 passes over the box. Larger materials were removed by hand and the matrix was screened through 5 mm mesh for the remainder. Only the results from the loess compartment was reported. Of 428 flakes, 157 were modified. They assigned 56 of these as pseudo-tools. These pseudo-tools were compared with replicated tools. They determined that similarities between the two could lead to mis-assignments. Attributes that could distinguish pseudo-tools are; 1) lack of patterning to the edge damage, 2) damage occurred on the dorsal and ventral surfaces, 3) lack of patterning in the modifications, 4) scratching and crushing on both sides, and 5) lack of polish.

The production of pseudo-tools was investigated by Goerke (1981). She placed a scatter of lithic debris over the surface and then allowed an indian elephant to walk over them. Some minor chippage occurred on the corners and sides of the flakes. Most of these were oriented randomly, divulging their origin. Some exhibited edge modification reminiscent of utilization.

To determine the types of alterations that can be inflicted by cattle, Fiorillo (1984) laid out 90 cow (*Bos taurus*) and pig (*Sus scrofa*) bones around a salt lick. These elements were checked before placement for existing markings. They were laid on a hard, dry sandy soil and left for five weeks. Shallow, subparallel grooves occurred on 49% of the elements. He contends that these were much like those attributed to cutmarks by Bunn (1981) and Potts and Shipman (1981), "series of fine linear grooves on bone surfaces constitutes the most unequivocal evidence of hominid involvement with bones" (Bunn ibid:574; cf. Behrensmeyer et al. 1986:770).

Tringham and her colleagues (1974) created a series of experiments to modify the edges of flakes. Unretouched lithics were used on a variety of materials. These were subsequently examined for usewear. To check for modifications that could be created by natural processes, some flakes were also exposed to water tumbling and trampling. For trampling, 10 flakes were placed just below the surface and walked on by participants for 30 minutes. They claimed that the scars produced could be easily distinguished from usewear. The scars were randomly distributed around the flake perimeter and had no fixed orientation or size.

Using fresh, naturally cleaned horse (*Equus caballus*) and cow (*Bos taurus*) bones, Behrensmeyer and her colleagues (1986) conducted an experiment to see if cutmarks could be distinguished from surface damage caused by trampling. Some areas of the bone were delineated and scored with a chalcedony flake. These elements were placed on damp sand and gravel from a natural stream and then exposed to three minutes of trampling by individuals wearing soft-soled shoes. Afterwards, the bones were gently cleaned and examined under a scanning electron microscope (SEM). Numerous scratches were acquired on the upturned surfaces where the moving foot pushed grain across the bone. Medipodals displayed marks oriented normal to the long axis. Ribs accrue scratches perpendicular to the long axis near the outside center of the curvature. Marks occurred singly or in parallel sets and were both V-shaped and rounded. Some showed the internal grooving that is traditionally considered characteristic of cutmarks. The preexisting cutmarks were substantially altered (see also Hill 1986).

In another experiment, Olsen and Shipman (1988) filled a series of four trays with pea gravel, course sand, fine sand, and potting soil including 23 flint flakes. The flakes ranged in size from 11 mm to 55 mm in their maximum dimension. They cleaned and placed eight to nine fresh cow (*Bos taurus*) and sheep (*Ovis aries*) elements in the trays with space around each. Participants then walked over these for two hours, making an effort to step directly on the bones. They were barefoot for the gravel and sand trays, and wore soft-soled rubber thongs for the soil and flake tray. With the exceptions of those in the soil, all the long bones developed a polish and fine, shallow striations with diverse orientations. The carpals and tarsals were little changed as these were buried. The bones in soil showed some short nicks which looked like chopping marks under a SEM. These were more shallow than butchery marks and had a broad V-shape. They occurred in superficial bands of parallel grooves.

Olsen and Shipman (1988) also recounted a study conducted by Newcomer and Olsen (in preparation) in a rockshelter in northwest Greece. A 1 m^2 x 20 cm deep unit was excavated and filled with sterile silt and limestone scree. Two layers of flint flakes and sheep and fish bones were included with an intervening 5 cm sterile layer. These were mapped in three dimensions when created. The unit was casually crossed by 25 excavators over the course of a week. The recovered bones showed no mimic cutmarks and few visible striations. However, broad, flat, parallel marks were visible with the SEM.

Experimental methods were used by Stockton (1973) to demonstrate lateral and vertical displacement of artifacts as a result of trampling. In this instance, glass sherds were positioned on and within a sandy substrate and then ". . . left to be trampled indiscriminately for a day . . ." (Stockton 1973:116). Some sherds penetrated up to 16 cm, but overall they were roughly sorted by mean weight declining with depth.

Villa and Courtin (1983; Villa 1981) placed artifacts in front of a rockshelter they were excavating and examined the movement resultant from the normal activities of the field crew. The artifacts were recovered and point plotted after 16 and 20 days of trampling. Objects moved downward as much as 7 cm while upward mobility was limited. No marked size sorting was evident. Artifacts were displaced horizontally as much as 85 cm with no obvious correlation between amount of movement and weight. Objects tended to be displaced away from the shelter.

The most recent effort in this direction was made by Gifford-Gonzalez et al. (1985). This work is a result of her earlier speculations regarding the site studied in northern Kenya (Gifford 1977, 1980; Gifford and Behrensmeyer 1977; Pryor 1982). In this experiment, two sites, one with a loam soil the other with sand, were created. At each, 1000 obsidian flakes of 3 size grades (650 at 3.0-6.5 mm, 300 at 6.5-13.0 mm, and 50 at 13.0 mm) were positioned within a 2 m area in a roughly circular pattern. These were then trampled by two individuals wearing rubber sandals or soft-soled moccasins for two hours. Cartesian coordinates were taken, the sites were excavated and screened. Given that locations were not recorded prior to running the experiment, the only observation of horizontal displacement they could offer was the subjective assessment that "[a]rtifacts at the loam site tended more to horizontal dispersal than vertical" (Gifford-Gonzalez et al. 1985:808). The artifacts at the sand site shifted in a general southern direction, but any causal relationship "remains speculative" (Gifford-Gonzalez et al. 1985:809-810).

A follow-up study to this experiment was performed by Pryor (1982). Utilizing the same parameters as defined in the first study, he performed the experiment again. However, this time no measurements of artifact placement were taken after the trampling trial, as he was interested mainly in the damage inflicted on the flakes rather than their dislocation. The primary difference between this experiment and the first is that the entire process was video taped. This technique led to two observations. First, it was alleged that the scatter seemed to have stabilized after about 20 minutes and that an equilibrium had been achieved by 30 minutes. Second, time-lapse photography of the first experiments suggested that artifacts were buried and resurfaced during the course of the experiment. However, video tape revealed these artifacts were not being pushed into the substrate, but were simply being covered by sediment kicked over them, which was subsequently scraped clear.

Summary

Each of the archaeological studies discussed above could only presume that trampling was responsible for the movements and modifications observed. No direct causal link could be established. Most of the ethnoarchaeological accounts encountered the same problem. Trampling was generally inferred post hoc.

The taphonomic experimental studies fared a bit better if for no other reason than the expressed goals were more limited. In many cases, the experiments were designed to generate trampled bone, largely to compare to cutmarks. This is particularly important in early man research as the evidence for intentional modification is often rather ephemeral. Of the lithic experiments, the testing strategy designed by Tringham and her colleagues (1974) was probably one of the best controlled of any experiment in archaeology to date. They went to great lengths not only to identify the relevant variables, but to measure and control for them as well.

With few exceptions, most of the experimental displacement studies made only a superficial attempt at quantification. The work by Villa and Courtin (1983) was a fairly limited study that resulted predominately in a cautionary tale. Their goal was to note that human occupation has an effect on the spatial distribution of artifacts, but the nature of this effect was not addressed. The paper by Gifford-Gonzalez et al. (1985) controlled very few critical factors and attempted to address far too many variables. As a result, they could draw no positive conclusions.

While progress has been made on examining trampling as a taphonomic process, particularly how it affects bone, discerning the effects on context has been much more limited. This may be more a function of the method than any unaddressability of the problem itself. In this study, the variables comprising human foot traffic are accounted for and defined.

CHAPTER V

METHODS

> Practical people often balk at this approach since the idealized situation may be so far removed from those of use as to appear highly academic.
> -E. Bright Wilson Jr. (An Introduction to Scientific Research, 1952)

The way in which an artifact responds to trampling is dependent on a variety of factors. Some of these components influence an artifact's movement more than others, but together they determine the direction and distance moved.

To provide an empirical basis for the study of trampling, an experiment was conducted. The primary goal of this experiment was to examine the effects of some of the individual components of trampling. Various control factors were identified and either held constant, measured, or randomized, depending on the nature of the variable. This allowed for the effects of three variables to be separated out and studied. These were set up on a factorial design to study the effects of their different states on artifact movement. By reducing trampling to human feet, surface artifacts and the sediment, the nature of occupational disturbance could be examined as a physical property.

This experiment was designed to reduce the dimensions of movement and thereby the range of artifact response. Trampling was simplified by restricting its vertical component as much as possible. Therefore, as the control variables were fixed, they were set to optimize lateral displacement and minimize vertical displacement. This strategy gauged the influence of the study variables under extreme conditions.

Resilient, uniform ceramic tiles were laid out on a hard, compact, dry sediment in a 5 m grid at known locations. The area was then subjected to human foot traffic for a brief period. Cartesian coordinates were then recorded for each item yielding beginning and ending points for each tile.

Controls

As many factors as possible were controlled so that the effects of the analysis variables could be observed. These factors are forces that physical properties and prior investigations indicate may control an artifact's response when exposed to trample stress. These forces can be broadly classified as environmental conditions, surface conditions, artifact conditions, and trampler conditions. These were held constant when possible and measured when not.

Environmental Conditions. Environmental conditions define the surroundings within which an artifact and its matrix exist. Many such as wind, cloud cover, etc. have little impact on the current study. Environmental conditions that may have a potential influence are ambient temperature and rain.

Temperature: In the current study, temperature is only an influencing factor at or below the freezing point of water. Frozen moisture in a soil will change its nature, making it more resistant to penetration by artifacts. Materials may also become "glued" to the surface if ice is present in sufficient quantities. Artifact movement is facilitated by processes at around this temperature range such as the freeze/thaw cycle and ice needles. Since these experiments were conducted in early July, these processes did not present a problem.

Precipitation: As the test plots utilized were in an open, unenclosed space, it was not possible to effectively control for rain. Of the two potential methods of preventing rain from impacting the site, suspended tarps or polyethylene sheets over the surface, the first was beyond the means of this experiment and the second would have accentuated any sheet wash. However, the potential for rainfall influence was considered minor as these experiments were conducted during a summer drought. Unfortunately rain did occur during the course of the experiment. Between bouts one and two, 3 mm of rain fell on the test plots. Immediately afterwards, several units were arbitrarily selected and compared to their map plots. Based on these comparisons, no noticeable movement of artifacts was detected. Therefore, if any artifact motion occurred, it was beyond the level of measurement.

Surface Conditions. Surface conditions specify the surroundings in which an artifact is situated. These surroundings are probably the most influential in determining an artifact's potential for movement. Surface conditions delineate the directions available for artifact movement when exposed to a motive force.

Slope: The greater the degree of slope present on the surface, the less impelling force necessary to set an artifact in motion. As the slope increases, distance of displacement increases as well. In order to minimize the impact of this variable, test plots were chosen that exhibited slope that was as close as possible to 0%. The test plots had to be within easy access of Knoxville, and an area with no slope was difficult to locate in mountainous East Tennessee. The area chosen, made available by Dr. John Hodges of the University of Tennessee Agriculture Experiment Station, was on the crest of an upper terrace of the Tennessee River, directly downstream from the confluence of the Tennessee and Holston rivers. Elevations were taken at each of the spatial control pins to document topographic relief within each of the test plots (Figure 1). The test plots exhibited maximum slopes of 3.7% in grid 1, 3.4% in grid 2, 2.5% in grid 3, and 2.7% in grid 4. Microtopography was minimized by raking the ground surface with garden rakes to remove rocks and detritus greater than 2.5 cm in diameter. This also had the effect of smoothing small variations in elevation.

Soil composition: Soil composition influences the vector of movement available to an artifact under physical stress. The artifact's response is a function of the resistance it meets from the substrate upon which it rests. On one extreme, force applied to an artifact resting on a loose, sandy substrate will tend to become displaced vertically. Its potential for horizontal movement is reduced. On the other extreme, force applied to an artifact resting on a compact, clayey surface is more likely to become laterally displaced. One essential difference is that if the impact across an area is equal and that an artifact remains within that area, then an artifact's potential for vertical movement remains constant. This is true regardless of however much horizontal displacement may occur. Whereas when an artifact is vertically displaced, its potential for lateral movement diminishes with depth.

Between these two extremes of loose, sandy and compact, clayey substrate is a vast continuum of soil types and densities. For the purposes of this experiment it was desirable to optimize horizontal displacement. Therefore, the site chosen had the highest clay content available (Table 2); the experiments were performed on a Wolfever silt clay loam, which is a well drained soil overlying terrace remnants along the Tennessee, Holston and French Broad rivers (Roberts et al. 1955).

(a)

(b)

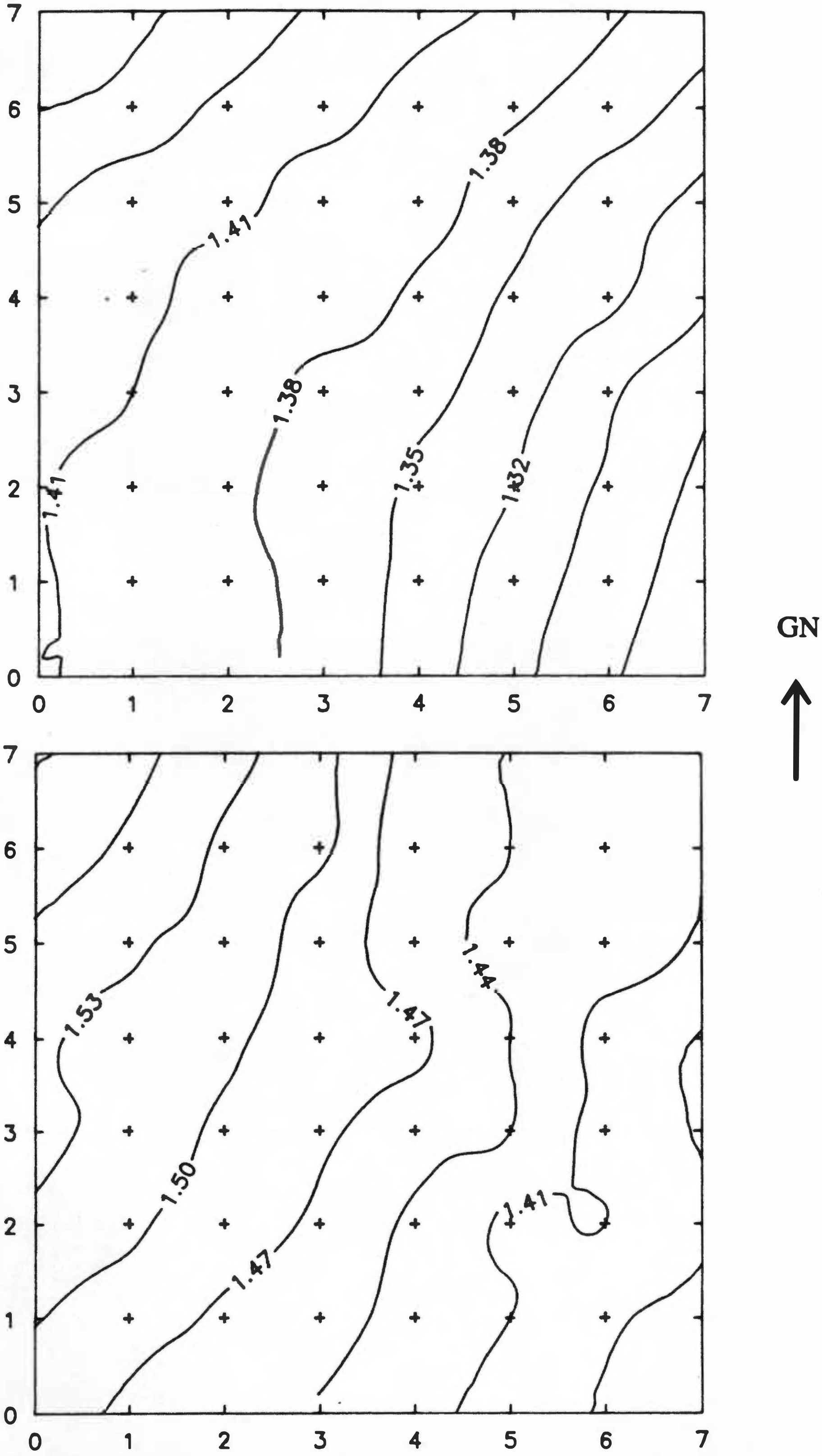


Figure 1. Contour maps for grids 1 (a), 2 (b), 3 (c) and 4 (d). Scale is in meters, elevations are relative with contours at 0.03 m intervals.

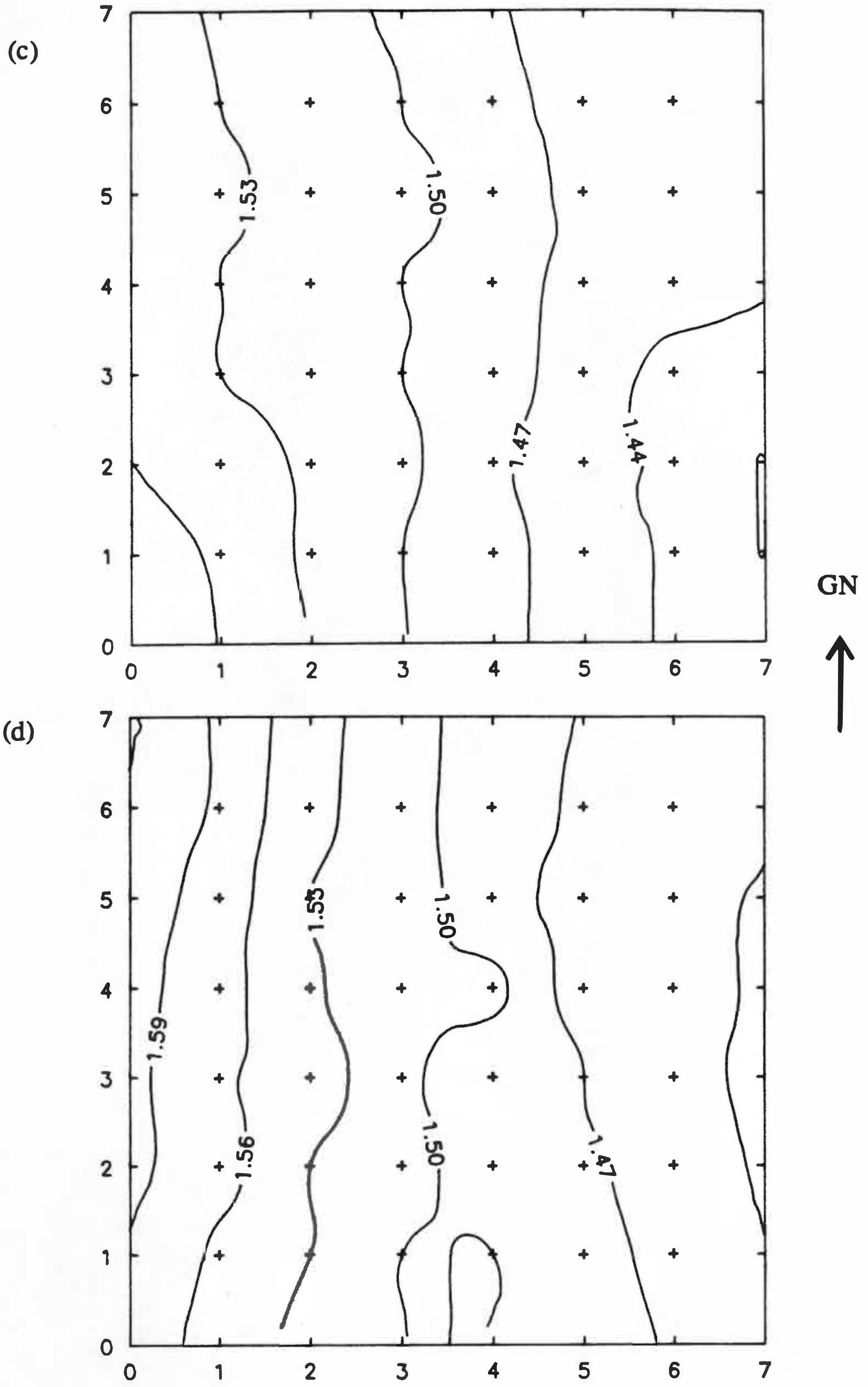


Figure 1 (continued)

Table 2. Soil characteristics.

Sample	Sand	Silt	Clay	Moisture
Grid 1	39%	29%	32%	6.47%
Grid 2	33%	30%	37%	5.95%
Grid 3	38%	25%	37%	6.32%
Grid 4	37%	27%	36%	5.16%
Total	37%	28%	36%	5.98%

Soil structure: The effect of soil structure on artifact movement is unknown. However, this variable was controlled by plowing, disking, and raking the surface. This granulated the surface leaving a homogeneous structure.

Vegetation: Ground cover can act on artifacts the same way that it acts on soils; to hold them in place. As the density of vegetation goes up, the ability for an artifact to move vertically or horizontally, diminishes. Vegetation was controlled for in this case by removing it. All extant plant materials were sprayed with a non-specific herbicide and plowed under in the first stage of ground preparation.

Bulk density: A soil's bulk density is a measure of compaction. It is measured in grams per cubic centimeter. Compaction determines an artifact's ability to penetrate the ground. The amount of soil compaction was increased by applying a push-type lawn roller across the surface. This substantially reduced the quantity of air remaining in the upper few centimeters after raking, and further reduced micro-topographic relief.. Once the ground surface had been prepared, approximately 10 mm of rain fell on the site, which resulted in further compaction after drying. A series of 10 cm x 10 cm x 10 cm sediment samples were recovered at the completion of the experiment. These yielded a final bulk density of 1.6 gm/cm^3 for the four test plots.

Moisture content: The amount of moisture contained within a soil is likely to become a factor only when it affects the behavior of the soil. As this is a factor impossible to control, it was checked during the course of the experiment by collecting soil samples. It is presumed that once the surface dries out, the moisture content in the upper few centimeters remains relatively stable, particularly during the brief course of these experiments. The surface was allowed to stand for three days after precipitation to allow it to stabilize.

Artifact Conditions. Artifact conditions define the make-up or physical conditions of cultural by-products. These are a suite of parameters that influence how the artifact itself will respond to trampling stress. The uniformity of artifacts was controlled by using ceramic tiles. This held all of the artifacts' physical characteristics constant. The range of variation within these parameters was very limited.

Mass: The higher an artifact's mass, the greater its inertia. According to Newton's second law of motion (expressed as force = mass x acceleration), as an object's mass increases, so does the force required to set it into motion. The tile mass within each size grade was as constant as possible within the factor's tolerances (Table 3).

Density: In artifact movement, density of the item plays a role as it is correlated with surface area and mass. An artifact with a higher specific gravity will have a higher mass per unit volume than one with a lower density. If two objects have different densities, the amount of surface area expressed on both will be

Table 3. Tile characteristics.

Dimension	Size	Descriptive Statistics								
		N	Mean	Std. Dev.	Maximum	Minimum	Median	Interq.	Normal	p> W
Length (cm)	2.5 cm	12	2.36	0.02	2.38	2.33	2.36	0.02	0.97	0.86
Width (cm)	2.5 cm	12	2.35	0.02	2.38	2.32	2.35	0.03	0.97	0.85
Thickness (cm)	2.5 cm	12	0.61	0.01	0.62	0.60	0.61	0.01	0.87	0.07
Area (cm^3)	2.5 cm	12	5.53	0.08	5.66	5.41	5.54	0.10	0.97	0.84
Volume (cm^2)	2.5 cm	12	3.38	0.08	3.51	3.24	3.38	0.10	0.94	0.15
Sp. Gravity	2.5 cm	12	1.68	0.02	1.72	1.66	1.67	0.02	0.86	0.29
Weight (gm)	2.5 cm	12	7.69	0.20	7.95	7.25	7.75	0.25	0.91	0.05
Length (cm)	4.0 cm	12	4.06	0.04	4.10	4.00	4.08	0.07	0.81	0.01
Width (cm)	4.0 cm	12	4.05	0.04	4.09	3.99	4.07	0.08	0.82	0.02
Thickness (cm)	4.0 cm	12	0.62	0.01	0.66	0.61	0.63	0.01	0.89	0.13
Area (cm^2)	4.0 cm	12	16.47	0.32	16.75	15.94	16.59	0.62	0.81	0.01
Volume (cm^3)	4.0 cm	12	10.29	0.36	10.97	9.77	10.30	0.60	0.97	0.80
Sp. Gravity	4.0 cm	12	1.70	0.02	1.77	1.68	1.70	0.01	0.65	0.44
Weight (gm)	4.0 cm	12	24.40	0.73	25.50	22.95	24.50	1.20	0.93	0.01
Length (cm)	5.0 cm	12	4.92	0.02	4.95	4.88	4.92	0.04	0.91	0.31
Width (cm)	5.0 cm	12	4.91	0.03	4.93	4.86	4.92	0.04	0.88	0.09
Thickness (cm)	5.0 cm	12	0.58	0.01	0.59	0.57	0.58	0.01	0.93	0.43
Area (cm^2)	5.0 cm	12	24.13	0.24	24.40	23.72	24.22	0.42	0.90	0.20
Volume (cm^3)	5.0 cm	12	13.93	0.29	14.38	13.40	13.94	0.32	0.94	0.46
Sp. Gravity	5.0 cm	12	1.73	0.02	1.77	1.72	1.72	0.00	0.57	0.50
Weight (gm)	5.0 cm	12	31.88	0.66	32.85	30.70	31.88	0.75	0.94	0.01

Note: Standard deviation is Std. Dev. and the interquartile range is Interq.

different. The density of the test materials, as measured by specific gravity, was relatively uniform within each size grade (Table 3).

Shape: The shape of an artifact can strongly influence the behavior of an artifact exposed to trample stress. Once in motion, one would expect spherical objects to move further than cubic ones, and round objects to move further than rectangular ones. Objects offering a low profile offer less area for lateral displacement than high profile objects. More angular objects have a greater probability of penetrating the substrate, thereby resisting lateral displacement. For this experiment, the shape of all the materials was identical (square), and within each size grade, the vertical and horizontal areas were uniform (Table 3).

Size: It has been recognized that size affects an artifact's recovery (Baker 1978; House and Schiffer 1975; Schiffer 1987) and the probability that it will be recycled or secondarily deposited (Schiffer 1976, 1987). It has also been asserted that size will affect an individual artifact's likelihood and degree of displacement when trampled (Gifford 1977; Gifford and Behrensmeyer 1977; Stockton 1973). In this experiment size was controlled. However, some range of variation may be expected in even the most uniform of mass produced artifacts, although, this variation exhibits a very small range (Table 3). To test differential intensity of trampling as a function of size, three material sizes were chosen; 2.5 cm, 4.0 cm and 5.0 cm.

Texture: One would expect the exterior texture of an artifact to influence its probability of being displaced in that a rough surface has a higher coefficient of friction than a smooth one. A rough surface will offer a greater amount of friction with whatever surface it contacts (in this case, the footgear of the trampler). Texture is a difficult characteristic to quantify, but the tiles exhibited a surface similar to 400 grit sandpaper. The only variant was size grade 1 which was slightly smoother. All tiles were non-glazed.

Fragility: The brittleness of an artifact influences indirectly its ability to become dislocated. On one extreme, a highly fragile artifact, when exposed to trample stress, will fragment rather than move. On the other extreme, a highly durable object will endure substantial quantities of stress and still retain its basic characteristics. For the purposes of this experiment, highly durable artifacts were chosen. If the character (e.g. size or shape) altered during the course of the test, the experimental conditions would thereby change with time. While some minor chippage of the tiles did occur during the experiment, only one break occurred. That tile was replaced.

Trampler Conditions. Trampler conditions are those parameters that define the physical make-up of the humans walking across artifact deposits. These include not just their basic structure, but also their patterns of stride and footgear. As volunteers were used to trample the test materials, no attempt was made to hold the physical characteristics of the tramplers constant (Table 4). However, a variety of parameters were measured on each individual so that their range of variation could be documented. Each of these factors will be summarized and analyzed for within and between bout variability.

Footgear: The foot surface has the same effect as the texture of the artifact. The rougher the surface, the greater the coefficient of friction between the foot and the artifact. In this experiment, footgear was held constant by tying sheets of burlap to the soles of the trampler's shoes. The shoes, sneakers of various sorts, all had firm rubber soles. The burlap covering the foot surface was smoothed so that no

Table 4. Relevant parameters of the tramplers.

Trampler	Weight (kg)	Inseam (cm)	Stride (m)	Area (cm^3)
1	53.297	73.4	0.604	1441.44
2	80.059	83.0	0.782	3196.80
3	83.461	78.6	0.646	2020.26
4	64.977	78.6	0.572	1422.04
5	74.276	92.2	0.630	1903.56
6	61.802	75.0	0.574	1440.80
7	77.564	89.0	0.690	2467.87
8	113.852	83.0	0.816	3031.78
9	69.173	85.2	0.898	2338.56
10	67.132	83.0	0.790	1841.36
11	86.636	80.7	0.750	2336.63
12	45.813	76.4	0.604	1509.58
13	56.245	82.0	0.560	1133.57
14	75.750	72.4	0.630	1420.02
15	53.184	97.4	0.736	1684.02
16	66.111	94.0	0.764	1967.56
17	60.668	78.9	0.702	1378.53
18	100.811	83.2	0.650	2695.68
19	58.060	80.0	0.560	949.81
20	85.502	91.4	0.644	2903.04
21	59.534	78.8	0.706	1234.94
22	63.503	82.5	0.770	2349.91
23	57.720	71.2	0.522	1301.83
24	51.709	80.8	0.588	1454.36

folds would interfere with its surface. This was more analogous to aboriginal conditions as burlap may interact with surface materials in approximately the same way as a textile covering of cloth or plant fiber. The actual material is not as important as it being held constant throughout the experiment.

Foot area: The size of a foot functions in direct correlation with the amount of area available to strike an artifact during walking. Larger feet have more area, and thus a higher probability of trampling during a single stride. Measurements were made of the total length of the foot, width across the ball of the foot, and width across the heel. These were used to calculate foot area (Table 5). Area was approximated by using the formula for calculating the area of a trapezoid. Length was multiplied by half of the sum of the two widths. Since it was felt this would be an overapproximation, this product was multiplied by a constant (0.9).

Stride length: The length of stride seems to be a highly variable factor. Over any given distance, an individual with a shorter stride will have a higher frequency of striking the ground than one with a longer stride. This would increase the materials on the surface exposure to trample stress. Stride length was gauged by averaging the distance covered in five steps (Table 5).

Leg length: The length of an individual's leg is a factor in determining the range of strides available. A longer leg does not necessitate a longer stride, although it permits a greater range than a shorter length. Leg length was determined by measuring the distance from the base of the pelvis to the base of the foot (Table 5).

Weight: The weight of an individual determines the amount of force available during a given footfall. This primarily affects the intensity of the vertical vector. This dimension was reduced as much as possible in this experiment, so the

Table 5. Descriptions of trampler characteristics by experiment.

			Descriptive Statistics							
Variable	Grid	Time	Count	Mean	Std. Dev.	Maximum	Median	Interq.	Norm	p> W
Area (cm^3)	1	1	4	1859.60	800.08	2695.68	1896.46	1530.46	0.95	0.59
Area (cm^3)	1	2	4	1849.95	611.96	2695.68	1662.80	1108.24	0.87	0.31
Area (cm^3)	1	3	4	1830.27	632.95	2695.68	1661.79	1166.27	0.90	0.40
Area (cm^3)	1	4	4	1870.43	391.20	2336.63	1852.14	755.93	0.98	0.87
Area (cm^3)	1		16	1852.56	560.26	2695.68	1793.79	917.55	0.91	0.16
Area (cm^3)	2	1	4	1859.60	800.08	2695.68	1896.46	1530.46	0.95	0.59
Area (cm^3)	2	2	4	1849.95	611.96	2695.68	1662.80	1108.24	0.87	0.31
Area (cm^3)	2	3	4	1830.27	632.95	2695.68	1661.79	1166.27	0.90	0.40
Area (cm^3)	2	4	4	1870.43	391.20	2336.63	1852.14	755.93	0.98	0.87
Area (cm^3)	2		16	1852.56	560.26	2695.68	1793.79	917.55	0.91	0.16
Area (cm^3)	3	1	4	2197.58	663.45	3031.78	2152.09	1275.33	0.99	0.97
Area (cm^3)	3	2	4	1747.45	452.80	2349.91	1630.69	833.87	0.89	0.36
Area (cm^3)	3	3	4	2293.79	608.08	2903.04	2408.89	1116.00	0.93	0.48
Area (cm^3)	3	4	4	2279.57	804.31	3196.80	2343.27	1474.71	0.94	0.54
Area (cm^3)	3		16	2129.60	621.08	3196.80	2336.63	984.03	0.92	0.24
Area (cm^3)	4	1	4	1747.45	452.80	2349.91	1630.69	833.87	0.89	0.36
Area (cm^3)	4	2	4	2293.79	608.08	2903.04	2408.89	1116.00	0.93	0.48
Area (cm^3)	4	3	4	2279.57	804.31	3196.80	2343.27	1474.71	0.94	0.54
Area (cm^3)	4	4	4	1513.04	344.35	1967.56	1475.51	642.53	0.96	0.70
Area (cm^3)	4		16	1958.46	624.76	3196.80	1904.46	924.54	0.92	0.22
Area (cm^3)			64	1948.30	589.30	3196.80	1903.56	927.88	0.19	0.01#
Inseam (cm)	1	1	4	82.30	2.36	85.20	82.00	4.50	0.94	0.56
Inseam (cm)	1	2	4	83.23	6.34	92.20	81.05	11.27	0.84	0.23
Inseam (cm)	1	3	4	79.75	9.90	92.20	77.80	18.45	0.90	0.39
Inseam (cm)	1	4	4	82.93	9.93	97.40	79.65	17.33	0.84	0.23
Inseam (cm)	1		16	82.05	7.11	97.40	80.75	6.10	0.94	0.39
Inseam (cm)	2	1	4	82.30	2.36	85.20	82.00	4.50	0.94	0.56
Inseam (cm)	2	2	4	83.23	6.34	92.20	81.05	11.27	0.84	0.23
Inseam (cm)	2	3	4	79.75	9.90	92.20	77.80	18.45	0.90	0.39
Inseam (cm)	2	4	4	82.93	9.93	97.40	79.65	17.33	0.84	0.23
Inseam (cm)	2		16	82.05	7.11	97.40	80.75	6.10	0.94	0.39

Table 5 (continued)

Variable	Grid	Time	Count	Mean	Std. Dev.	Maximum	Median	Interq.	Norm	p> W
			Descriptive Statistics							
Inseam (cm)	3	1	4	84.63	6.34	94.00	81.90	10.53	0.75	0.05
Inseam (cm)	3	2	4	79.20	4.89	83.00	80.70	8.85	0.87	0.31
Inseam (cm)	3	3	4	85.93	5.08	91.40	85.75	9.57	0.91	0.42
Inseam (cm)	3	4	4	81.25	1.91	83.00	81.60	3.60	0.93	0.49
Inseam (cm)	3		16	82.75	5.13	94.00	82.50	2.30	0.89	0.05
Inseam (cm)	4	1	4	79.20	4.89	83.00	80.70	8.85	0.87	0.31
Inseam (cm)	4	2	4	85.93	5.08	91.40	85.75	9.57	0.91	0.42
Inseam (cm)	4	3	4	81.25	1.91	83.00	81.60	3.60	0.93	0.49
Inseam (cm)	4	4	4	81.45	9.09	94.00	79.20	16.85	0.92	0.45
Inseam (cm)	4		16	81.96	5.80	94.00	82.25	4.17	0.93	0.35
Inseam (cm)			64	82.20	6.20	97.40	81.40	4.37	0.22[#]	0.01
Stride (m)	1	1	4	0.67	0.15	0.90	0.62	0.27	0.83	0.2
Stride (m)	1	2	4	0.64	0.05	0.70	0.64	0.10	0.99	0.95
Stride (m)	1	3	4	0.61	0.06	0.65	0.63	0.10	0.76	0.07
Stride (m)	1	4	4	0.68	0.08	0.75	0.69	0.15	0.91	0.43
Stride (m)	1		16	0.65	0.09	0.90	0.64	0.11	0.89	0.06
Stride (m)	2	1	4	0.67	0.15	0.90	0.62	0.27	0.83	0.2
Stride (m)	2	2	4	0.64	0.05	0.70	0.64	0.10	0.99	0.95
Stride (m)	2	3	4	0.61	0.06	0.65	0.63	0.10	0.76	0.07
Stride (m)	2	4	4	0.68	0.08	0.75	0.69	0.15	0.91	0.47
Stride (m)	2		16	0.65	0.09	0.90	0.64	0.11	0.89	0.06
Stride (m)	3	1	4	0.73	0.10	0.82	0.76	0.17	0.87	0.31
Stride (m)	3	2	4	0.72	0.07	0.79	0.74	0.14	0.93	0.49
Stride (m)	3	3	4	0.67	0.08	0.77	0.67	0.15	0.99	0.95
Stride (m)	3	4	4	0.75	0.03	0.78	0.76	0.06	0.92	0.47
Stride (m)	3		16	0.72	0.07	0.82	0.75	0.11	0.89	0.07
Stride (m)	4	1	4	0.72	0.07	0.79	0.74	0.14	0.93	0.49
Stride (m)	4	2	4	0.67	0.08	0.77	0.67	0.15	0.99	0.95
Stride (m)	4	3	4	0.75	0.03	0.78	0.76	0.06	0.92	0.47
Stride (m)	4	4	4	0.63	0.09	0.76	0.60	0.15	0.81	0.16
Stride (m)	4		16	0.70	0.08	0.79	0.70	0.16	0.89	0.06
Stride (m)			64	0.68	0.09	0.90	0.65	0.14	0.16[#]	0.01

Table 5 (continued)

				Descriptive Statistics						
Variable	Grid	Time	Count	Mean	Std. Dev.	Maximum	Median	Interq.	Norm	p> W
Weight (kg)	1	1	4	69.94	21.81	100.81	63.62	39.60	0.89	0.37
Weight (kg)	1	2	4	75.18	18.00	100.81	69.63	32.43	0.87	0.33
Weight (kg)	1	3	4	77.14	17.77	100.81	75.01	32.69	0.94	0.55
Weight (kg)	1	4	4	71.27	16.35	86.64	72.63	30.50	0.88	0.36
Weight (kg)	1		16	73.38	16.90	100.81	71.72	27.13	0.90	0.10
Weight (kg)		2 1	4	69.94	21.81	100.81	63.62	39.60	0.89	0.37
Weight (kg)		2 2	4	75.18	18.00	100.81	69.63	32.43	0.87	0.33
Weight (kg)		2 3	4	77.14	17.77	100.81	75.01	32.69	0.94	0.55
Weight (kg)		2 4	4	71.27	16.35	86.64	72.63	30.50	0.88	0.36
Weight (kg)		2	16	73.38	16.90	100.81	71.72	27.13	0.90	0.10
Weight (kg)		3 1	4	79.58	26.97	113.85	76.37	51.74	0.98	0.81
Weight (kg)		3 2	4	66.76	6.55	75.75	65.32	12.22	0.94	0.51
Weight (kg)		3 3	4	69.57	14.98	85.50	70.53	28.86	0.97	0.78
Weight (kg)		3 4	4	72.43	12.99	86.64	71.78	24.47	0.91	0.42
Weight (kg)		3	16	72.09	16.03	113.85	66.62	22.76	0.91	0.11
Weight (kg)		4 1	4	66.76	6.55	75.75	65.32	12.22	0.94	0.51
Weight (kg)		4 2	4	69.57	14.98	85.50	70.53	28.86	0.97	0.78
Weight (kg)		4 3	4	72.43	12.99	86.64	71.78	24.47	0.91	0.42
Weight (kg)		4 4	4	55.37	8.40	66.11	54.77	15.96	0.99	0.89
Weight (kg)		4	16	66.03	12.09	86.64	63.50	20.04	0.96	0.58
Weight (kg)			64	71.22	15.54	113.85	66.62	22.79	0.14[#]	0.01

[#]Note: Used Kolomogorov D as a normal statistic instead of Shapiro-Wilk.

weight variable is not likely to be as influential as others. Nevertheless, mass was recorded for all of the tramplers for interbout comparisons (Table 5).

All of the individuals used in these experiments were Euro-americans, with the exception of one Turk and one Asiatic Indian. It is assumed that the elements of stride in this group will be roughly analogous to those of early Native Americans. However, ethnographic accounts suggest the possibility that Native Americans may have had a different pattern of stride than modern Euro-americans.

> The Cherokees have a peculiar walking gait consisting of short steps with the foot pointed straight forward and the back humped a little [Gilbert 1978:196, from 1934].

In contrast, others suggest that the stride of Native Americans was more or less comparable.

> [The Micmac] walk with dignity as if they had always some great affair to think upon, and to decide, in their minds [LeClercq 1910:240, from 1691].

For the purposes of this experiment, it is assumed that the pattern of stride between races is insignificant when compared to within racial variation.

To ascertain if trampler characteristics were significantly different between trials and times, an analysis of variance was performed on each of the trampler conditions presented above versus time and test plot. The analysis of variance indicated that there was no effect between different test plots and times. The individual trampler characteristics, separately (Table 6) and together (Table 7) were not significantly different from one another. This implies that individual bias was not a factor.

Table 6. ANOVA tables for trampler characteristics.

Source	df	Sum of Squares	Mean Square	F Value	p> F	R-square	Variable	df	Type III SS	F Value	p> F
Foot Area	15	3,462,220.793	230,814.720	.60	.859	.1582	Grid	3	820,861.804	.71	.5489
Error	48	18,416,201.843	383,670.872				Time	3	281,031.903	.24	.8651
Total	63	21,878,422.636					Grid*Time	9	2,360,327.086	.68	.7199
Leg Length	15	276.707	18.447	.41	.968	.1143	Grid	3	6.510	.05	.9856
Error	48	2,143.563	44.658				Time	3	12.419	.09	.9637
Total	63	2,420.270					Grid*Time	9	257.778	.64	.7561
Avg. Stride	15	.131	.009	1.20	.302	.2733	Grid	3	.059	2.70	.0562
Error	48	.348	.007				Time	3	.015		.5607
Total	63	.478					Grid*Time	9	.057		.5532
Weight	15	1,896.233	126.416	.46	.951	.1247	Grid	3	592.128	.71	.5497
Error	48	13,308.037	277.251				Time	3	346.455	.42	.7419
Total	63	15,204.270					Grid*Time	9	957.650	.38	.9372

Table 7. MANOVA to determine potential trampler bias.

	Wilks' Lambda	F Value	Num df	Den df	p> F
Grid	0.701961	1.423	12	119.35	0.1645
Time	0.856962	0.598	12	119.35	0.8406
Grid*Time	0.559489	0.793	36	170.37	0.7914

Analysis Variables

Two classes of pattern variables were designed for study. These were set up in factorial design so that the individual factors and their interactions could be analyzed. They will show how walking patterns and artifact distribution patterns will affect material displacement. A third analysis variable, artifact size, will be embedded within these.

The first analysis variable relates to how the artifacts are dispersed. In one state, the tiles were placed at intervals giving an even distribution across the site (Figure 2). This distribution pattern consisted of tiles placed every 20 cm. In the other state, areas of high and low density were created which simulated the types of dispersal which could be expected with activity areas (Figure 3). This clustered distribution consisted of 4 randomly selected 1 m x 1 m squares with tiles placed 10 cm apart, and the remainder at 30 cm apart. This gave a total of 676 tiles for the even distribution experiments, and 722 for the clustered distribution experiments.

The second analysis variable relates to types of disturbance. One form entailed a uniform trampling across the site so that the zone of disturbance intensity was roughly the same at all points. In this pattern the participants walked across the test plot in a row. After the first pass, they shifted 45 degrees and then walked in

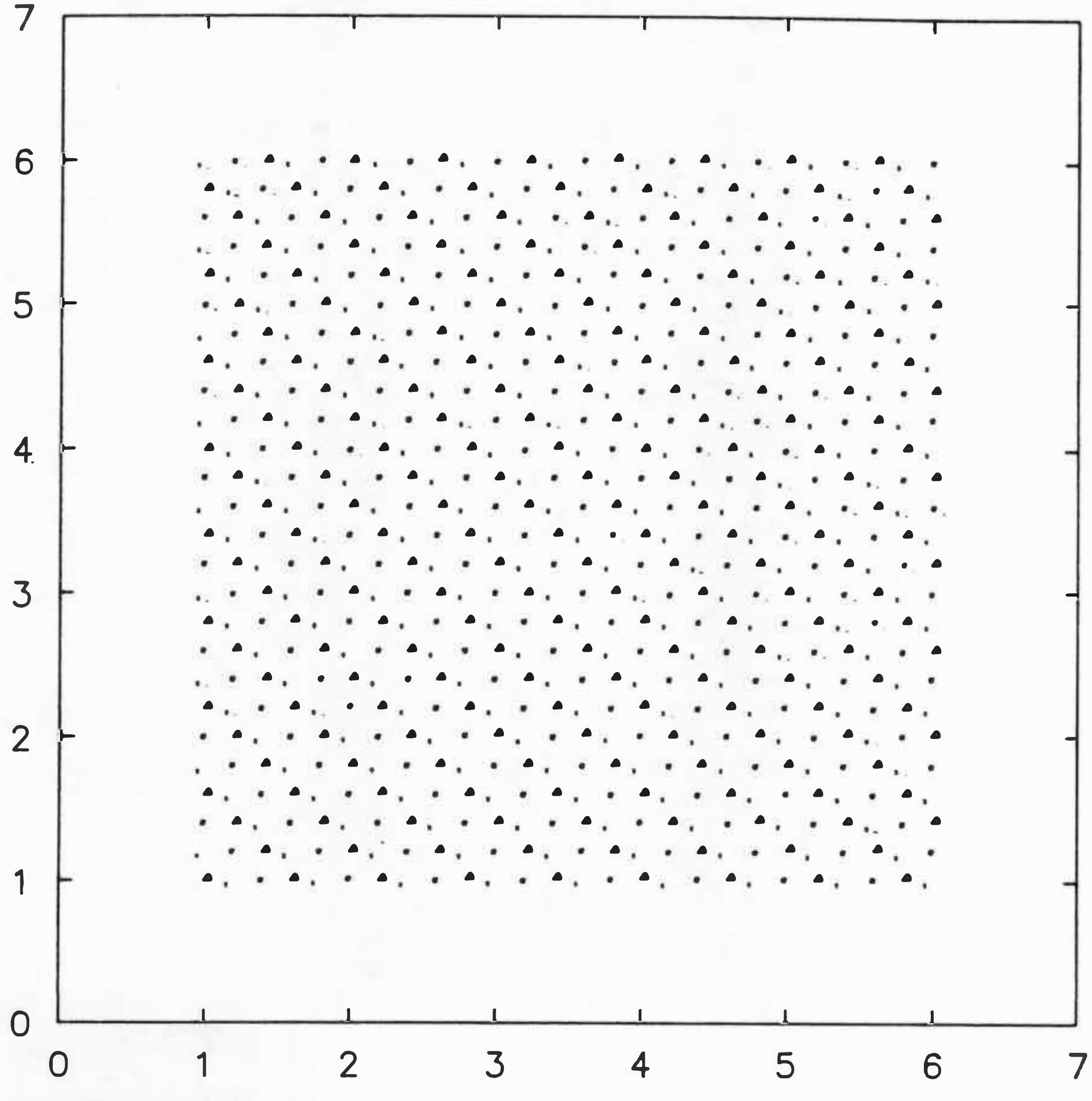


Figure 2. Even artifact distribution. Scale is in meters, tiles are spaced 20 cm apart. They alternate between sizes 2.5 cm (dots), 4.0 cm (squares) and 5.0 cm (triangles).

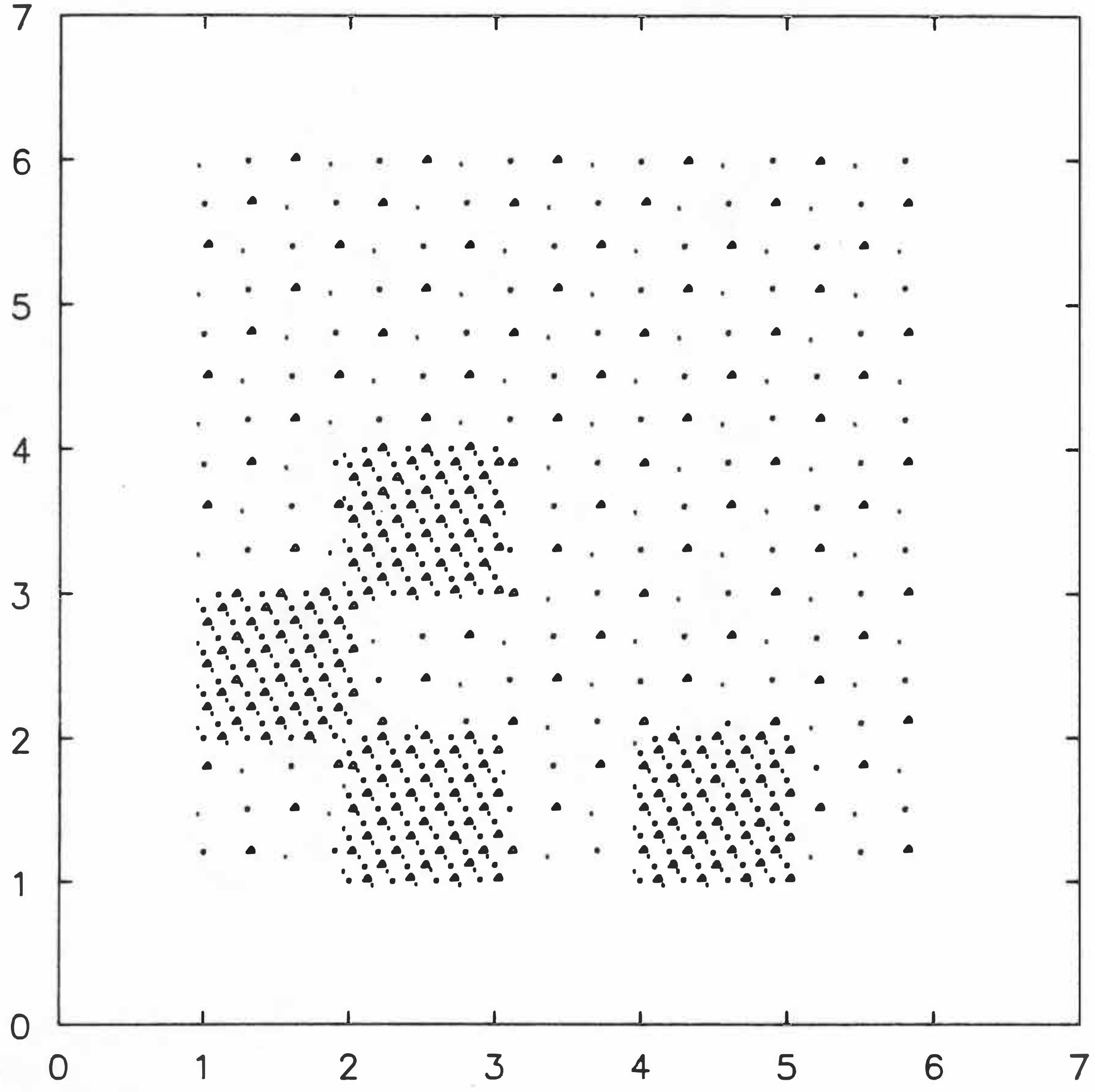


Figure 3. Clustered artifact distribution. Scale is in meters, tiles are spaced 10 cm and 30 cm apart. They alternate between sizes 2.5 cm (dots), 4.0 cm (squares) and 5.0 cm (triangles).

the opposite direction. This process was repeated for all of the cardinal directions and the diagonals. The second form of disturbance entailed a variable-intensity pattern. This pattern consists of the participants arbitrarily walking over the 35 m^2 area with no established movement pattern. This "non-pattern" subjected the sites to varying degrees of impact intensity. While this was not random, it was arbitrary.

A third analysis variable relates to material size. As artifact size increases, so does volume, area and weight (within a given material class). Three size grades of tiles were chosen based on tile availability. These were staggered, 2.5, 4, and 5 cm, the third twice as large as the first, and the second intermediate.

To exhaust all of the possible permutations of the spatial variables, four experiments were required (Table 8). The size factor was nested within these by including all sizes within each test. This allowed for two factors with two treatment levels, each containing the size factor with three treatment levels. This yields a 2 x 2 x 3 factorial design. A total of four trials for each experimental condition were performed.

Table 8. Possible permutations of the experimental variables.

	Artifact Distribution	
Trampling Pattern	Even	Clustered
Uniform	U/E	U/C
Variable	V/E	V/C

Execution

Once the ground surface had been prepared, four 7 x 7 m test plots were delineated. Within each of these, a 5 x 5 m grid was established by placing 19 cm spikes flush to the ground at 1 m intervals. Tiles were laid and mapped using a 1 x 1 m angle iron grid frame. This frame had color coded monofilament spaced at 10 cm intervals. The grid frame was marked so that it was always placed in the same orientation to the test plot. The minimum and maximum strings served as cross hairs to be placed over the four grid control pins.

Each tile was marked with an "X" denoting the exact center of the artifact. Above each center, a three digit artifact number was assigned. The numbers and centers were marked in waterproof ink on both sides and coated with a clear nail polish. This coating was intended to protect the markings, but it was applied conservatively to reduce its impact on the surface texture.

The tiles were placed by first orienting the grid frame, then placing the tile beneath its assigned cross hairs. The cross hairs were aligned with the center "X". This served not only to set the initial location of each tile, but also it assured that their beginning orientations were identical.

Each bout consisted of four walkers trampling a test plot for 30 minutes. After each bout, the grid frames were again oriented to the control points and maps were made of each meter square. The maps were coded in patterned lines similar to the set-up of the grid frames. Mapping consisted of looking straight down on the tile, and marking its location with an "X" on the map. The associated artifact number was also recorded (Figure 4). After mapping the plots were trampled again.

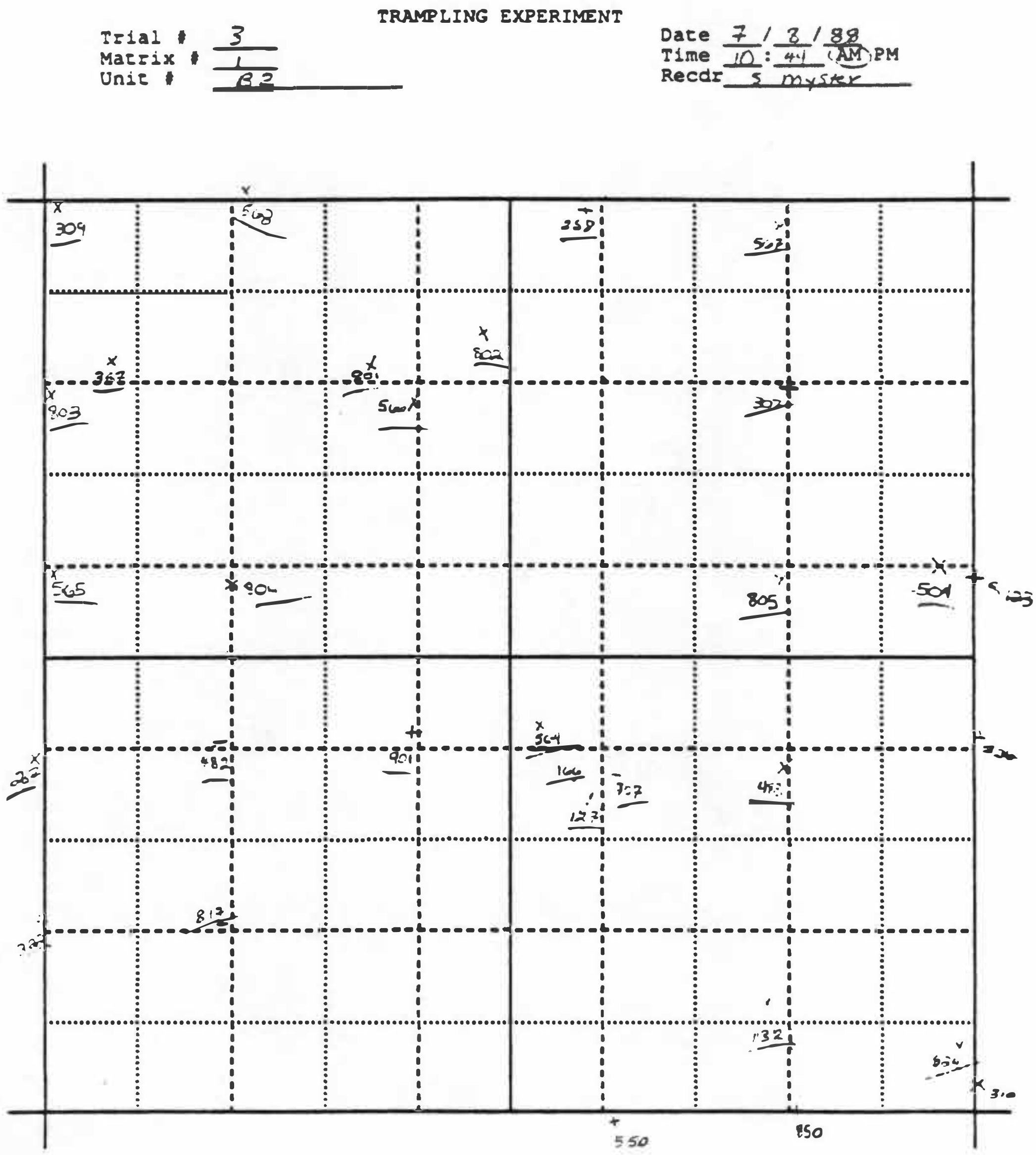


Figure 4. Sample recording map. Recording form mimics the 1 x 1 m grid frame by having lines every 10 cm. These are differentiated on the 50 cm line (solid), 0, 20, 40, 60, 80, and 100 cm lines (dashed), and 10, 30, 70 and 90 cm lines (dotted).

The tiles were not reset since this would obscure patterns which may have been developing.

The maps generated were checked for redundant information between adjacent plots and duplicate points were removed. An attempt was made to be conservative by assigning a point to the unit in which it occurred in the previous bout. These maps were then placed on a Tektronix 4954 digitizing tablet and linked to a Fortran data entry program using Terminal Control Language (TCS) subroutines. This program (written by the author) "tagged" the map to the tablet, then allowed for entry of an artifact number followed by digitizing its associated point. The program calculated the real coordinates of the test plot, and recorded this information plus the grid, bout and unit numbers.

Error introduced by the digitizing process was measured using maps which recorded tile locations before the first trampling episode. Each initial tile coordinate, as digitized, was compared to what it should have been; that is, it's assigned location. These were subtracted from one another for a difference and descriptive statistics were generated (Table 9). If no digitizing error occurred, the differences would equal zero. For the horizontal measure, the vast majority of errors were zero (2,260). Those that were not zero were either 0.95 cm to the west (259) or 0.95 cm to the east (277). The majority of vertical errors were also zero (2,725). Those that were not zero were either 0.90 cm to the north (51) or 0.90 cm to the south (19) with a single value at 1.90 cm. This discrete distribution is produced by the nature of the digitizing tablet itself. The tablet is divided into a series of pixels (4,096 x 3,120). The errors represented give the level of resolution of the tablet.

Table 9. Measurement of digitizing tablet error.

	Descriptive Statistics								
Dimension	Count	Mean	Std. Dev.	Maximum	Minimum	Median	Interq.	Normal(D)	p> D
Horizontal	2796	-0.0001	0.0044	0.0100	-0.0100	0.0000	0.0000	0.4068	0.01
Vertical	2796	0.0001	0.0016	0.0200	-0.0100	0.0000	0.0000	0.5113	0.01

After entry the artifact numbers were checked for recording errors by sorting them, and since they were numbered consecutively, looking for skipped and duplicate numbers. Once these were filtered out, the data sets were reoriented so that each artifact number was followed by its coordinates for each bout. This allowed for a check of possible mapping errors. As the maps and grid frames were scaled to a 10 cm interval, it is possible that a mapper could have shifted an artifact by that amount when transcribing it onto paper. To check for potentially mis-mapped artifacts, each point was checked against its coordinate two bouts later to see if they were similar. If so, it was checked against the coordinates of the subsequent bout. If the middle bout was 10 cm shifted, it was suspected that this point had been mis-mapped. Only 63 out of 11,184 movements met these criteria. These points were corrected only if it was determined with a reasonable degree of certainty that they had not moved because of trampling. Obviously, this procedure would only catch mis-mapped artifacts that were stationary over three bouts. Artifacts mis-mapped during the last bout would not be identified by this procedure as there is nothing with which to compare them. These comparison checks can find many of the incorrectly mapped and numbered tiles, but they can not locate all of them. It is assumed that whatever mapping errors remain are outweighed by the substantial number of correct observations.

In the course of mapping tile locations, numerous tiles were noted as remaining stationary. To measure the error introduced by the instrument (the entire recording sequence) a comparison was made between the various trials of these tiles. This procedure measures error introduced by the grid frames, control points, maps, observers, digitizing, and any other unknown variables. No error would be represented by zero movement between trials. There were 387 measures among 167 tiles that had been noted to be stationary. These were divided by test plot and combined (Table 10). These indicate that, overall, all measurements should cluster around ±3.6 cm of its actual value. This is slightly better on some plots (grid 3 at ±0.7 cm) and worse on others (grid 4 at ±5.9 cm).

Table 10. Measurement of experimental error.

	Descriptive Statistics							
Grid	Count	Mean	Std. Dev.	Maximum	Median	Interq.	Normal(D)	p> D
1	18	0.02	0.01	0.03	0.01	0.01	0.87[a]	0.02
2	183	0.02	0.04	0.35	0.01	0.01	0.38	0.01
3	126	0.01	0.01	0.02	0.01	0.01	0.24	0.01
4	60	0.03	0.06	0.47	0.01	0.02	0.37	0.01
All	387	0.02	0.04	0.47	0.01	0.01	0.35	0.01

[a]Note: Used Shapiro-Wilk as a normal statistic instead of Kolomogorov D.

Analysis

In order to present the results of this experiment, descriptive statistics will be generated for each of the variables of interest (size grade, distribution, and trample pattern). In addition, heuristic graphs of movements for each test plot will be generated. Comparisons will be made to investigate within and between group variation. This will be used to quantify the range of variation within the tests (as a control) and between test conditions (to determine their effects).

Within and between group variation was investigated using Analysis of Variance (ANOVA). This generated an adequate quantitative expression of the model.

Summary

The relevant components of human occupational disturbance have been stipulated and controlled by either measuring, holding constant or randomizing them. Three variables of interest were set up in a 2 x 2 x 3 factorial design to examine their effects and interactions. An experiment was then conducted which created a data set of Cartesian coordinates over a series of trampling bouts. This data set provides a basis for an empirical assessment of the effects of human foot traffic on surface materials.

The results of these experiments have been described by tabulating and creating heuristic displays. This gives a sense of the scale of displacement involved and the characteristics of a trampled assemblage. The different factors held for analysis will be quantified.

CHAPTER VI

ANALYSIS

> . . . one should avoid statistics whenever possible, abolish superfluous rituals and routines, and get on with the business of science.
> -Robert C. Bolles (Why You Should Avoid Statistics 1988)

The experiment conducted provided a measure of artifact movements due to trampling. Any differential activity between treatment levels was a function of the analysis variables. Once the effects of these variables were characterized, generalizations from the results were derived.

Expectations

A series of expectations were generated based on prior knowledge of how artifacts respond when trampled and the statistical and physical nature of surface artifacts exposed to foot traffic.

Differential Movement. On a given pass, in a trampled assemblage each artifact has a certain probability of being kicked. If the distribution starts with no displacement, it becomes skewed to the right (into the higher movement classes) as artifacts are trampled. The speed of this migration is a function of impact intensity.

Size Effect. As artifact area and volume decrease, the probability of coming into contact with human feet diminishes. Therefore, one might expect smaller materials to be less inclined to move than large ones. They have less surface area, and are therefore less likely to be struck. However, once impacted, they may be more prone to move farther due to a lower mass. Less of an impelling force is required to set them into motion and they will travel farther with the same amount of force. This is expressed in an algebraic conversion of Newton's second law of motion:

$$f/m = a$$

Where (f) is force, (m) is mass and (a) is acceleration. Acceleration, and thus distance traveled, is directly related with the force of impact, and inversely related to the artifact's mass.

Differential Impact Intensity. The response of a surface artifact will depend on the pattern of traffic across the surface. Restricted paths or patterns of walking will cover an area uniformly, giving all artifacts (of a given size) equal probabilities of being struck.

A non-restricted walking pattern over a surface, as is possible in an open area, will impact areas differentially due to simple random chance. Some areas will receive more trampling than others and thus have a greater potential for artifact movement.

Description

A subjective assessment of trampling effects is useful in gaining a "feel" for the basic impacts and characteristics of a trampled assemblage. These data can be described in a variety of ways.

A frequency bar chart displayed the overall shape of the distribution by size grade. This was useful for exhibiting the basic pattern of artifact movement. Frequency tables, while not as visually oriented, did show a more refined breakdown along all treatment levels. These frequencies were quantified by generating descriptive statistics and measures of central tendency. Displacement patterns were visualized by generating scatterplots for each grid for each bout.

For display purposes, movements were summarized by calculating a standardized score. This Z-score was based on the mean and standard deviation by treatment level (grid and size). Each grid was divided into 50 cm x 50 cm units and the median score was obtained. The surfaces generated for each plot were scaled to one another so that a feature on one plot represents the same movement as a similar feature of the same size on another plot. A peak represents a greater average amount of relative displacement per unit area.

Size Grade. Overall, the majority of tiles had limited motion, while a few shifted a substantial distance. This produced a standard logarithmic distribution of movement (Figure 5a includes zero movements and Figure 5b clarifies the other classes by excluding zero). This is a spread heavily weighted toward little or no movement. Frequencies rapidly decrease with larger displacements. Slightly more artifacts show up in the zero movement category as size decreases.

Total displacement over four trials yielded 11,038 tiles that moved less than 0 cm to 10 cm, and 1,888 that moved more than 10 cm (Table 11). Most of these movements were less than 1 meter while one tile moved 6.25 m (size 1 in grid 4). The size trend is only apparent here in that the smaller size grade has higher frequencies in the no movement category.

However, the means and medians for the overall population increase by size grade (Table 12). As size increases, so does the average movement. The spread of the distribution, as expressed by the interquartile range also increases. The

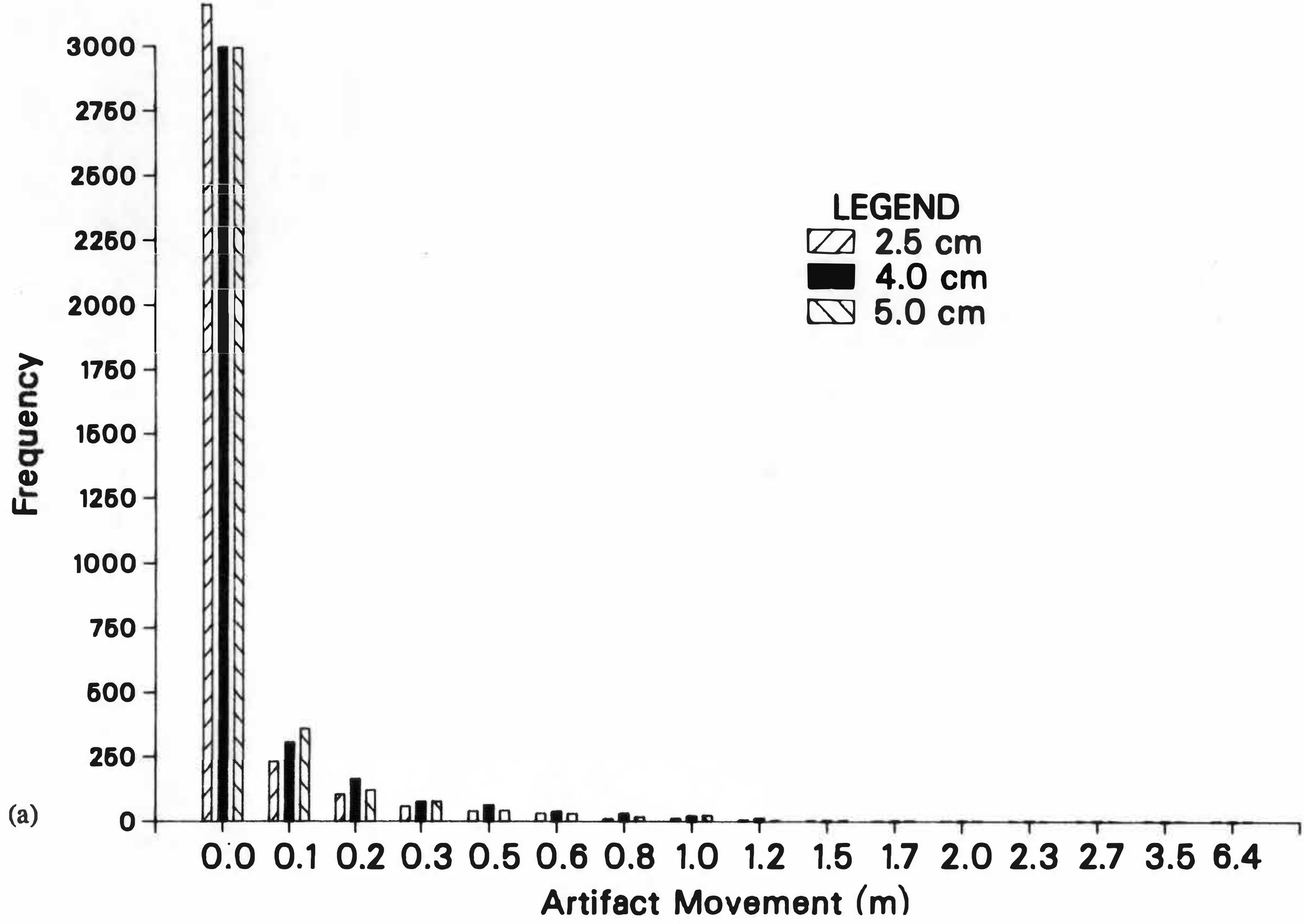


Figure 5. Distribution of tiles by size grade (a) and by size grade without zero (b).

(b)

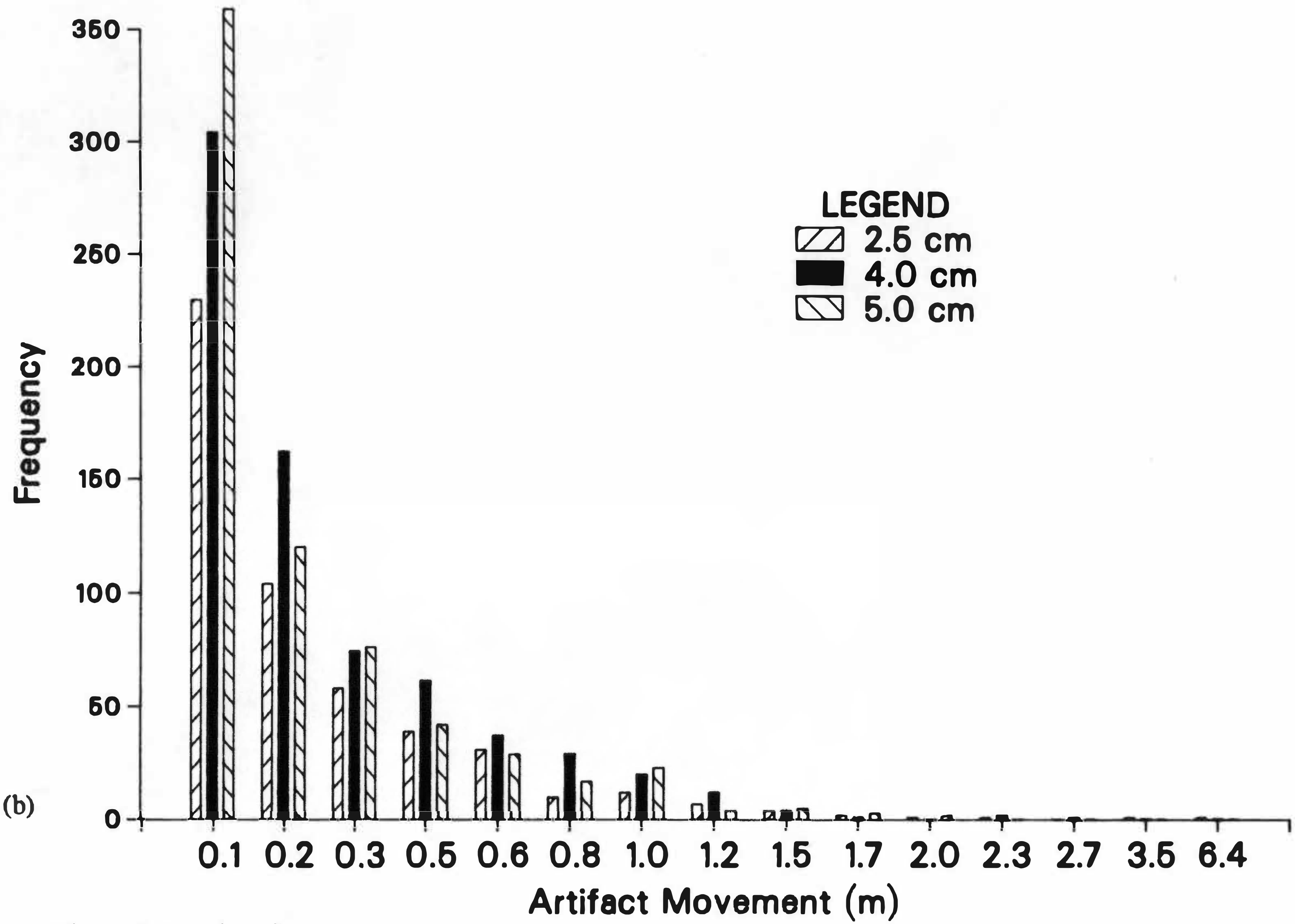


Figure 5 (continued)

Table 11. Cell frequencies of lateral displacement by Size grade.

	Log Displacement (m)																
Size	0	0.1	0.2	0.3	0.5	0.6	0.8	1	1.2	1.5	1.7	2	2.3	2.7	3.5	6.4	Total
2.5 cm	3163	230	104	58	39	31	10	12	7	4	2	1	1	0	1	1	3664
4.0 cm	2994	304	162	74	61	37	29	20	12	4	1	0	2	1	0	0	3701
5.0 cm	2993	359	120	76	42	29	17	23	4	5	3	2	0	0	0	0	3673
Total	9150	893	386	208	142	97	56	55	23	13	6	3	3	1	1	1	11038

Table 12. Descriptions of movement by size grade.

	Descriptive Statistics							
Size	Count	Mean	Std. Dev.	Maximum	Median	Interq.	Normal(W)	p> D
2.5 cm	3664	0.05	0.19	6.25	0.01	0.01	0.39	0.01
4.0 cm	3701	0.07	0.18	2.53	0.01	0.02	0.36	0.01
5.0 cm	3673	0.06	0.16	1.96	0.02	0.03	0.35	0.01

maximum amount of displacement represented decreases dramatically with size. Smaller tiles have a greater maximum shift than larger tiles.

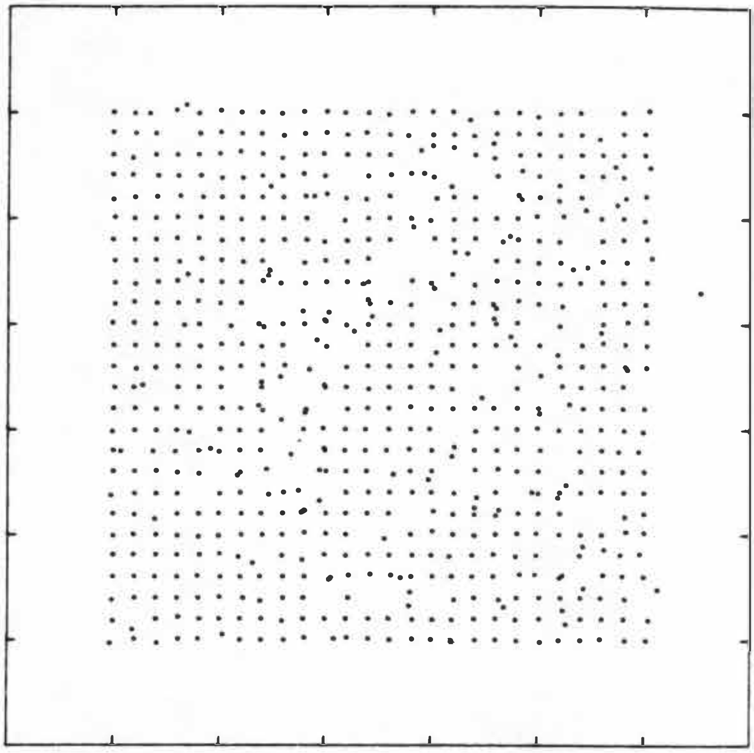
Figure 2 (p. 52) shows the initial tile locations for test plots 1 and 2, Figure 3 (p. 53) those for test plots 3 and 4. The tiles occupied a 5 m x 5 m area with a 1 m buffer all around. While all grids exhibited a gradual degeneration from their initial patterns from time 0 through time 4, some had more of a deterioration than others (Figures 6 through 9).

Artifact Pattern. A tabulation by artifact pattern presents somewhat higher frequencies in the no movement class of the clustered distribution (Table 13). While the clustered arrangement has a slightly longer tail, the even distribution shows higher frequencies in the 10 cm through 50 cm classes. Clustered artifacts moved a great deal or none at all while the even items moved slightly.

The measures of central tendency by artifact distribution indicates a trend similar to that seen in the frequency tables (Table 14). The means, medians and interquartile ranges are similar for all levels, increasing with size. The trend seen in maximum movements seems to hold true only for the clustered distributions.

Even after two hours of trampling, the patterns and clusters subjected to the regular walk are highly recognizable and reveal little disturbance (Figures 6d and

(a)



(b)

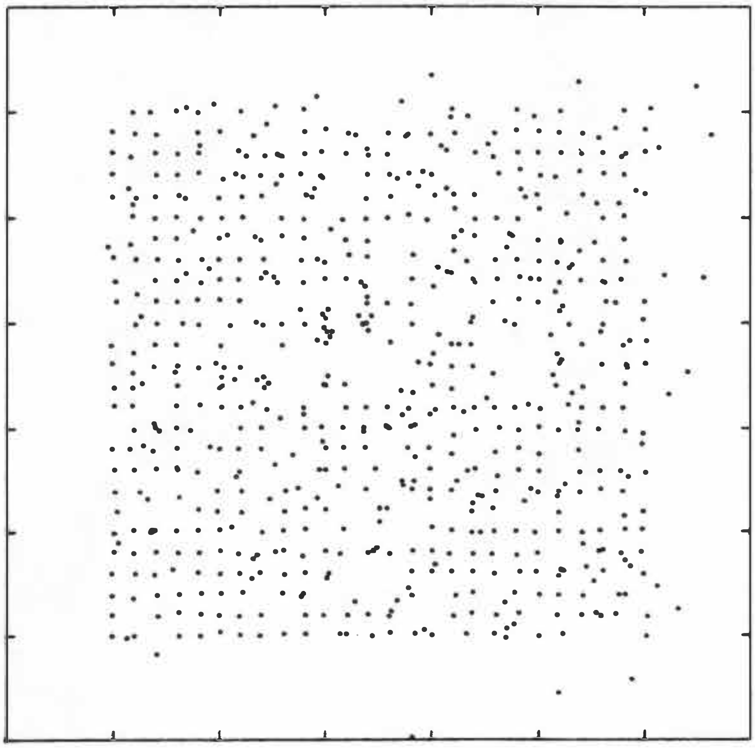


Figure 6. Grid 1: even distribution, uniform trampling at time 1 (a), time 2 (b), time 3 (c) and time 4 (d). Scale is in meters.

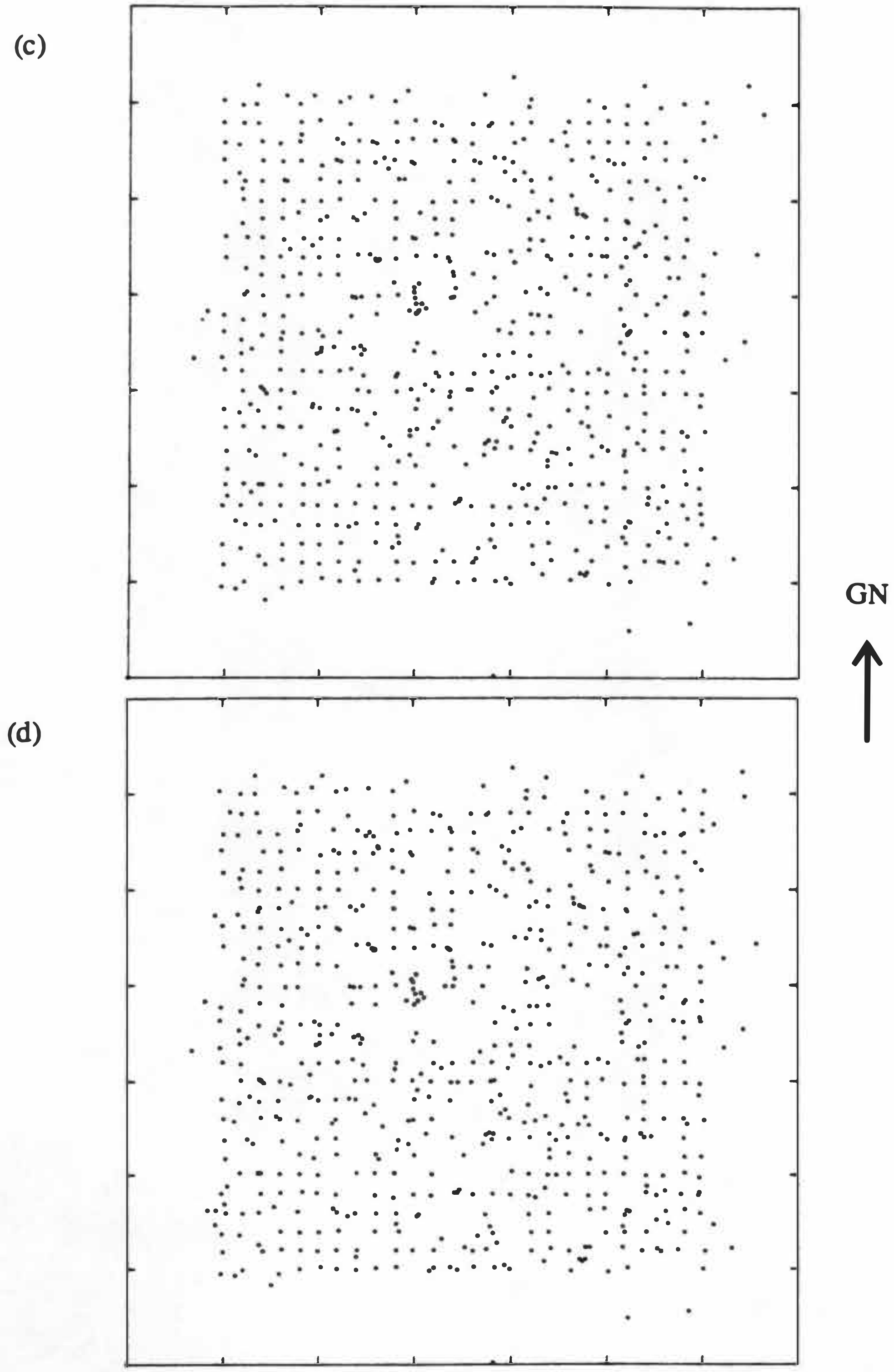


Figure 6 (continued)

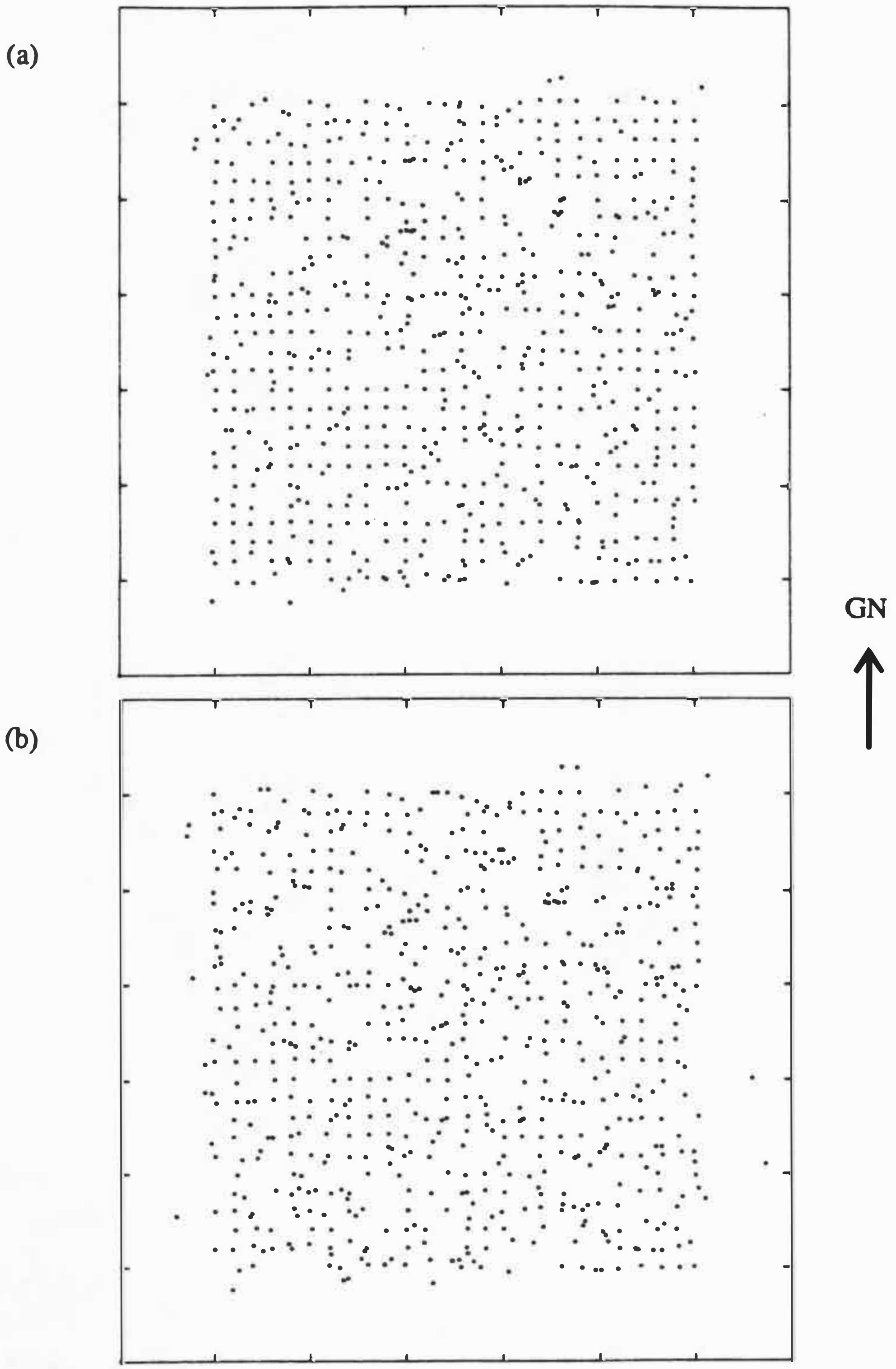


Figure 7. Grid 2: even distribution, arbitrary trampling at time 1 (a), time 2 (b), time 3 (c) and time 4 (d). Scale is in meters.

(c)

(d)

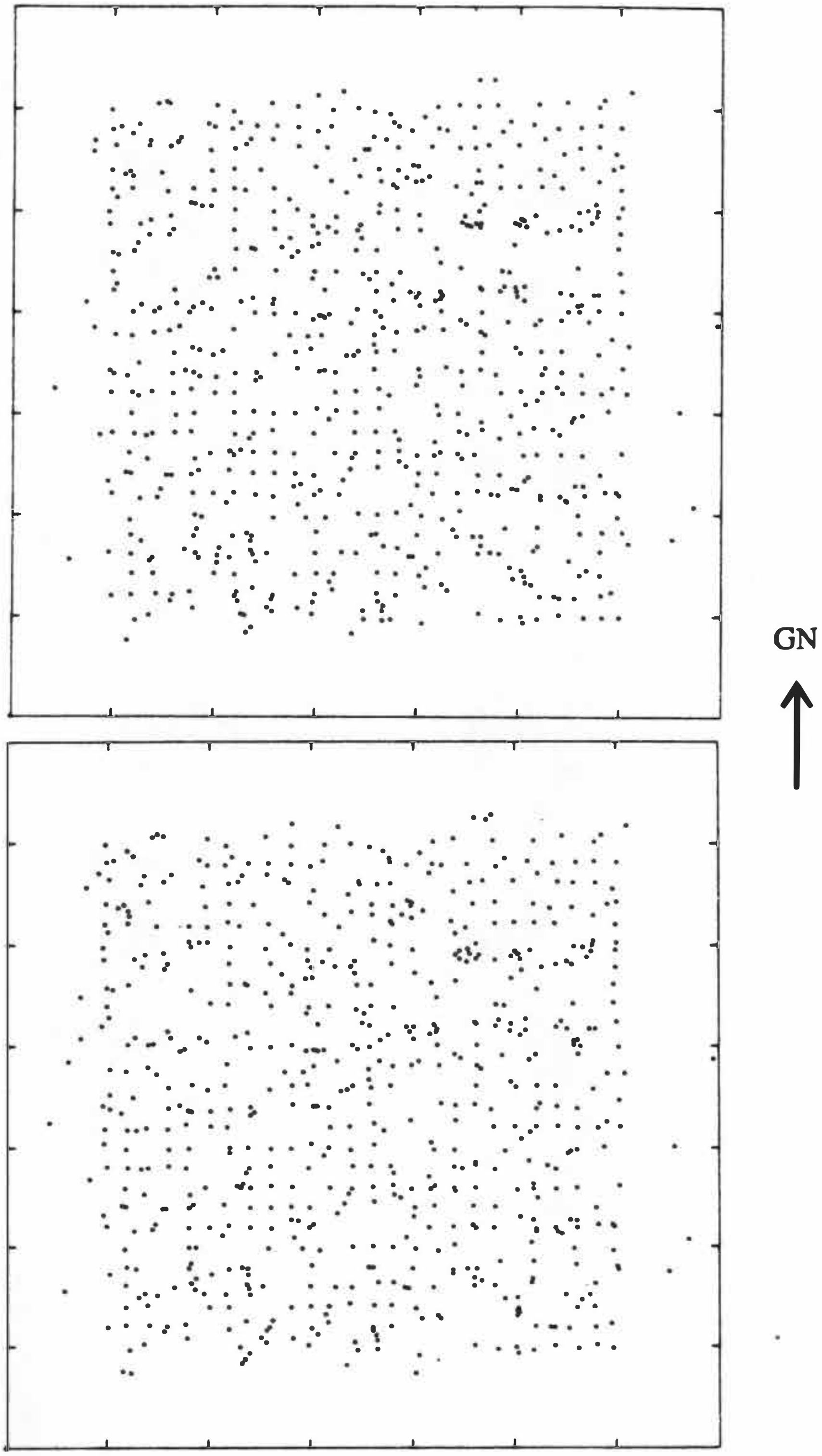


Figure 7 (continued)

(a)

(b)

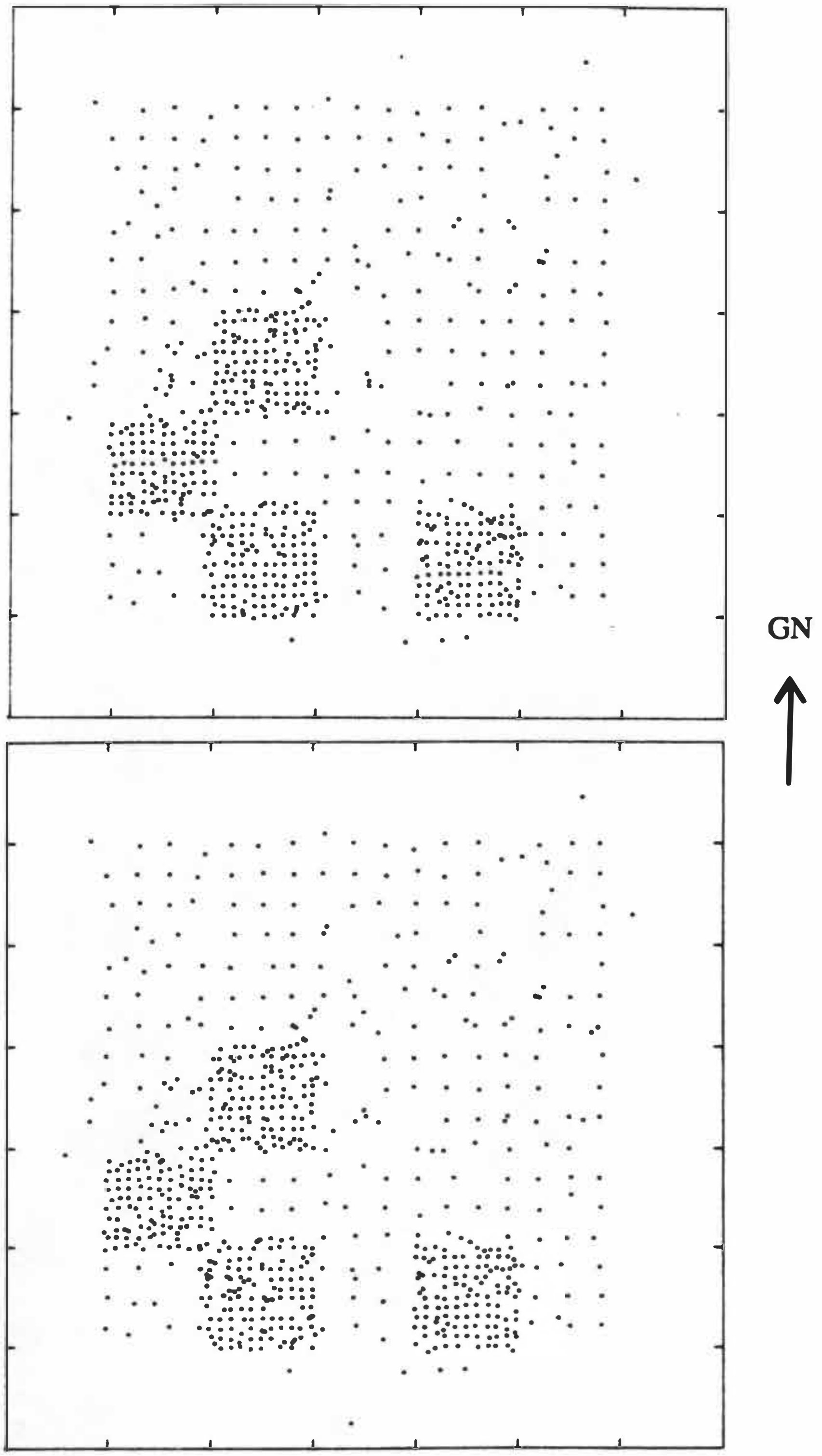


Figure 8. Grid 3: clustered distribution, uniform trampling at time 1 (a), time 2 (b), time 3 (c) and time 4 (d).

(c)

(d)

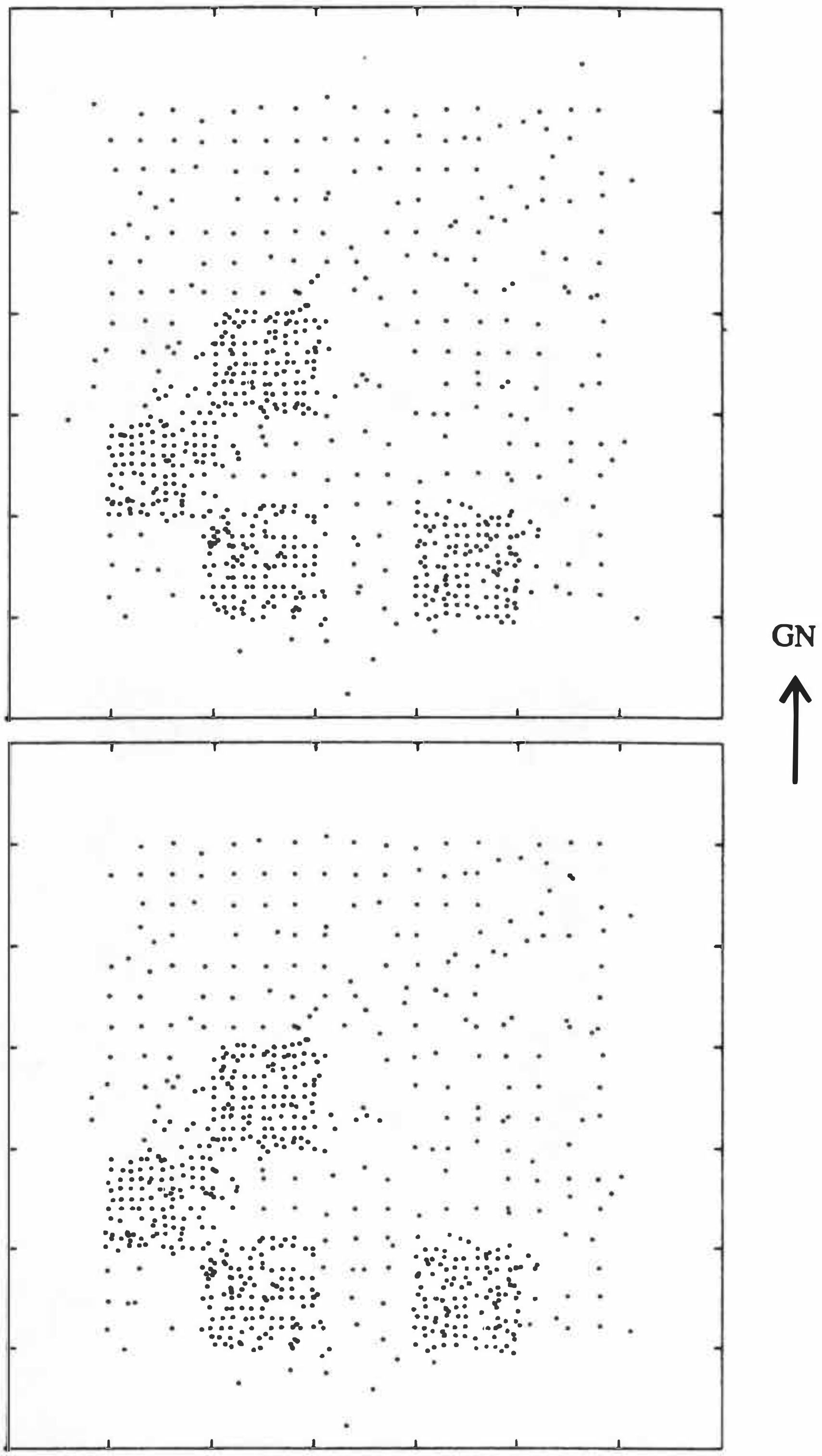


Figure 8 (continued)

(a)

(b)

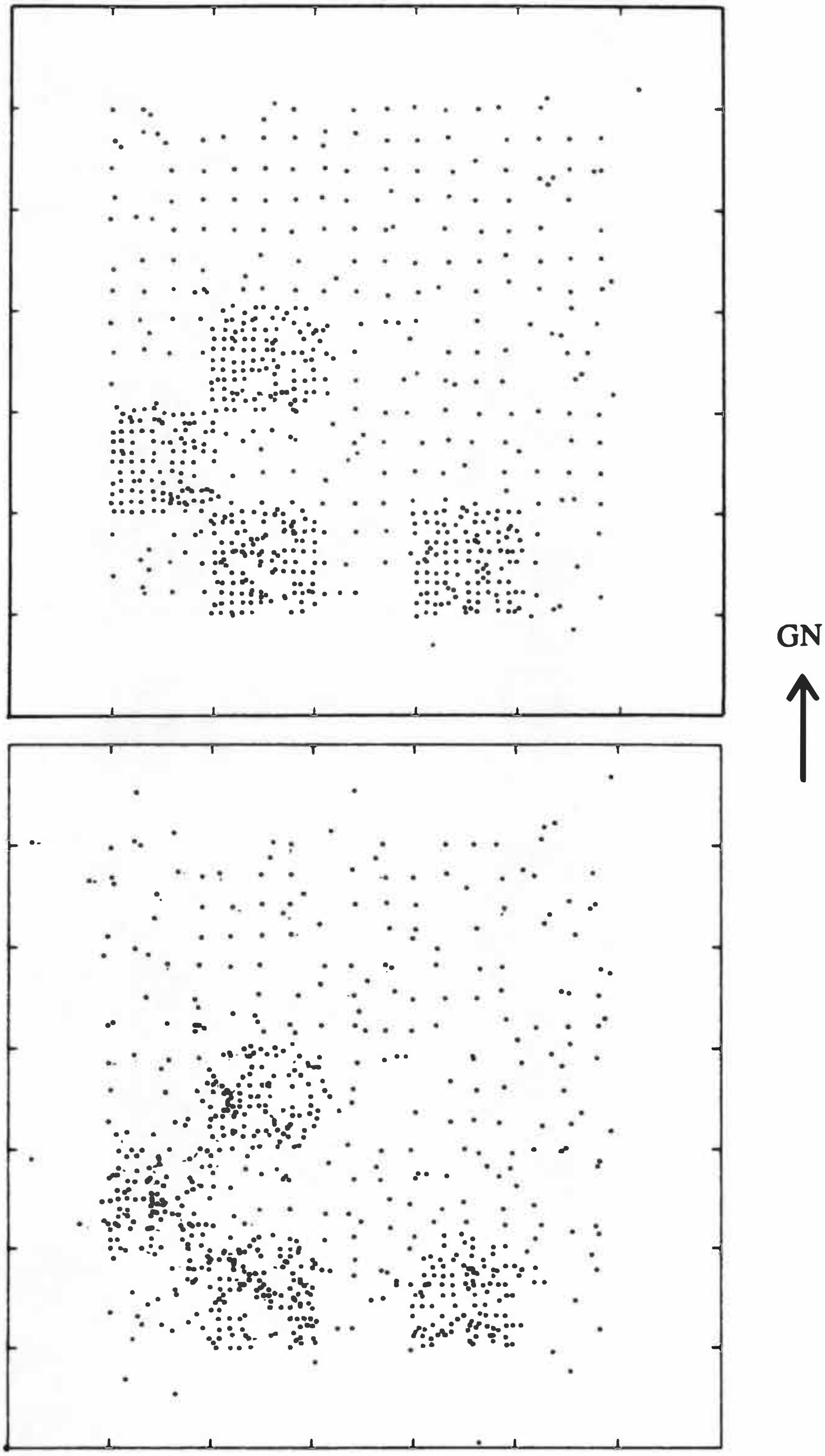


Figure 9. Grid 4: clustered distribution, arbitrary trampling at time 1 (a), time 2 (b), time 3 (c) and time 4 (d). Scale is in meters.

(c)

(d)

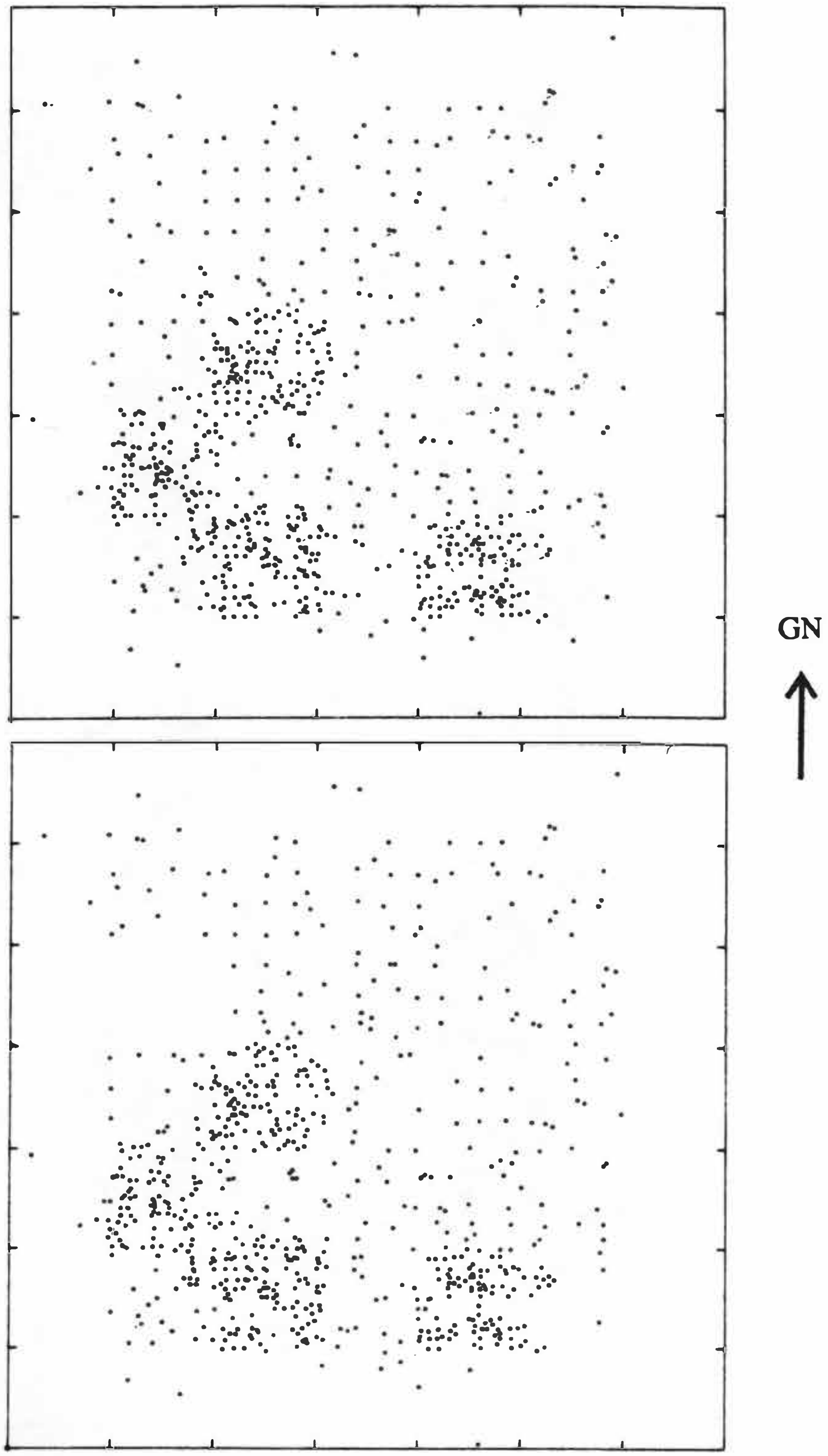


Figure 9 (continued)

Table 13. Cell frequencies of lateral displacement by artifact distribution.

Artifact Distribution	Size	Log Displacement (m) 0	0.1	0.2	0.3	0.5	0.6	0.8	1	1.2	1.5	1.7	2	2.3	2.7	3.5	6.4	Total
Even	2.5 cm	1521	118	57	42	26	16	5	7	1	1	0	0	0	0	0	0	1794
	4.0 cm	1402	169	91	42	30	24	13	8	8	2	0	0	0	0	0	0	1789
	5.0 cm	1425	183	79	38	21	12	7	12	2	3	1	1	0	0	0	0	1784
Total		4348	470	227	122	77	52	25	27	11	6	1	1	0	0	0	0	5367
Clustered	2.5 cm	1642	112	47	16	13	15	5	5	6	3	2	1	1	0	1	1	1870
	4.0 cm	1592	135	71	32	31	13	16	12	4	2	1	0	2	1	0	0	1912
	5.0 cm	1568	176	41	38	21	17	10	11	2	2	2	1	0	0	0	0	1889
Total		4802	423	159	86	65	45	31	28	12	7	5	2	3	1	1	1	5671
Total		9150	893	386	208	142	97	56	55	23	13	6	3	3	1	1	1	11038

Table 14. Descriptions of movement by artifact distribution.

Artifact Distribution	Size	Count	Mean	Std. Dev.	Maximum	Median	Interq.	Normal(W)	p> D
		Descriptive Statistics							
Even	2.5 cm	1794	0.05	0.13	1.48	0.01	0.01	0.38	0.01
Even	4.0 cm	1789	0.08	0.17	1.38	0.02	0.03	0.35	0.01
Even	5.0 cm	1784	0.07	0.16	1.96	0.02	0.03	0.34	0.01
Cluster	2.5 cm	1870	0.06	0.23	6.25	0.01	0.01	0.40	0.01
Cluster	4.0 cm	1912	0.07	0.19	2.53	0.01	0.02	0.37	0.01
Cluster	5.0 cm	1889	0.06	0.16	1.91	0.01	0.02	0.36	0.01

8d). The patterns and clusters subjected to the arbitrary walk show little resemblance to their original state (Figures 7d and 9d). The patterns have disintegrated and the boundaries between the three western clusters are blurred. Depending on one's interpretation, the eastern cluster has either broken into two or can no longer be identified as a cluster at all. Judging from these results, it appears that the pattern of walking has a profound impact on material displacement.

Trampling Pattern. A tabulation of distance frequencies by trampling pattern is quite different (Table 15). Uniform trampling demonstrates much higher frequencies in the zero movement category, while the arbitrary walk has higher frequencies on the 10 cm through 100 cm classes. The irregular walk also has a greater representation in the larger displacement categories. Since these counts are constant across artifact sizes, this is an indication that tiles may have been more likely to move, and move a greater distance, under a variable trampling pattern.

A breakdown by trampling pattern is demonstrably different than the artifact distribution trends (Table 16). The means, medians and interquartile ranges are

Table 15. Cell frequencies of lateral displacement by trample pattern.

Trample Pattern	Size	Log Displacement (m)																
		0	0.1	0.2	0.3	0.5	0.6	0.8	1	1.2	1.5	1.7	2	2.3	2.7	3.5	6.4	Total
Uniform	2.5 cm	1652	83	41	25	14	9	6	3	3	1	1	1	0	0	1	0	1840
	4.0 cm	1612	112	51	33	20	12	8	9	6	1	0	0	0	0	0	0	1864
	5.0 cm	1615	119	43	23	12	9	7	9	4	3	1	1	0	0	0	0	1846
	Total	4879	314	135	81	46	30	21	21	13	5	2	2	0	0	1	0	5550
Arbitrary	2.5 cm	1511	147	63	33	25	22	4	9	4	3	1	0	1	0	0	1	1824
	4.0 cm	1382	192	111	41	41	25	21	11	6	3	1	0	2	1	0	0	1837
	5.0 cm	1378	240	77	53	30	20	10	14	0	2	2	1	0	0	0	0	1827
	Total	4271	579	251	127	96	67	35	34	10	8	4	1	3	1	0	1	5488
Total		9150	893	386	208	142	97	56	55	23	13	6	3	3	1	1	1	11038

Table 16. Descriptions of movement by trample pattern.

Trample Pattern	Size	Descriptive Statistics							
		Count	Mean	Std. Dev.	Maximum	Median	Interq.	Normal(W)	p> W
Uniform	2.5 cm	1840	0.04	0.15	3.35	0.01	0.01	0.40	0.01
Uniform	4.0 cm	1864	0.05	0.14	1.38	0.01	0.01	0.39	0.01
Uniform	5.0 cm	1846	0.05	0.15	1.96	0.01	0.01	0.38	0.01
Arbitrary	2.5 cm	1824	0.07	0.22	6.25	0.01	0.02	0.38	0.01
Arbitrary	4.0 cm	1837	0.09	0.21	2.53	0.02	0.04	0.33	0.01
Arbitrary	5.0 cm	1827	0.08	0.17	1.91	0.02	0.04	0.32	0.01

markedly increased in the arbitrary trampling pattern. The smaller size grades show a greater maximum movement in both pattern categories.

The patterned walk grids (Figures 6 and 8) show a gradual obscuring of the original pattern. Displacement is much more pronounced in the arbitrary walk grids (Figures 7 and 9). This is especially apparent in time 1. The uniform walk left the tile positions largely intact while the irregular walk smeared the initial patterns after 30 minutes.

Interactions. Finally, tabulations were made by all treatment levels (Table 17). The same tendencies apparent before are exhibited here with finer resolution. The zero displacement class reveals slightly larger frequencies in the smaller size ranges in most treatment levels; the only exception being uniform trampling with a clustered distribution. Some differences between these counts and the earlier tables are that under uniform trampling, the even distribution shows lower frequencies in the zero class and more in the 10 cm through 100 cm classes than the clustered distribution. While this is as before, it is not true of the arbitrary subclasses, indicating that the lower response shown by the even distribution versus the

Table 17. Cell frequencies of lateral displacement by artifact distribution and trample pattern.

Trample Pattern	Artifact Distribution	Size	Log Displacement (m) 0	0.1	0.2	0.3	0.5	0.6	0.8	1	1.2	1.5	1.7	2	2.3	2.7	3.5	6.4	Total
Uniform	Even	2.5 cm	784	47	25	20	10	4	4	3	0	0	0	0	0	0	0	0	897
		4.0 cm	732	74	31	19	13	9	5	5	5	1	0	0	0	0	0	0	984
		5.0 cm	756	62	32	14	8	5	4	5	2	3	0	1	0	0	0	0	892
		Total	2272	183	88	53	31	18	13	13	7	4	0	1	0	0	0	0	2683
	Clustered	2.5 cm	868	36	16	5	4	5	2	0	3	1	1	1	0	0	1	0	943
		4.0 cm	880	38	20	14	7	3	3	4	1	0	0	0	0	0	0	0	970
		5.0 cm	859	57	11	9	4	4	3	4	2	0	1	0	0	0	0	0	954
		Total	2607	131	47	28	15	12	8	8	6	1	2	1	0	0	1	0	2867
		Total	4879	314	135	81	46	30	21	21	13	5	2	2	0	0	1	0	5550
Arbitrary	Even	2.5 cm	737	71	32	22	16	12	1	4	1	1	0	0	0	0	0	0	897
		4.0 cm	670	95	60	23	17	15	8	3	3	1	0	0	0	0	0	0	895
		5.0 cm	669	121	47	24	13	7	3	7	0	0	1	0	0	0	0	0	892
		Total	2076	287	139	69	46	34	12	14	4	2	1	0	0	0	0	0	2684
	Clustered	2.5 cm	774	76	31	11	9	10	3	5	3	2	1	0	1	0	0	1	927
		4.0 cm	712	97	51	18	24	10	13	8	3	2	1	0	2	1	0	0	942
		5.0 cm	709	119	30	29	17	13	7	7	0	2	1	1	0	0	0	0	935
		Total	2195	292	112	58	50	33	23	20	6	6	3	1	3	1	0	1	2804
		Total	4271	579	251	127	96	67	35	34	10	8	4	1	3	1	0	1	5488
Total			9150	893	386	208	142	97	56	55	23	13	6	3	3	1	1	1	11038

clustered distribution is a factor in uniform trampling, but not arbitrary trampling. The variable trampling, clustered distribution, shows a slight increase in the zero movement, and is more weighted toward the extreme. The remaining arbitrary classes are very similar. This indicates that the differential pattern of movement between artifact patterns is mostly a function of the uniform subclasses. It is not reflected within the arbitrary walk grids.

An analysis by all treatment levels appears more uniform on all levels (Table 18). The grid 3 means are lower than those for the other grids while the medians are similar in all categories. The size trend for means and medians is not apparent here, nor is the trend for maximum displacement, with the exception of grid 4. The interquartile range is larger for size grade one and two for the two arbitrary walk grids (2 and 4). Otherwise they are similar.

Table 18. Descriptions of movement by artifact distribution and trample pattern.

		Descriptive Statistics							
Grid	Size	Count	Mean	Std. Dev.	Maximum	Median	Interq.	Normal(D)	p> D
1	2.5 cm	897	0.05	0.11	1.06	0.01	0.01	0.39	0.01
1	5.0 cm	894	0.07	0.16	1.38	0.02	0.02	0.36	0.01
1	5.0 cm	892	0.06	0.17	1.96	0.01	0.02	0.37	0.01
2	2.5 cm	897	0.06	0.15	1.48	0.01	0.02	0.37	0.01
2	5.0 cm	895	0.08	0.17	1.34	0.02	0.04	0.33	0.01
2	5.0 cm	892	0.07	0.15	1.66	0.02	0.04	0.32	0.01
3	2.5 cm	943	0.04	0.17	3.35	0.01	0.01	0.42	0.01
3	5.0 cm	970	0.04	0.11	1.24	0.01	0.01	0.40	0.01
3	5.0 cm	954	0.04	0.13	1.78	0.01	0.01	0.39	0.01
4	2.5 cm	927	0.07	0.27	6.25	0.02	0.02	0.40	0.01
4	5.0 cm	942	0.10	0.24	2.53	0.02	0.04	0.34	0.01
4	5.0 cm	935	0.08	0.18	1.91	0.02	0.04	0.33	0.01

Grid 1 (Figure 10) exhibits fluctuations across the entire area. The impact of foot traffic is less intensive than in the other three grids and is evenly dispersed. Movement across grid 2 (Figure 11) is more pronounced with slightly more activity in the northern portion.

Grid 3 yielded a greater intensity of impact (Figure 12). Much of this was concentrated in the northeastern quadrant of the grid. This differential intensity across the grid is mainly a function of material density. While generating a median standardized score per unit area was intended to remove density as a factor, a unit with more items has a better representation of the range of displacements. Therefore, the median is lower because the larger movements are an uncommon event. These events have more impact when the sample size is lower. This effect is also apparent in grid 4 (Figure 13). While the intensity of movement is greater, much of the disturbances represented are a result of edge effects. Tiles that moved into the 1 m buffer zone around each 5 x 5 m test plot had to move a greater distance to get there. Since the sample size is lower in the margins, the consequence of greater movement is accentuated.

Analysis of Variance

In order to determine the effects of the factors under study, an analysis of variance (ANOVA) was calculated for each treatment level. This technique was chosen as it permits comparisons within and between several categorical variables. It is also a fairly robust technique, allowing for some deviation from its assumptions (Zar 1984). This is essential if the conclusions are to be valid.

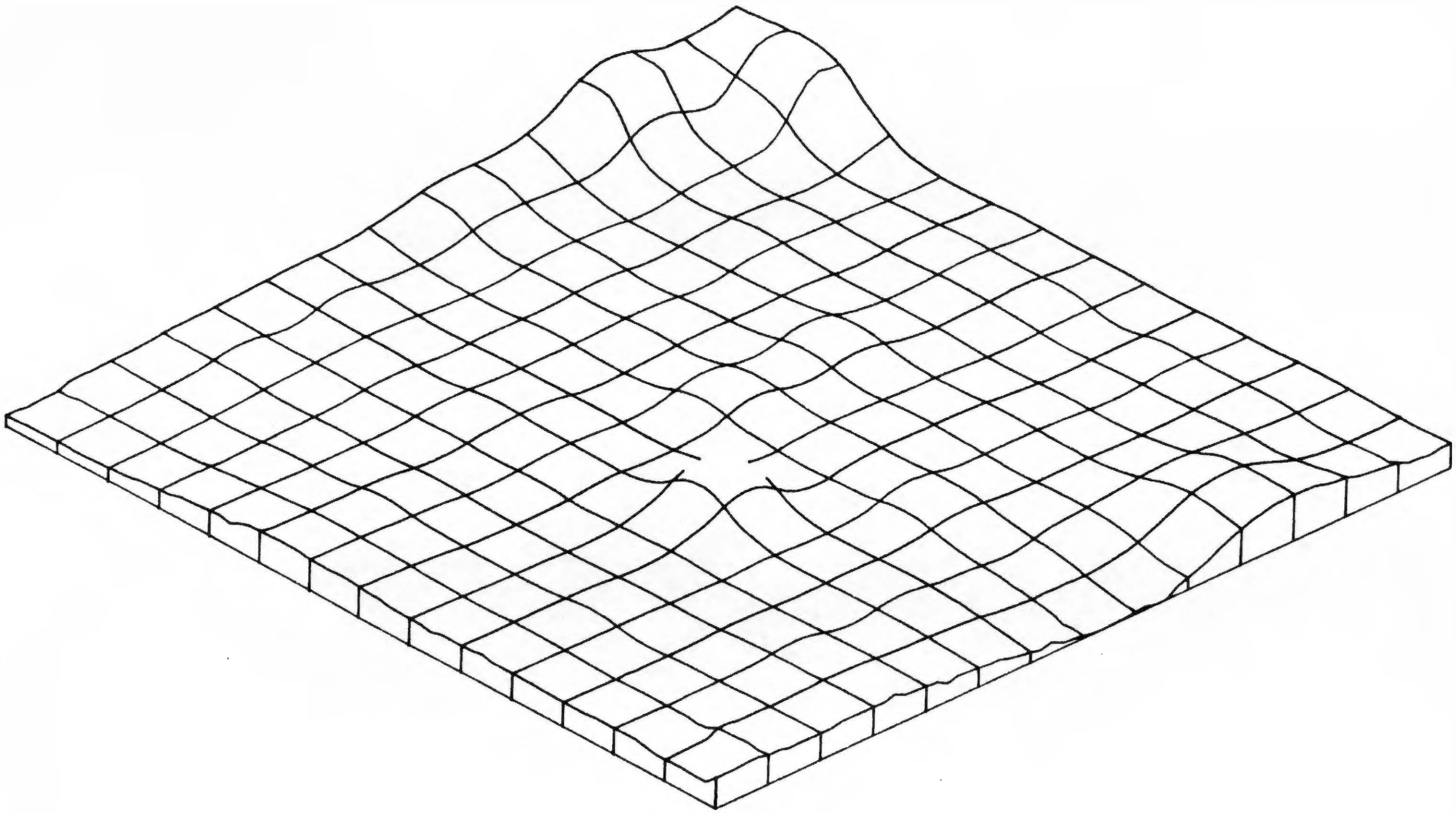


Figure 10. Grid 1 standardized average displacement per unit area. View is from the southwest and the lines are at 50 cm intervals.

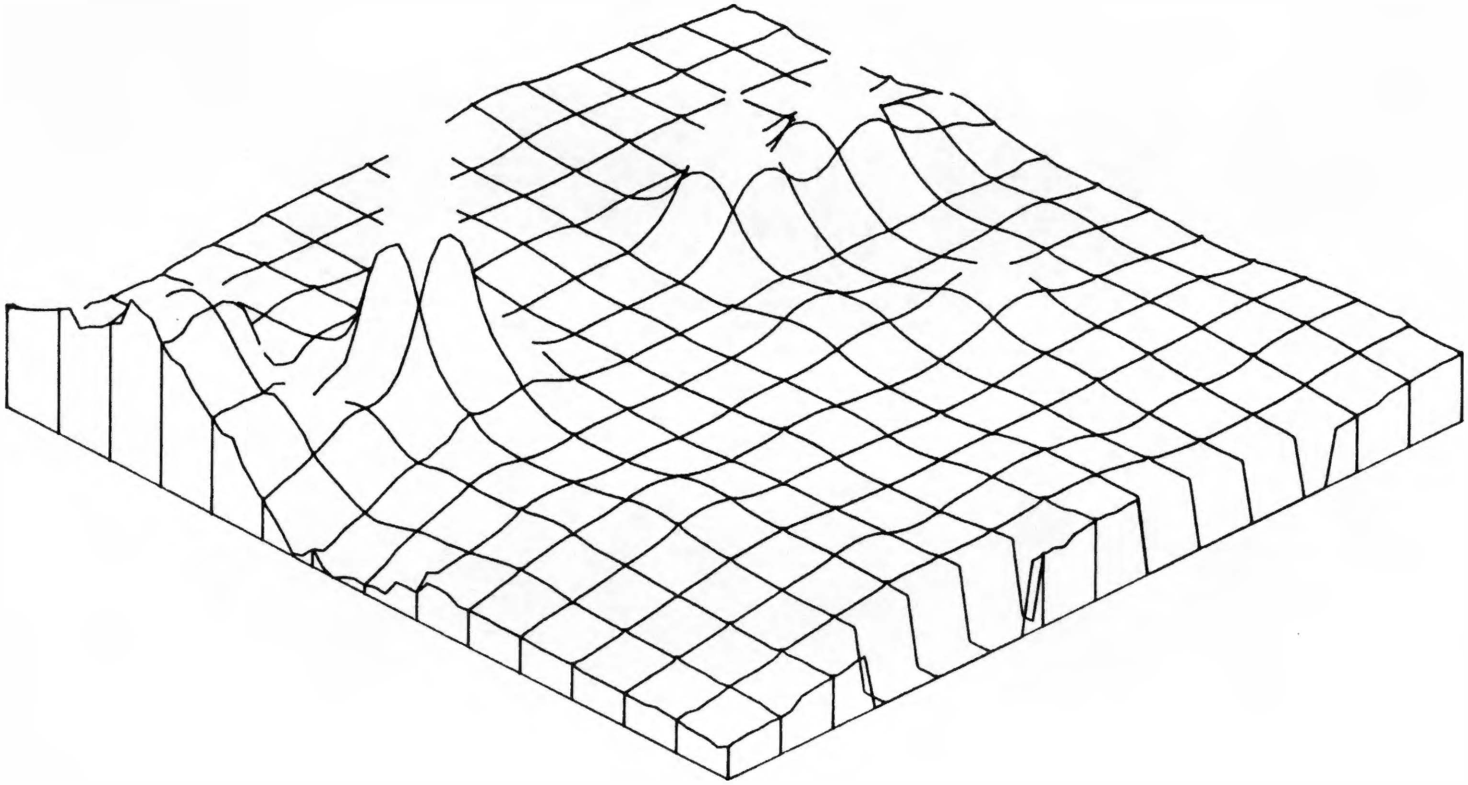


Figure 11. Grid 2 standardized average displacement per unit area. View is from the southwest and the lines are at 50 cm intervals.

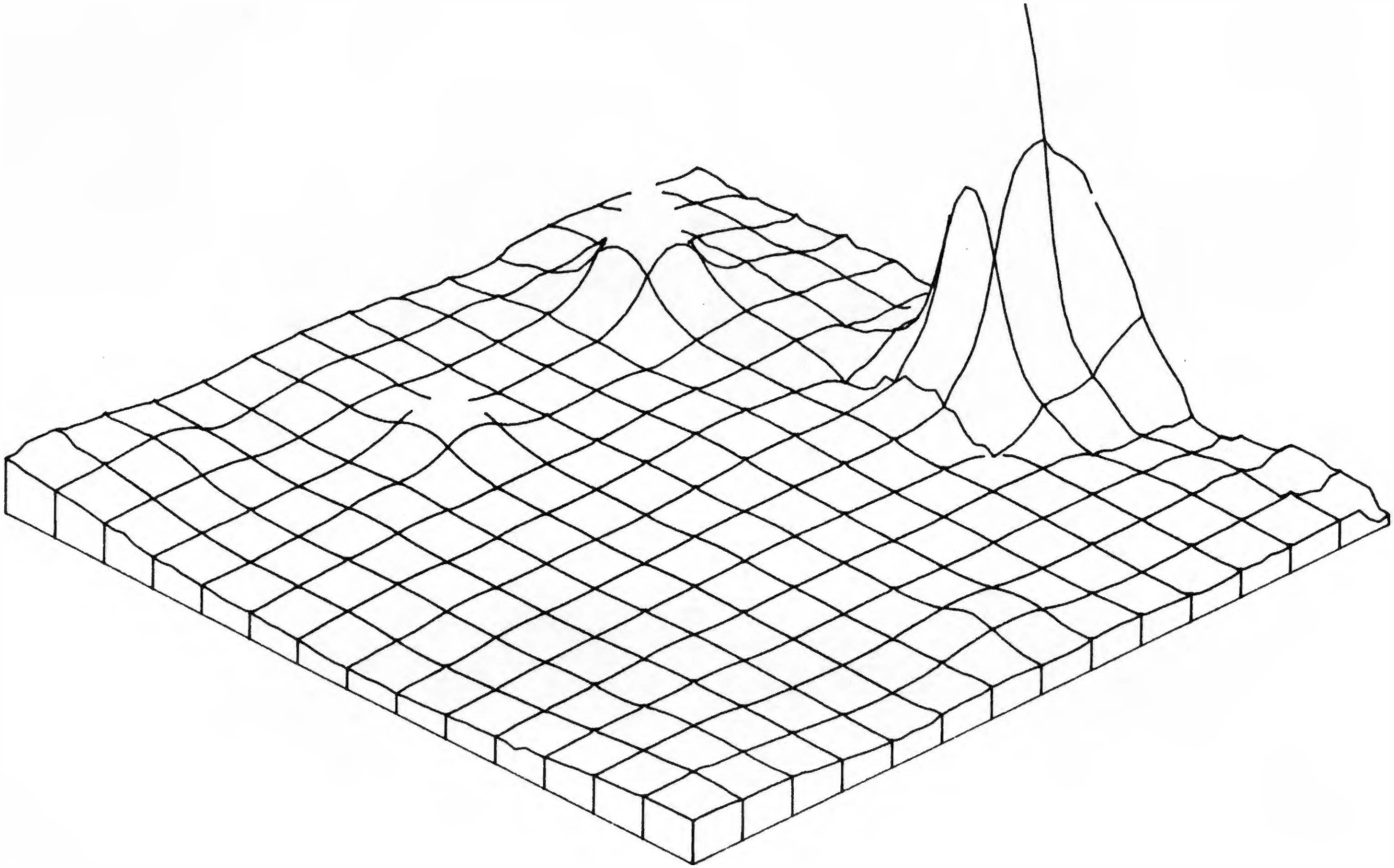


Figure 12. Grid 3 standardized average displacement per unit area. View is from the southwest and the lines are at 50 cm intervals.

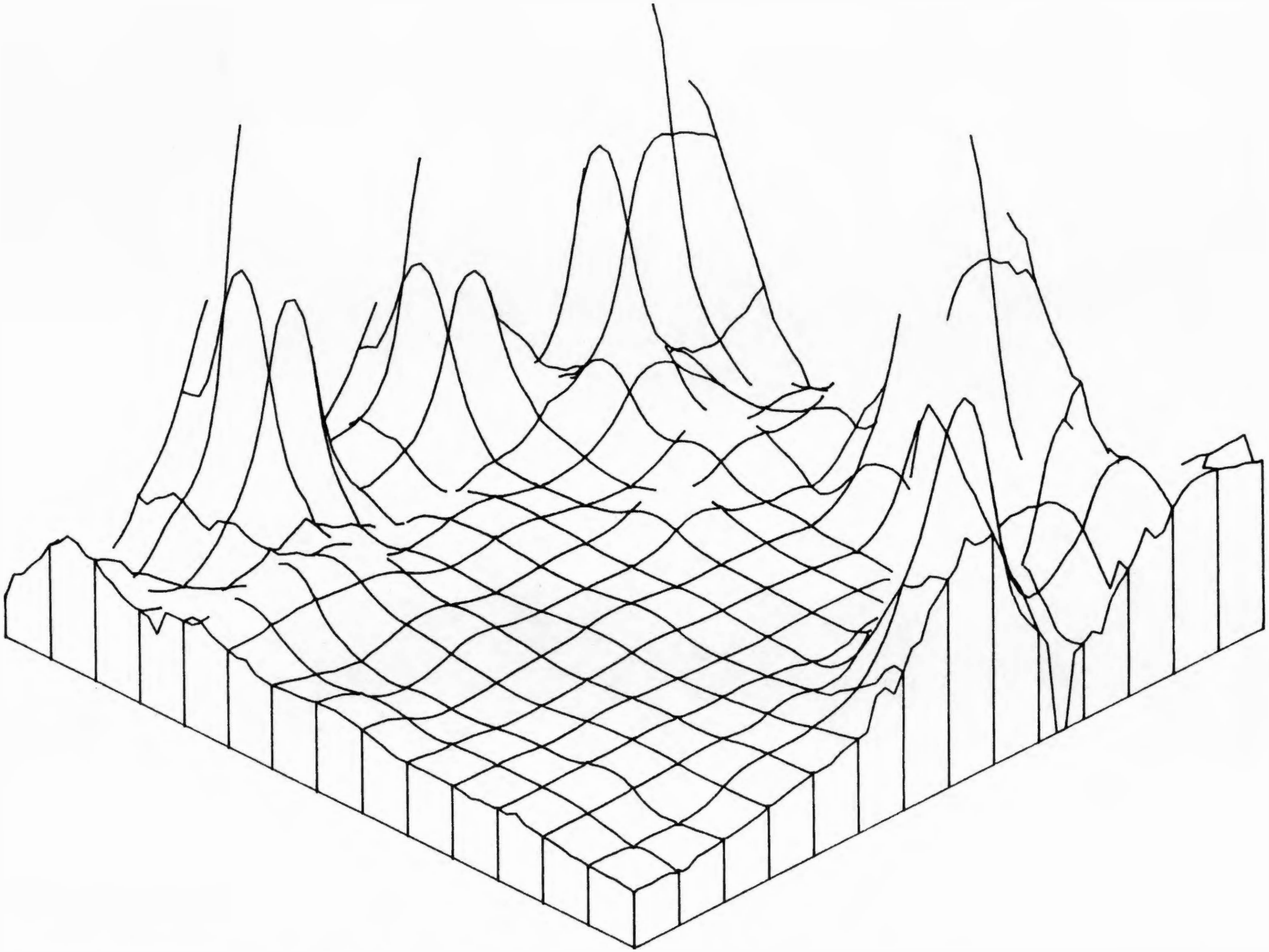


Figure 13. Grid 4 standardized average displacement per unit area. View is from the southwest and the lines are at 50 cm intervals.

Data Preparation. In order to normalize the distribution of movements, each tile displacement value was converted to its natural logarithm. This served to make the higher movements less extreme and therefore more appropriate for ANOVA. Additionally, since the entire range of movements was represented in each grid, this yielded a range of variation from no movement to the maximum. Therefore, to standardize this variance and give a better characterization of the data, tile movements were grouped by 1 x 1 m unit. Unit assignments were made by whatever unit the tile originated in for that bout. An average movement per unit was derived. Since low frequency units can produce erratic results, units with sample sizes of less than five were removed from the analysis.

Before setting up the model, a check was made to determine if there was a significant difference between trampling episodes. This was to determine if there was any change in response to the experimental parameters over time. In performing an ANOVA with repeated measures, displacement being repeated over four trampling bouts, an effect was detected. Wilk's lambda is an absolute value of the ratio of the model variance to the total variance. This yields a measure of the error introduced by the within subjects effects. It varies between zero and one, one being no error. Wilk's lambda for time in this population was 0.938. This had an F-value of 59.57 ($p > 0.0001$) which means that the null hypothesis of no time effect was rejected. However, since Wilk's lambda was so high, there was relatively little effect on the overall model. Nonetheless, time was incorporated into the model so that it could account for the maximum amount of variation. Artifact movement changed over time. Failure to include this factor into the model would have produced spurious results.

To observe the effect of time, plots were generated of time versus average displacement for trampling, distribution, and size factors (Figures 14 through 16). These plots show a decline in overall movement over time, with a slight perk at time 2. This suggests that while every effort was made to maximize lateral and minimize vertical displacement, the tiles had a tendency to "settle in" after about an hour of exposure to trample stress.

A slight positive correlation exists between displacement and artifact size. This could mean that larger artifacts are more likely to move, they are move likely to move further, or both.

Model. With time incorporated into the model, this produced four factors with two, three and four levels, plus interactions. At first, all available factors with all potential interactions were set up as a model. This produced a model that explained a reasonable proportion of the data variation, but not all terms were contributing to the model's fit. By looking at the Type III sums of squares, those factors and interactions that did not significantly contribute to the overall fit were dropped. This left trampling pattern, artifact distribution, size and time, and the interactions between pattern and time, pattern and distribution, pattern, time and distribution, time, size and distribution and pattern, size, time and distribution (Table 19). Each of these remaining elements contributed a significant proportion to the overall model, which explained a substantial portion of the data variation.

Since each of these factors were deemed significant to the model, an analysis of within factor effects was calculated. Tukey tests were also performed to examine differences within each factor. Least squares means were used to analyze differences between factor levels with interactions.

Table 19. ANOVA table for tile displacement (m).

Source	df	Sum of Squares	Mean Square	F Value	p> F	R-square	Variable	df	Type III SS	F Value	p> F
Model	17	.705	.041	21.94	.000	.2637	Time	3	.222	39.13	.0001
Error	1,041	1.967	.002				Trample P.	1	.113	59.94	.0001
Total	1,058	2.671					Size	2	.050	13.33	.0001
							Artifact D.	1	.024	12.52	.0004
							Time*Tr	3	.041	7.28	.0001
							Art*Tr	1	.019	9.91	.0017
							Time*Art*Tr	6	.219	19.35	.0001

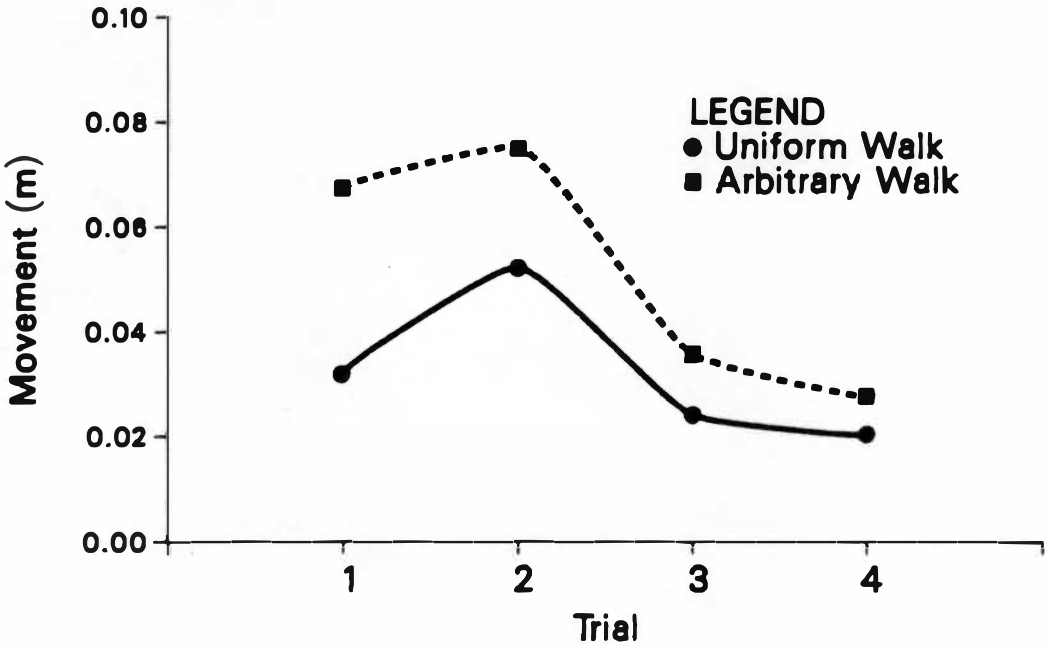


Figure 14. Plot of displacement versus time and trampling pattern.

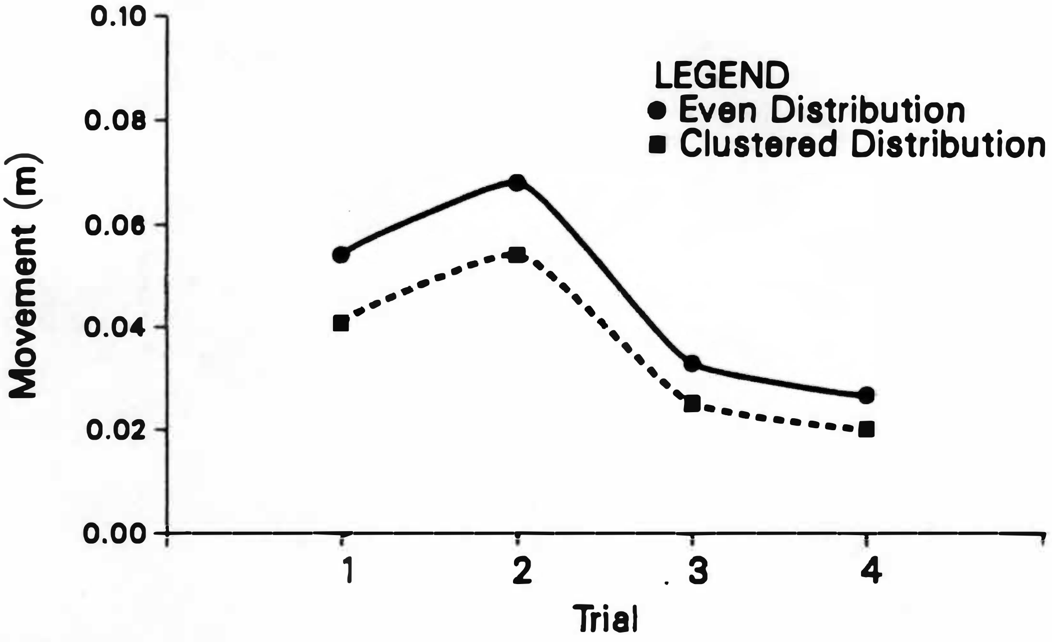


Figure 15. Plot of displacement versus time and artifact distribution.

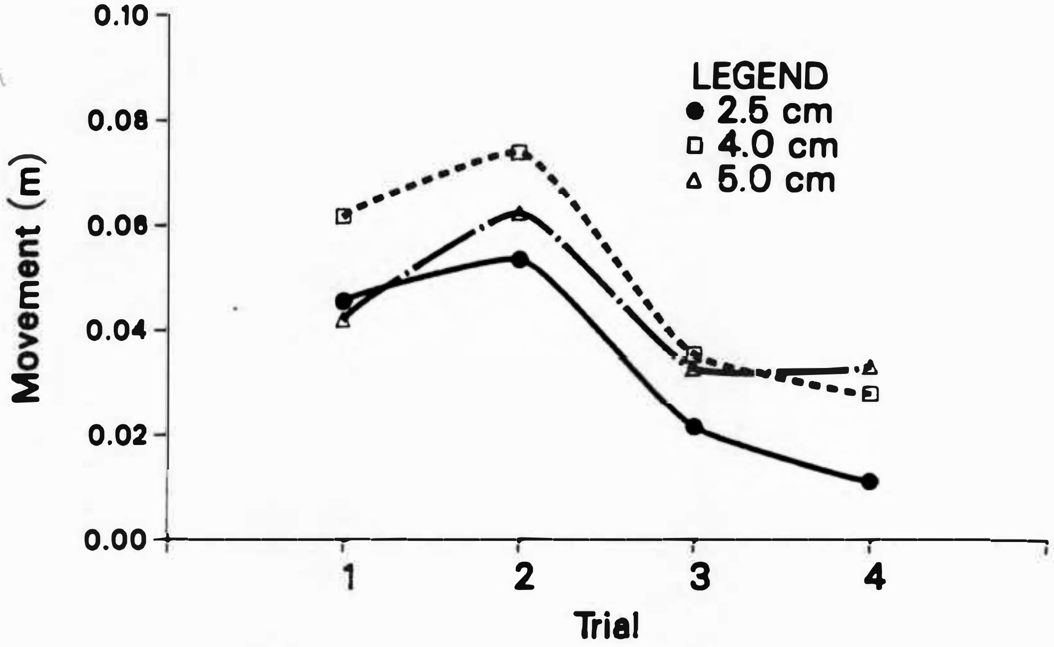


Figure 16. Plot of displacement versus time and size grade.

An arbitrary trampling pattern showed significantly greater movement than a uniform one (Table 20). Non-patterned walking, the type that may be performed in an open area, has a greater impact on the surface materials than directional walking, such as the type performed on pathways.

The even distributions had significantly higher movements than clustered distributions (Table 21). This potentially is a function of interference between artifacts in high density areas. Although all obstructions had been removed from the surface, there remained the obstructions presented by neighboring artifacts. A moving artifact was move likely to come into contact with another tile as the density increased. Therefore, while more artifacts could become impacted, their potential for long distance moves was diminished.

Table 20. Tukey comparison between trampling patterns.

Trample Pattern	Count	Mean	NSD	Compare with	Lower Confidence Limit	Difference Between Means	Upper Confidence Limit	NSD
Arbitrary	525	0.0521		Uniform	0.0142	0.0195	0.0247	
Uniform	534	0.0327		Arbitrary	-0.0247	-0.0195	-0.0142	

Note: Patterns designated with '*' are not significantly different (NSD) from each other.

Table 21. Tukey comparison between artifact distributions.

Artifact Distribution	Count	Mean	NSD	Compare with	Lower Confidence Limit	Difference Between Means	Upper Confidence Limit	NSD
Even	692	0.0462		Clustered	0.0058	0.0113	0.0168	
Clustered	367	0.0350		Even	-0.0168	-0.0113	-0.0058	

Note: Distributions designated with '*' are not significantly different (NSD) from each other.

While 4 cm tiles moved somewhat further on the average than 5 cm tiles, this difference was not significant (Table 22). The artifact's mass may be influential at these sizes. As the difference was not significant, this can not be determined with certainty. However, 2.5 cm tiles moved less than either of these. This supports the contention that the larger the tile, the higher the probability it will be displaced.

Tiles moved a significantly greater distance in time 2 than in time 1, and both early time periods involved significantly more movement than times 3 and 4 (Table 23). Tiles tended to become lodged in the substrate from which a greater energy input was required to set it into motion. It also allowed the tile to offer a lower surface area available for impact. Since movements over the last two bouts were not significantly different from each other, this suggests that tile displacements were stabilizing. The implication is that an equilibrium may have been reached.

Arbitrary walk in times 1 and 2 are different from each other, and significantly greater than all other patterns and times (Table 24). This is due to the combined effect of greater displacement under arbitrary walk and more mobility earlier in the trial. Another effect of tiles' greater mobility before becoming impressed into the surface is evident in the non-patterned walk. Displacements in time 2 were significantly greater than that in time 4.

Materials moved less when uniformly trampled and clustered, significantly more when evenly spaced, and an arbitrary walk moved artifacts a greater distance regardless of artifact distribution (Table 25). Although, non-patterned walking again shows up to be more detrimental to artifact placement, it yields no distinction based on artifact pattern. The difference between even and clustered distributions is only manifest in the uniform trampling patterns. The differential intensity of impact inherent in a non-patterned walk is not consistent enough to bring out the difference in movements due to artifact distribution.

In time 2, the clustered and arbitrary grid and the even and uniform grid are yielded significantly greater movements than any other time within those grids (Table 26). While these two "opposing" treatment levels contribute the greatest movements for time 2, the clustered and arbitrary grid is significantly larger. Thus, while higher artifact densities will detract from artifact movement, this is outweighed by a non-patterned walk.

Table 22. Tukey comparison between size grades.

Size	Count	Mean	NSD	Compare with	Lower Confidence Limit	Difference Between Means	Upper Confidence Limit	NSD
4.0 cm	355	0.0503	*	5.0 cm	-0.0002	0.0075	0.0152	*
				2.5 cm	0.0089	0.0166	0.0243	
5.0 cm	355	0.0428	*	4.0 cm	-0.0152	-0.0075	0.0002	*
				2.5 cm	0.0014	0.0091	0.0168	
2.5 cm	349	0.0337		4.0 cm	-0.0243	-0.0166	-0.0089	
				5.0 cm	-0.0168	-0.0091	-0.0014	

Note: Sizes designated with '*' are not significantly different (NSD) from each other.

Table 23. Tukey comparison between trampling episodes.

Time	Count	Mean	NSD	Compare with	Lower Confidence Limit	Difference Between Means	Upper Confidence Limit	NSD
2	271	0.0631		1	0.0040	0.0135	0.0230	
				3	0.0234	0.0332	0.0429	
				4	0.0292	0.0390	0.0487	
1	282	0.0496		2	-0.0230	-0.0135	-0.0040	
				3	0.0100	0.0197	0.0293	
				4	0.0158	0.0255	0.0352	
3	255	0.0300	*	2	-0.0430	-0.0332	-0.0234	
				1	-0.0293	-0.0197	-0.0100	
				4	-0.0042	0.0058	0.0157	*
4	251	0.0242	*	2	-0.0487	-0.0389	-0.0292	
				1	-0.0352	-0.0255	-0.0158	
				3	-0.0157	-0.0058	0.0042	*

Note: Times designated with '*' are not significantly different (NSD) from each other.

Table 24. Least square means comparison between trampling patterns and episodes.

Time	Trample Pattern	Move LSmean	Std Error LSmean	p> |T| LSmean=0+	i/j	p> |T| H_0: LSmean(i)=LSmean(j)# 1	2	3	4	5	6	7	8
1	Arbitrary	0.0613	0.0039	0.0000	1	.	0.0001	0.0003	0.0003	0.0001	0.0001	0.0001	0.0001
1	Uniform	0.0332	0.0039	0.0001	2	0.0001	.	0.0001	0.1347	0.9346	0.1360	0.4113	0.0059
2	Arbitrary	0.0817	0.0040	0.0000	3	0.0003	0.0001	.	0.0001	0.0001	0.0001	0.0001	0.0001
2	Uniform	0.0415	0.0039	0.0001	4	0.0003	0.1347	0.0001	.	0.1184	0.0029	0.0213	0.0001
3	Arbitrary	0.0328	0.0040	0.0001	5	0.0001	0.9346	0.0001	0.1184	.	0.1634	0.4643	0.0082
3	Uniform	0.0249	0.0040	0.0001	6	0.0001	0.1360	0.0001	0.0029	0.1634	.	0.5093	0.2083
4	Arbitrary	0.0286	0.0040	0.0001	7	0.0001	0.4113	0.0001	0.0213	0.4643	0.5093	.	0.0559
4	Uniform	0.0177	0.0040	0.0001	8	0.0001	0.0059	0.0001	0.0001	0.0082	0.2083	0.0559	.

+Note: P value of the T-test that the least square mean (LSmean) is equal to zero.

#Note: P value of the T-test that from pairwise comparisons between least square means. At a group alpha of 0.05, the individual alpha level is 0.0018.

Table 25. Least square means comparison between trampling patterns and artifact distributions.

Artifact Distribution	Trample Pattern	Move LSmean	Std Error LSmean	p> |T| LSmean=0[+]	i/j	p> |T| H_0: LSmean(i)=LSmean(j)[#] 1	2	3	4
Clustered	Arbitrary	0.0505	0.0032	0.0000	1	.	0.0001	0.7835	0.0031
Clustered	Uniform	0.0199	0.0032	0.0001	2	0.0001	.	0.0001	0.0001
Even	Arbitrary	0.0516	0.0024	0.0000	3	0.7835	0.0001	.	0.0001
Even	Uniform	0.0387	0.0023	0.0000	4	0.0031	0.0001	0.0001	.

[#]Note: P value of the T-test that the least square mean (LSmean) is equal to zero.

[+]Note: P value of the T-test that from pairwise comparisons between least square means. At a group alpha of 0.05, the individual alpha level is 0.0083.

Table 26. Least square means comparison between trampling patterns, artifact distributions and episodes.

Time	Artifact Distribution	Trample Pattern	Move LSmean	Std Error LSmean	p> |T| LSmean=0[+]	i
1	Clustered	Arbitrary	0.0443	0.0065	0.0001	1
1	Clustered	Uniform	0.0370	0.0065	0.0001	2
1	Even	Arbitrary	0.0783	0.0044	0.0000	3
1	Even	Uniform	0.0295	0.0044	0.0001	4
2	Clustered	Arbitrary	0.1035	0.0065	0.0000	5
2	Clustered	Uniform	0.0076	0.0063	0.2248	6
2	Even	Arbitrary	0.0599	0.0047	0.0001	7
2	Even	Uniform	0.0754	0.0045	0.0000	8
3	Clustered	Arbitrary	0.0223	0.0064	0.0005	9
3	Clustered	Uniform	0.0274	0.0064	0.0001	10
3	Even	Arbitrary	0.0432	0.0048	0.0001	11
3	Even	Uniform	0.0223	0.0048	0.0001	12
4	Clustered	Arbitrary	0.0321	0.0064	0.0001	13
4	Clustered	Uniform	0.0077	0.0064	0.2290	14
4	Even	Arbitrary	0.0251	0.0049	0.0001	15
4	Even	Uniform	0.0277	0.0049	0.0001	16

Table 26 (continued)

	$p > \|T\|$ H_0: LSmean(i)=LSmean(j)[#]															
i/j	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	.	0.4296	0.0001	0.0595	0.0001	0.0001	0.0513	0.0001	0.0160	0.0641	0.9033	0.0067	0.1829	0.0001	0.0182	0.0418
2	0.4296	.	0.0001	0.3350	0.0001	0.0011	0.0044	0.0001	0.1058	0.2900	0.4388	0.0694	0.5906	0.0013	0.1418	0.2523
3	0.0001	0.0001	.	0.0001	0.0014	0.0001	0.0045	0.6469	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
4	0.0595	0.3350	0.0001	.	0.0001	0.0046	0.0001	0.0001	0.3571	0.7903	0.0351	0.2788	0.7320	0.0054	0.5102	0.7940
5	0.0001	0.0001	0.0014	0.0001	.	0.0001	0.0001	0.0004	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
6	0.0001	0.0011	0.0001	0.0046	0.0001	.	0.0001	0.0001	0.1027	0.0278	0.0001	0.0622	0.0064	0.9917	0.0277	0.0116
7	0.0513	0.0044	0.0045	0.0001	0.0001	0.0001	.	0.0177	0.0001	0.0001	0.0139	0.0001	0.0005	0.0001	0.0001	0.0001
8	0.0001	0.0001	0.6469	0.0001	0.0004	0.0001	0.0177	.	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
9	0.0160	0.1058	0.0001	0.3571	0.0001	0.1027	0.0001	0.0001	.	0.5732	0.0090	0.9903	0.2773	0.1086	0.7235	0.4987
10	0.0641	0.2900	0.0001	0.7903	0.0001	0.0278	0.0001	0.0001	0.5732	.	0.0477	0.5317	0.6008	0.0303	0.7786	0.9655
11	0.9033	0.4388	0.0001	0.0351	0.0001	0.0001	0.0139	0.0001	0.0090	0.0477	.	0.0022	0.1645	0.0001	0.0081	0.0238
12	0.0067	0.0694	0.0001	0.2788	0.0001	0.0622	0.0001	0.0001	0.9903	0.5317	0.0022	.	0.2234	0.0675	0.6875	0.4344
13	0.1829	0.5906	0.0001	0.7320	0.0001	0.0064	0.0005	0.0001	0.2773	0.6008	0.1645	0.2234	.	0.0072	0.3840	0.5857
14	0.0001	0.0013	0.0001	0.0054	0.0001	0.9917	0.0001	0.0001	0.1086	0.0303	0.0001	0.0675	0.0072	.	0.0307	0.0132
15	0.0182	0.1418	0.0001	0.5102	0.0001	0.0277	0.0001	0.0001	0.7235	0.7786	0.0081	0.6875	0.3840	0.0307	.	0.7051
16	0.0418	0.2523	0.0001	0.7940	0.0001	0.0116	0.0001	0.0001	0.4987	0.9655	0.0238	0.4344	0.5857	0.0132	0.7051	.

[+]Note: P value of the T-test that the least square mean (LSmean) is equal to zero.

[#]Note: P value of the T-test that from pairwise comparisons between least square means. At a group alpha of 0.05, the individual alpha level is 0.0021.

The even and arbitrary grid shows more movement in time 1 and less over time, but the distinctions are not clear (Table 26). The clustered and uniform grid actually yielded the least displacement in time 2 and significantly more in time 1. There is no effective distinction between these and the last two bouts. This maximum was significantly less than the maximum movements for any other grid. The minimum movements for all grids were not significantly different.

Summary

From these analyses, it is apparent that trampling has a distinctive signature. The majority of artifacts experienced little to no shift while some moved a great distance. This produced a logarithmic distribution of movement frequencies. While larger artifacts were more liable to move, they did not move as far. This relationship is a function of two factors. First, is the statistical probability that an artifact will be impacted on a given pass. This probability is positively correlated with size. As artifact size increases, the probability of coming into contact with a human foot increases. The second factor is physical. Since acceleration is inversely proportional to mass, a more massive artifact will not move as far once kicked.

A non-patterned walk over the surface had a greater impact on artifact spatial integrity than a uniform walk. This occurred even though the overall duration of trampling was identical. Movements were larger and covered a greater range. Material distribution was not a factor when being subjected to an arbitrary walk. However, within a uniform trampling pattern material density was a factor. The differential intensities of impact typical of a non-patterned walk may not be enough to produce differential impact due to density.

The duration of impact was also a factor. There was an initial "settling in" period during which surface materials were more liable to move. After this, artifacts became impressed into the substrate and their probability for movement was reduced. This probability may stabilize over time.

CHAPTER VII

SUMMARY AND CONCLUSIONS

> Every body continues in its state of rest, or in uniform motion in a right line unless it is compelled to change that state by forces impressed upon it.
> -Sir Isaac Newton (First Law of Motion, 1686)

Human activity interacts with materials in such a way as to leave traces of the activities which created them. In attempting to decipher the material traces of past cultural activity, it is essential that those forces which alter and move items through space be understood. Numerous factors interact with these by-products of human activity. Cultural remains lie within a dynamic matrix, a matrix that holds, moves and alters these remains over time. A critical step in understanding this process is being able to recognize how the patterns generated by cultural activities are affected. Middle range theory serves to bridge the gap between deciphering human activities and the traces they leave behind.

This study makes a first step toward understanding one of the forces that alter the spatial relations among materials; human foot traffic. The various elements that comprise this process, can be identified and defined. This permits the application of experimental methods to study some of these components. Some of the elements that are known or suspected to have an effect on how surface items respond to trampling are controlled. Aspects of this process to be examined are allowed to vary. Thus, any differences observed in response to each of the experimental conditions will be a result of the study variables.

Three components of trample disturbance were investigated. Two of these were spatial, and the third addressed material variability. For the first spatial variable, surface items were impacted in one of two ways. They were walked over in an established pattern, or they were walked over arbitrarily. This is partially analogous to the types of traffic patterns encountered over pathways, and over open areas with no established paths. The second spatial variable examined the effects of material distribution. Items were placed uniformly over the surface, or they were arranged in clusters. This was designed to observe what affect trampling would have on the patterning of materials. The third analysis variable was artifact size. Since several parameters change with size (volume, surface area and mass), a differential response to trampling was expected.

The variables to be studied were set up in a 2 x 2 x 3 factorial design. This had the advantage of permitting an examination of each of the components effects, and the interactions between them. Since each of the experimental conditions were repeated for four cycles, time was checked and also determined to be a factor.

Time. The greatest amount of displacement was observed in trials 1 and 2. This was true in all grids for all size grades. While the control variables were chosen to maximize the lateral movement vector, after about an hour of trampling, materials tended to become impressed onto the sediment. This occurred despite every effort to decrease the vertical vector of trampling as much as possible. The choices made in setting the control variables all concentrated in optimizing the lateral vector. While no materials were buried or pushed beneath the sediment, many did become embedded into it. This reduced an item's probability of becoming dislodged by reducing the surface area available for impact and increasing its coefficient of friction with the ground surface. After this time, movements began to stabilize. One conclusion of this study, then, is that materials will become resistant to movement by trampling after only a brief period of time, even when deposited on a hard, compact soil surface.

Trampling Pattern. Walking pattern had a marked effect on material movement. A non-patterned walk over the surface moved more materials farther, regardless of size. The patterned walk had significantly less impact. This implies that if an open area and a pathway (minus edge effects) are exposed to identical intensities of trampling, materials in the open area will undergo more displacement.

Artifact Distribution. The distribution of materials also has an effect. Foot traffic moves materials less where material densities are higher. In part, this is a result of the shape of the characteristic trampled assemblage distribution. That is, a majority of materials will move little to none at all, while a few will move a larger distance. In lower density areas, the sample size per unit area is lower; therefore, large displacement values will have a greater effect on the whole. Higher density areas will have a greater representation in the low movement categories, so an occasional high value will not have as large of an effect. Another aspect of this observation may have to do with interference between tiles. Artifacts may simply be constrained in their movements by collisions with neighboring artifacts.

Artifact Size. Material size was also a significant factor. On the whole, the two larger tile sizes, 4 and 5 cm, tended to move farther than the smaller, 2.5 cm, tile size. Even though a larger item requires a greater impelling force to move, it has a substantially greater surface area. Therefore, it has a greater probability of becoming struck on a given trampling pass.

Not examined here are the results of "edge effects"; the accumulation of items in peripheral zones as they migrate away from high impact areas. These are mainly the result of differential intensity of impact across a surface. There may even be a gradient of intensity; a high impact zone that gradually diminishes as one moves away. This is the type of impact encountered along pathways. The most intense walking occurs along the centerline, with a rapid decrease of intensity away from the centerline. Therefore an artifact's probability of being impacted over a given period of time is much greater in the center, and less toward the edge. This permits the accumulation of materials along the edge as they migrate from the point of greatest impact (Schiffer 1987:127; Wilk and Schiffer 1979). Although such impact gradients are not treated, the effects within an impact zone ***is*** considered.

Archaeological Implications

Some interesting implications may be derived from these preliminary conclusions. The ramifications of these results are primarily applicable in extreme cases such as those established here; dense, compact, clayey sediments. In these situations, movement will be primarily horizontal. Other than materials becoming "set" onto the sediment, no vertical displacement will occur. In this experiment, no tiles were buried at any time. Looser or sandier sediments might create a different range of movements. As a soil becomes sandier and less compact, the ability of an artifact to penetrate the surface increases. With this increase, the potential for lateral movement is likely to diminish.

The specific implications of this study are as follows:

1. While the different components of trampling will increase or decrease the degree of artifact displacement, depending on the nature of the component, deposits

are naturally resilient. ***The majority of surface materials will remain in place, or move only slightly***. Even though individual cases can show a considerable amount of movement (6.25 m in one instance), movements of greater than 10 or 20 centimeters are unlikely, and movements greater that a meter will be rare. This resistance is independent of material density, material size, traffic pattern or walking duration.

2. As a correlate of (1) above, ***since some items will move a great distance, smaller sample sizes can show a greater range of variation.*** Thus, areas within a site with few artifacts will not have enough stationary items to be representative of the original distribution. There will not be enough low movement artifacts to offset any high values that might occur. Since they have less with which to counterbalance any potential high movements, lower density areas will be less resistant to trample damage. Thus, they will show a lower proportion of their original associations.

3. Schiffer (1976, 1987) has noted that humans will treat different sizes of materials differentially. This is also true of trampling. ***Although larger artifacts are more resistant to moving by virtue of their greater mass, their greater size means they are more likely to become impacted by trampling.*** Movement distance is directly proportional to the force of impact and inversely proportional to the item's mass, although the probability of impact is directly proportional to size. While this makes larger artifacts more liable to move, they are more resistant to substantial changes. Thus, while the initial pattern of large items will be largely coherent, it will become gradually more diffuse when there is no predominant direction of traffic. This may create false associations between immediately adjacent larger

artifacts. However, associations between items within the general vicinity are likely to be accurate.

4. Conversely, ***smaller materials are less likely to move as a function of having less available surface area for impact, although if impacted they will move much farther.*** Since they will not shift around as much, there will be much more internal coherence among small artifacts, and these are less likely to change over time. Therefore, close associations have a greater probability of being accurate. However, the greater distance that these artifacts tend to move will create occasional exceptions. Should it occur that a small artifact is displaced, it will move much farther.

5. ***Dense clusters of small artifacts, particularly those exposed to a restricted walking pattern, are more resistant to trample damage than any other set of conditions.*** Since different artifact sizes are treated differentially, this may affect the size range of materials remaining in a cluster. Although smaller artifacts require a respectable sample size to show the original context with less distortion, by virtue of their size they are less likely to move. For example, a highly maintained activity area, as long as a substantial quantity of material remains, will retain its fine and course grained structures even when extensively trampled. This is especially true in cases where the direction of movement over the area is restricted. This type of situation could be created in a well maintained lithic reduction area within a rockshelter or between facilities.

6. Archaeological sites are characterized by a non-random distribution of materials. Trampling affects these patterns because it affects differential densities of materials unequally. ***Since higher densities of materials are more resistant to change, activity areas and dumping grounds which leave a high proportion of***

waste will retain their coherence. Obviously if the deposits themselves are an impediment to traffic, a material cluster's resistance to impact is even greater. But the cluster's resistance to change is higher than lower density deposits even when traffic passes right over them. This conservancy based on material density means that occupation sites with richer deposits will keep more of their original patterning than more sparse sites. Additionally, dump areas and site activity areas which generate material remains will retain their initial patterning better than the areas around them.

Trampling in these kinds of situations will not produce any patterning of its own. When there are no edge effects, materials become more diffuse but will not create new patterns. And since the ability of material patterns to resist trample damage increases over time, longer or more intense episodes of trampling will not yield a proportional amount of displacement. Some movement will occur as trample disturbance continues, but significantly less than when first deposited. Therefore, while richer sites may indicate a greater use of an area, the amount of disturbance imposed by foot traffic will not proportionally increase. This implies that beyond a certain threshold, population density on a site will not be as much of a factor in how much displacement occurs. It is true that the likelihood and frequency of impact will be greater in a more intensely occupied site, but so is an artifact's ability to become impressed into the sediment making it less likely to move.

7. This suggests that ***neither the length of site occupation nor population density will be influence artifact displacement.*** While it is unlikely that there will be *no* artifact movement, most of the trample damage to spatial integrity will occur in the early phases after deposition. Any movement will quickly diminish and

stabilize as the artifacts become impressed into the soil. Therefore, if length of occupation and potentially population density are not substantial factors in trampling disturbance, then small, briefly occupied sites will not exhibit significantly more integrity than larger, more intense occupations.

8. ***Open areas which would have had a highly variable trampling pattern, such as in the center of a cluster of households, will suffer more trampling displacement regardless of artifact distribution.*** This will hold true as long as the level of trampling intensity between variable and limited walking areas are similar. A zone exposed to a restricted range of walking will yield similar disturbance only if more intensely trampled. Material densities will be less susceptible when the trampling pattern is more uniform. In the instance of a pathway, there will be differential displacement across the short axis of the path. The highest impact zone of a path, the center, would have to receive a greater overall incidence of foot traffic per unit area than a non-patterned impact zone to produce an equivalent amount of displacement.

Conclusion

While this study gives an indication of the effects of some trampling elements, it is just a beginning. As discussed above, there are a variety of components that comprise trampling. Many of these were set to specific values that optimized only one dimension of movement. While the analysis variables were permitted to vary, they were restricted to only a few states. In one sense, this may be considered a weakness of the study as it examines such constrained cases. However, it is only through such restriction of variation that such definitive conclusions could be derived. In future experiments, the consequences of other factors may be examined. Through a reiteration of this process, a more complete picture of trampling effects will emerge.

While this is by no means the final word on the study of trampling, it does establish a firm foundation. The application of an experimental technique yielded useful results. The utilization of this method to study this and other formation processes has the potential to make quantitative characterizations of the patterns observed in the archaeological record.

The archaeological record is vast and varied. Materials occur on and within surfaces much different than the one used here. As conditions tend to move away from this extreme of dense, clayey, dry, flat sediments, the vertical component of trampling will become more influential. The next phase of this research will be to allow some of the elements which were controlled here to vary. Alternatively, some of the analysis variables can be altered to give a different range of effects (e.g. a broader range of artifact sizes, or more variable artifact materials). This approach promises to ultimately unravel the complex nature of this seemingly simple process, an unconscious effect of human occupation.

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VITA

The author was born on April 20, 1958. His mother was cleaning underneath the refrigerator when she found a fuzz ball that moved of its own volition. She was about to smack it with a broom when she looked at it and thought it was kinda cute in a strange sort of way. After feeding it a steady diet of graham crackers, Fruit Loops and Pixie Sticks, it grew up and traipsed off to join the ranks of the adolescent education system. While there, he spent much of his time staring wistfully at clouds, and speaking with trees, rocks, worms and such in their native tongues. Most of the other kids wouldn't play with him for fear that it was contagious.

After meandering through 12 years of a rural public education system which focused most of its energy on teaching young minds to be farmers, he moved to the big city where most people had only seen corn from the freeway or on a plate and had never heard of playing "wheelbarrow" with piglets. He attended a university which had a reputation for radicalism, but on the surface seemed to be a typical midwestern school with typical midwestern values. After a few years of observation, the true nature of the community came to light -- a typical midwestern school with typical midwestern values. After learning how to play Euchre, flipping and catching 12 quarters off of his wrist and acquiring a taste for certain fermented beverages, he was awarded a Bachelor's degree in anthropology.

Realizing the vast wealth attainable with such certification, he enrolled in the graduate program in a southern university; not unlike the midwestern one he had left behind. While the town was bigger, still, no one had heard of playing "wheelbarrow" with piglets and persons versed in the art of "poohsticks" were hard to find. Nonetheless, along the way he was able to find a few kindhearted souls who would occasionally scratch him behind the ears, would tell him he was kinda cute in a strange sort of way, and didn't seem to be too worried about catching whatever it was he seemed to have.