Plow-Zone Experiments in Calabria, Italy

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The experiments reported here were carried out in the Acconia area of southern Italy between 1977 and 1983. They represent the first long-term study of the effects of plowing on material seen on the surface of a site. A series of observations was made at a site over a period of six years in order to monitor the dynamics of patterns of surface material placed at the site by the researchers. The specific questions examined include the ratio of surface to plow-zone material and the extent of lateral displacement of material resulting from plowing. The results of the experiments support the proposition that the site surface operates in effect as a sampling process with respect to material circulating in the plow-zone. They also show how local factors at a site, such as slope, can affect patterns of lateral displacement. A prime feature of the experimental design is its economy in terms of the work effort that it requires in the field. This means that plow-zone experiments of this kind can readily be incorporated into most multi-year survey projects.

Introduction

This report on plow-zone experiments that were started in Calabria, Italy, in 1977 has two main aims. The first is to describe briefly the experimental design that was employed in the study, since it offers the advantage of requiring comparatively little work in the field and, for this reason, can be put to good use in survey projects done in other parts of the world. In fact, as we shall see below, the design arranges for time itself to do much of the work in the experiments. The second aim is to present the main results of the experiments and to discuss some of the insights along more general lines that they provide into the nature of surface material at a site that is plowed. Part of the motivation for undertaking the experiments was to improve the interpretation of surface collections made at Neolithic sites during the course of survey work in Calabria. For this reason, it was also important to consider the ways in which local factors, such as surface conditions and slope, enter into the actual results of the experiments. The dual task of trying to develop a general understanding of how archaeological material circulates in the plow-zone and makes its appearance on a site's surface, and at the same time trying to document the ways in which local conditions play their part in terms of what is observed in the field, points up the need to have an efficient method for conducting such experiments as a regular part of survey projects.

The surface of a site is the one part of the archaeological record that we have economical access to and yet archaeologists have been remarkably slow in turning to its controlled study. In light of the increasing importance of surveys in archaeological research as well as the extent of the earth's surface that now is, or once was, under cultivation, it is surprising how few studies have been concerned with the nature of plow-zone material.[1] Several studies that were published in the early 1970s looked at the question of the congruence between surface and subsurface material as seen in terms of global pat-

1. For a recent review of the literature on studies concerned with plow-zone material, see D. Lewarch and M. O'Brien, "The Expanding Role of Surface Assemblages in Archaeological Research," in M. Schiffer, ed., *Advances in Archaeological Method and Theory* 4 (Academic Press: New York 1981) 297–342. For a recent review of archaeological surveys, see A. Ammerman, "Surveys and Archaeological Research," *Annual Review of Anthropology* 10 (1981) 63–88. For previous articles and reports in this journal related to the topic, see especially P. Tolstoy and S. K. Fish, "Surface and Subsurface Evidence for Community Size at Coapexco, Mexico," *JFA* 2 (1975) 97–104; K. G. Hirth, "Problems in Data Recovery and Measurement in Settlement Archaeology," *JFA* 5 (1978) 125–131; and Robert J. Mallouf, "An Analysis of Plow-Damaged Chert Artifacts: the Brookeen Creek Cache (41HI86), Hill County, Texas," *JFA* 9 (1982) 79–98.

terns at a site.[2] It is only more recently with a second generation of experimental studies that greater attention is being paid to questions of process as such.[3] But a common limitation of the few plow-zone experiments that have been reported in the literature to date is their short duration: they usually involve only one or a few episodes of plowing. In conducting the experiments in Calabria, the region forming the toe of southern Italy, the plan has been to make observations over a series of years in order to monitor changes in the patterns of surface material over a longer term.

My own interest in doing the experiments stemmed from work that we had previously done on the repeated collection of site surfaces (e.g., counts of obsidian observed in grid squares on different dates).[4] One of the ideas to emerge from this study was that the surface of a site acts in effect as a sampling process with respect to material circulating in the plow-zone. In other words, the pieces seen on the surface at any one time represent a sub-set or sample of the set of pieces moving within the plow-zone as a consequence of periodic episodes of tillage. As the repeated collections themselves showed, this sample is subject to change from one bout of plowing to the next. In order to evaluate this idea and to find out what kind of sampling process was actually involved, it was necessary to carry out more controlled experiments in which known quantities of material were placed in the ground at the start of the study.

There were four main questions that the experiments in Calabria were designed to address. The first was to provide an estimate of the ratio between the material on the surface and that in the plow-zone and also to see how this ratio behaved over time. Knowledge of this ratio would be of considerable immediate value in interpreting the surface collections made at sites during the course of our survey in the Acconia area of Calabria.[5] The second question concerned the nature of the sampling process as mentioned above. It was of broad interest to know, for example, if surface material could be regarded as a realization of a Poisson sampling process, the simplest model to work with in mathematical terms. Under a Poisson model, each piece of a given size circulating in the plow-zone would be considered to have a fixed low probability of making its appearance on the surface and to comprise an independent sampling trial.[6] Without going into a more formal account here, what this would mean in archaeological terms is that surface material, as a sample, would form a "fair" representation of the population of remains circulating in the plow-zone. Deviations from a Poisson model would mean that the relationship between surface material and plow-zone material would be a more complicated one, and the interpretation of surface collections would accordingly become a more complex matter. For the archaeologist, it would be favorable if a Poisson model turned out to provide a reasonable first approximation. The third question (or set of questions) concerns the lateral displacement of pieces as a result of plowing. How far on average do pieces in the plow-zone move? Does displacement tend to increase as a field is subjected to more bouts of plowing? Such considerations are of obvious interest to those who do surveys, since one would like

2. C. Redman and P. Watson, "Systematic, Intensive Surface Collection," *AmAnt* 35 (1970) 279–291; L. Binford, S. Binford, R. Whallon, and M. Hardin, *Archaeology at Hatchery West, Carlyle, Illinois. SAAMem* 24 (1970) 1–91; A. Hesse, "Tentative Interpretation of the Surface Distribution of Remains on the Upper Fort of Mirgissa (Sudanese Nubia)," in F. Hodson, D. G. Kendall, and P. Tautu, eds., *Mathematics in the Archaeological and Historical Sciences* (Edinburgh and Chicago 1971) 436–444. These studies focus on the extent of the correlation between surface and subsurface patterns of material at a site and not on the actual mechanisms that are involved as such. There is also a failure to make a fundamental distinction when it comes to the subsurface: namely, the plow-zone itself, where material is in circulation as a consequence of tillage, and deeper parts of the subsurface, where such plow-induced circulation does not occur.

3. D. Lewarch and M. O'Brien, "Effect of Short Term Tillage on Aggregate Provenience Surface Pattern," in M. O'Brien and D. Lewarch, eds., *Plowzone Archaeology: Contributions to Theory and Technique. Vanderbilt University Publications in Anthropology* 27 (1981) 7-49; N. Trubowitz, "The Persistence of Settlement Pattern in a Cultivated Field," in E. Engelbrecht and D. Grayson, eds., *Occasional Publications in Northeastern Anthropology* (Department of Anthropology, Franklin Pierce College: Rindge, New Hampshire 1978) 41–66.

4. A. Ammerman and M. Feldman, "Replicated Collection of Site Surfaces," *AmAnt* 43 (1978) 734–740.

5. A. Ammerman and G. Shaffer, "Neolithic Settlement Patterns in Calabria," *CA* 22 (1981) 430–432; A. Ammerman, *The Acconia Survey: Neolithic Settlement and the Obsidian Trade* (Institute of Archaeology: London in press). Support for the fieldwork in Calabria was provided by grants from the National Science Foundation (BNS 76-15095 and BNS 79-06187). A preliminary version of this report was given as a paper as part of the "Symposium on Plowzone Archaeology: Tillage Process and Archaeological Material" at the Annual Meeting of the Society for American Archaeology held at San Diego in 1981.

6. For an introduction to the Poisson distribution, see R. Sokal and R. Rohlf, *Biometry* (San Francisco 1981) 81–93; for a brief account, see also J. Doran and F. Hodson, *Mathematics and Computers in Archaeology* (Cambridge, Massachusetts 1975) 47–48. The tiles visible on the surface at any one time can be thought of as the positive realizations of sampling trials in which each tile has a given probability p of appearing on the surface as an event. The chance of a tile remaining in the plow-zone (the event of not appearing on the surface), using conventional notation for probabilities, would be q, where $p + q = 1$. An estimate of the value of p, at least as a first approximation, is given by the surface-to-plow-zone ratio which is discussed below in the text.

to use what is seen on the surface to make inferences about such things as the size of sites and spatial patterns within them. The fourth question is related to the breakage of pieces and their edge-damage as a consequence of tillage. Ideally, it would be useful to know the rates of breakage that hold for a given class of material such as pottery under a given set of conditions. If rates of breakage are relatively high, the population of material in the plow-zone is progressively being increased in number and at the same time being transformed into smaller pieces. If breakage rates are quite low, the population tends to remain much the same over time and the archaeologist is in a more favorable situation.

An important part of the experimental design is the use of what are known as "replications," or the systematic repetition of test rows. They are a common feature of the design of experiments in agriculture and biology. By holding other factors the same between the test rows, variability inherent in the process of interest can be examined. In the design to be described below, the four rows of tiles with a N-S orientation make it possible to document the level of stochastic variation in the surface-to-plow-zone sampling process. Another major feature of the design is the use of observations made over a series of different points in time. Such sequential observations make it possible to monitor over time the dynamic behavior of patterns and processes. This is of particular importance in the case of questions in archaeology that pertain to the plow-zone, since plowing is often a regularly repeated practice and one that has been engaged in for many years in most parts of the world.

Design of the Experiments

It is best to begin with the choice of the material to be placed in the ground. The decision was made that the pieces to be used should all have the same size, shape, and color. From earlier work on the replicated collection of surface material, it was known that larger pieces seem to have a better chance of occurring on the surface than smaller ones.[7] This fact stems in part from the way in which a piece is recognized as being on the surface; i.e., whenever any part of it is visible on the surface. It would be more correct in terms of what one actually sees to describe material as being "in" the surface.[8] There is a greater chance on average for some part of a large piece to break the surface than a small one. Rather than deal with the complex relationships between size and surface visibility in the small-scale experiments that were being planned, we decided that size would be held constant and attention would be paid to the four questions mentioned above. Small ceramic tiles that measure 2.5 cm × 2.5 cm × 0.5 cm were eventually selected. They are somewhat smaller in size than the average Neolithic sherd recovered from the land surface at Acconia and yet larger than most of the pieces of obsidian found at sites in the area. The yellowish grey color of the tiles corresponds well with that of the soil incrustations (when seen in a dry state) that form on the surface of artifacts in the dune soils at Acconia. The tiles also have a glassy and brittle character in line with what is required for the studies of breakage and edge damage. The tiles appear to be more brittle than pieces of obsidian and their edges also damage more easily in the ground. In the design, one group of tiles would be collected and set aside during the second year of the experiment (1979) and a second group during the fourth year (1981), so that rates of edge-damage over time could be examined. One disadvantage of the tiles is that numbers written on them (whether in ink or in paint) did not always survive after a number of years in the soil. This meant that the movement of tiles had to be studied in terms of their displacement from the lines in which they were originally placed. In all, 1,000 tiles were used in the experiments.

The area chosen for conducting the experiments was part of a known Neolithic site in the dune area at Acconia.[9] The olive trees grown at the site today, which are planted on a regular grid system, provided a convenient and permanent guide to set out rows of tiles. Figure 1 shows the layout of the six lines that were employed: note the pattern of alternation of the N-S and E-W lines. For each of the four N-S rows (lines 3 through 6), 125 tiles were placed in the ground. For each of the two E-W rows (lines 1 and 2), 250 tiles were used. The tiles were spaced 20 cm apart along a line and placed at a depth of ca. 2 cm below the modern land surface. By setting out the two groups of "replications" at right angles to one another, it would be possible to measure

7. Ammerman and Feldman, op. cit. (in note 4) 736–739. For a review of the literature on the size question, see Lewarch and O'Brien, op. cit. (in note 1) 307. Some of the best evidence currently available on the size factor comes from the short-term experiment conducted by Lewarch and O'Brien, op. cit. (in note 3) 8–17. Their data can, in fact, be reworked to show the following. After three equipment passes and considering only Pattern 1 (the richest one in material), the ratios of surface to plow-zone material for their three size classes are respectively: 0.111 for pieces larger than 1 inch, 0.079 for pieces falling between $\frac{1}{2}$ and 1 inch, and 0.050 for pieces less than $\frac{1}{2}$ inch. A progressive decline with size is seen in the ratio here.

8. To give an example, the following was observed on the fourth date: one-third or less of a tile was visible for 41% of the tiles; one-third to two-thirds for 11% of the tiles; and two-thirds or more for 48% of the tiles.

9. The site is number 68 in the Acconia Survey; it is the same one where replicated collections were also previously carried out; see Ammerman and Feldman, op. cit. (in note 4) 737–738.

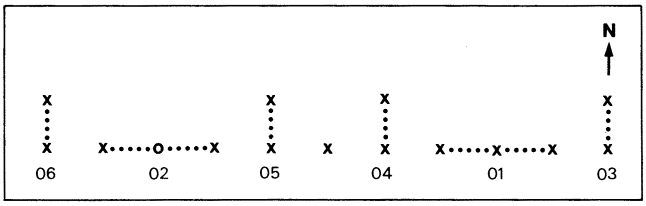

Figure 1. The layout of the six lines of tiles. The x's represent olive trees, which are spaced ca. 14 m apart.

displacement both in an E-W direction (using the rows with 125 tiles) and in a N-S direction (using the rows with 250 tiles). One of the reasons for choosing the site is that it has a gradual slope from north to south of about 1 in 10. The relief is essentially flat in an E-W direction. This situation made it possible to monitor the effects of slope on displacement.

The parent material of the soil in the site area is a fairly coarse sand of aeolian origin. Soil profiles show well developed soil formation to a depth of more than a meter. According to the classification system of the Soil Survey Staff, the soil would be described as an entic haploxerall.[10] The plowing done at the site, which might better be described as harrowing, is quite shallow, ranging 15–20 cm in depth. It is done in the form of a continuous loop for the olive grove as a whole two or three times each year: in the early spring, so that soil moisture is not lost through transpiration of ground vegetation; in the late spring or early summer, in order to avoid fires when the ground cover is dry; and in autumn, in preparation for harvesting the olive trees. The plowing does not seem to be done in any consistent direction, although it is constrained by the grid of olive trees to be done in one of four possible directions (i.e., N-S, S-N, E-W, or W-E). There were at least three and perhaps as many as six episodes of plowing prior to the first set of observations in 1979.[11] Since we were not in Calabria throughout each year, we were not able to make direct observations on all episodes of plowing over a period of four years. But from the orientations of furrows that were observed on several dates, it would appear that plowing was done primarily in the directions of E-W and W-E from 1977 through 1980. It was done at least once in a N-S direction in 1981, and this plowing episode had a major effect on the displacement of tiles, as we shall see below.

The procedure used for making observations in the field was to have two or three people systematically cover the area surrounding a given line. Each tile visible on the surface was flagged and left in position. The following information was recorded for each flagged tile: (a) its displacement from the line where it started (measured at right angles to the line); (b) its position along the line; (c) whether it was whole or broken; and (d) the proportion of the tile actually visible on the surface. Except for the two dates when certain tiles were removed for the edge-damage experiments, the tiles, after being examined for breakage, were placed back in the ground in their encountered positions. Notes were also taken on the conditions of the surface as part of each visit.

Results of the Experiments

Observations were made at the site on four main dates: (1) March 21, 1979, (2) July 1, 1979, (3) April 7, 1980, and (4) June 4, 1980. All six rows were recorded on the first and third visits, while only the two E-W rows were examined on the other two dates. The conditions of the surface were best during the first visit and reasonably good for the fourth date. They were only fair for the second and third dates. In addition, a fifth visit was made on August 1, 1981, in order to collect tiles for the edge-damage study and a sixth visit was made on June 3, 1983. While ground cover at the site prevented systematic coverage on the latter two dates, it was possible to make valuable observations of a more qualitative nature on displacement. Few broken tiles were observed on the surface during any of the visits. In fact, broken tiles were encountered only on three dates and in each case only a single tile was involved. On the first date, there was one broken tile out of 69 visible on the surface. On the third date, there was one out of 39 tiles. Even by the fifth date when the area had probably been plowed at least 10 times, only one tile out of the 29 observed on the surface turned out to be broken. This is a heartening result which suggests that the population of tiles in the plow-zone is not being substantially transformed at least over the short run.

The results on the surface-to-plow-zone ratio are presented in Table 1.[12] It varies to some extent between the

10. Soil Survey Staff, *Soil Taxonomy. A Basic System of Soil Classification for Making and Interpreting Soil Surveys* (Washington D.C. 1975). The soil descriptions at Acconia were made by A. Remmelzwaal of the Institute of Physical Geography and Soil Science, University of Amsterdam.

11. One strategy that has been adopted in plow-zone experiments is for the episodes of plowing to be controlled by those doing the experiment; see Lewarch and O'Brien, op. cit. (in note 3) 8–12. While this control can be accomplished in an experiment of short duration, it is not feasible for a multi-year study. We were interested in seeing the patterns that would result after numerous episodes of "natural" plowing at the site. One distinct advantage of having many plowing episodes is that the patterns eventually observed are less likely to be contingent upon the way in which the pieces are set out (i.e., on the surface or inserted in the plow-zone) at the start of the experiment.

12. For the estimation of a ratio from samples, see W. Cochran, *Sampling Techniques* (New York 1963) 29–33. The best estimator of

Table 1. Estimation of the ratio of surface to plow-zone material for four dates.

Date	*Surface*	*Plow-Zone*	*Ratio*	*1:X*
First	69	931	0.074	1:14
Second	20	441	0.045	1:22
Third	39	892	0.044	1:23
Fourth	27	434	0.062	1:16
Combined	155	2698	0.057	1:18

visits, ranging from 1:14 for the first date to 1:23 for the third date. The values of the ratio seem to reflect the differences in surface conditions at the times of the respective visits. The counts of surface tiles are high enough for the first and third dates so that the differences in the ratios here are not likely to be the results simply of stochastic sampling effects. There is no clear evidence in Table 1 for time-dependent trends either of increase or decrease in the ratio. The values for the first and fourth dates, allowing for slightly less favorable surface conditions on the latter date, are much the same. Apparently, the episodes of plowing carried out between the start of the experiment in the spring of 1977 and the first date of observation two years later (i.e., at least three episodes of plowing and perhaps as many as six) were enough so that equilibrium is already being approached with regard to this ratio.[13] As a central tendency or average value for the first four dates, the ratio would be 1:18. This figure represents the relationship between surface and plow-zone material under ordinary conditions for fields without ground cover at the site. It should be stressed that it applies only to a class of given size. Archaeological pieces smaller in size than the tiles would be expected to have lower values for the ratio and larger pieces the opposite.[14] It is evident that even for a fairly large-sized class such as the tiles, only a small fraction of the material in the plow-zone is visible on the surface at any one time. Conversely, a ratio of 1:18 would mean that if one finds six tiles on the surface in one part of the site, it would be reasonable to infer that on the order of 100 tiles occur in the plow-zone there. In such a case, light scatters of surface material warrant our closer attention.

this ratio for any one visit is supplied by the total of the surface tiles for the lines examined on that date divided by the total number of tiles in the ground for those lines (i.e., the tiles originally placed in the ground along the line less any previously taken out of circulation, such as those for the edge-damage studies, minus those now visible on the surface).

13. In the literature on agricultural engineering, equilibrium is considered to be reached after 10–15 equipment passes; Lewarch and O'Brien, op. cit. (in note 3) 12.

14. For a mathematical formulation in terms of multinomial sampling, see Ammerman and Feldman, op. cit. (in note 4) 738–739; see also note 7.

Table 2. Fluctuations in the surface counts of the four N-S rows for two dates.

Date	*03*	*04*	*05*	*06*	*m*	*V*	*V/m*
First	6	5	7	12	7.5	7.25	0.97
Third	6	5	3	6	5.0	1.50	0.30

The counts of tiles seen on the surface of each of the four N-S rows are presented in Table 2. Each replication begins with the same number of tiles laid out in the same configuration. Through a given date, each is subjected to the same episodes of plowing. Observations on a given date are also being made under essentially the same surface conditions, so that the variations between the replications should represent fluctuations that are inherent in the mechanics of tile circulation in the plow-zone. The counts range between 5 and 12 for the first date, and between 3 and 6 for the third date. On both dates, the largest count is about twice that of the smallest. Fluctuations of the kind that we would expect to encounter if the surface operates as a sampling process are observed. In order to see whether or not the counts conform to a Poisson model, the variance/mean ratio has also been calculated in Table 2 for the two dates.[15] The value of the ratio for the first date seems to be in accord with a Poisson model; the ratio for the third date looks too small. While the results cannot be regarded as conclusive, they do not indicate—and this is perhaps the most important thing at the present time—that a Poisson model has to be rejected.

A summary of the results on displacement for the first four dates is given in Table 3 for the N-S lines and in Table 4 for the E-W lines. The third column in Table 3 indicates the percentage of tiles that have moved to the west of their starting lines. There is an overall balance between the two directions (i.e., east and west) for both the first and third dates. The fourth and fifth columns in Table 3 give the range of values observed or the maximum distances moved to the west and east respectively. For the first date, this distance usually falls between 2 m and 4 m in each direction. Values for the range have in most cases become larger by the third date. There are two different ways by which we can calculate a mean of the displacement from a line. The first is to look at the distances from the line, where tiles on one side of the line have positive values (the west side here) and those on the other side have negative values. The second

15. Sokal and Rohlf, op. cit. (in note 6) 88–90.

Table 3. Displacement values for the N-S lines on two dates (distances are in m).

Line	*No.*	*%W*	*Max.* W	*Max.* E	$\overline{m}$	*S.D.*	$\lvert\overline{m}\rvert$	$\lvert S.D.\rvert$
				First Date				
03	6	33	2.83	2.04	−0.14	1.74	1.35	0.94
04	5	80	2.44	1.02	+0.77	1.28	1.18	0.81
05	7	43	3.75	2.29	+0.53	1.80	1.74	1.21
06	12	42	3.50	2.54	+0.38	1.65	1.23	1.11
Comb	30	46	3.75	2.54	+0.38	1.68	1.36	1.03
				Third Date				
03	6	67	2.58	1.55	+0.97	1.95	1.95	0.62
04	5	40	3.14	1.36	+0.14	1.76	1.17	1.18
05	3	0	—	3.39	−2.43	1.77	2.43	1.77
06	6	100	6.65	—	+3.16	2.61	3.16	2.61
Comb	20	60	6.65	3.39	+0.91	2.70	2.19	1.76

Table 4. Displacement values for the E-W lines on four dates (distances are in m).

Line	*No.*	*%S*	*Max.* S	*Max.* N	$\overline{m}$	*S.D.*	$\lvert\overline{m}\rvert$	$\lvert S.D.\rvert$
				First Date				
01	24	96	2.47	0.70	+0.77	0.72	0.86	0.60
02	15	67	3.09	5.58	+0.06	0.97	1.33	1.41
Comb	39	84	3.09	5.58	+0.49	1.36	1.04	1.00
				Second Date				
01	9	100	1.80	—	+0.91	0.52	0.91	0.52
02	11	73	2.00	1.98	+0.40	1.09	0.91	0.66
Comb	20	85	2.00	1.98	+0.63	0.91	0.91	0.59
				Third Date				
01	13	77	9.80	1.35	+1.41	2.72	1.66	2.56
02	6	83	2.43	3.47	+0.77	2.20	1.93	1.05
Comb	19	79	9.80	3.47	+1.12	2.56	1.74	2.17
				Fourth Date				
01	13	77	2.31	0.52	+0.82	0.78	0.94	0.62
02	14	71	4.05	0.55	+0.72	1.16	0.88	1.03
Comb	27	74	4.05	0.55	+0.74	1.00	0.91	0.84

approach is to look at the distances moved irrespective of sign or in absolute terms. The two means are given respectively in columns six and eight of Table 3 and their associated standard deviations in adjacent columns. For the first date, the values of $\overline{m}$ show a slight shift to the west with the combined value for the four rows being less than 0.5 m. The mean distance that an individual tile moved in an E-W direction (i.e., $\lvert\overline{m}\rvert$) varies between 1.18 m and 1.74 m among the replications and has a combined value of 1.36 m. When a comparison is made with the third date, the mean values calculated in both ways show a more or less consistent pattern of increase over time. The average distance that a tile moved in an E-W direction has now reached 2.19 m. While displacement as observed here cannot be described as pronounced, and few tiles have moved as much as 5 m away from their starting lines, many tiles are no longer within 2 m of their starting positions.

The same basic format is used in presenting the results on displacement for the two E-W lines in Table 4. A clear tendency for tiles to move to the south or downslope is seen. The percentages for the two earliest dates are particularly high. But counter to what we might expect, they decline somewhat on the fourth date. An explanation here might be an episode of plowing in a S-N direction, or upslope, at some time just before the fourth date. The range values show a considerable amount of variation from one date to the next. There is one case where a tile moved 9.80 m from its starting line. But again in overall terms, few tiles moved as much as 5 m in a N-S direction. The values for the mean $\overline{m}$ indicate a progressive downslope shift through the first three dates. The values of $|\overline{m}|$ are more or less comparable on the first and third dates with those observed for the N-S lines in Table 3.[16] Again the values for the fourth date are smaller than those for the third date, perhaps for the reason mentioned above. In general, there is the impression that slope has some effect on displacement but not a major one. The shift downslope after three years and perhaps as many as nine episodes of plowing is only on the order of 1 m. Observations made on the fifth and sixth visits to the site, however, revealed a different picture. Out of a total of 29 tiles visible on the surface in the summer of 1981, nine had moved at least 15 m south of their starting lines and another 15 tiles fell in the range of 5–15 m to the south. A major change in patterns of displacement had apparently occurred since the fourth date. Furrows at the time of the fifth visit had a N-S orientation and presumably one or more episodes of plowing had recently been done in a downslope direction. It is worth recalling that previously furrows usually had an E-W orientation in the area. During a brief sixth visit to the site, all seven of the tiles visible on the surface were at least 15 m to the south of the 01 line. The tiles observed on the latter date were not the same ones that had been seen on the fifth date, since the tiles on that visit had been removed for the study of edge-damage. In retrospect, it is likely that no episodes of downslope plowing were done through the time of the fourth visit, and the effects of slope being monitored up to this point were "passive" ones in the sense that plowing was being done at right angles to the slope and perhaps even up it. When plowing was eventually done downslope after the fourth date, the more "active" effects of slope on displacement were unleashed.

Discussion

One of the prime aspects of the experiments is the small amounts of work effort that they required in the field. Using a crew of three people, work at the site on a given visit was usually completed in less than a day. At the time that the experimental design was developed, we were in the midst of a busy field season in Calabria which, as is often the case in archaeology, offered little time for undertaking new kinds of work whose potential was as yet unknown. It was only possible to conduct experiments on a modest scale, and yet they were able to provide the kinds of information that we need in order to develop a more general understanding of the nature of surface material as well as to be in a better position for making inferences about actual surface collections in the context of local conditions in an area. The point to be made here is that such experiments can easily be incorporated into most multi-year survey projects. If experiments of this kind are carried out in a range of different areas over the next decade, it will be possible to put survey archaeology on a much sounder footing.

In terms of our general view of surface material, the experiments reveal in an even clearer way than the previous work on repeated collections that the surface operates as a sampling process with respect to material circulating in the plow-zone. The exact nature of the sampling process, however, remains uncertain. With regard to what would be the most favorable case, a Poisson model, the results as seen in Table 2 are mixed. In retrospect, especially given the small amounts of additional time and effort that would have been required in the field, it is unfortunate that more replication rows (e.g., six or eight N-S lines instead of only four) were not employed in the experiments, since they probably would already have permitted this fundamental question to be answered. It should not be long, however, before we can specify the essential character of the sampling process.

It is evident, as shown by the results in Table 1, that the surface-to-plow-zone ratio varies as surface conditions at the site change from one visit to the next. This change is something that all those who have done survey work for any length of time are familiar with intuitively: more pieces will be seen on the surface of a field after it has rained.[17] The experiments illustrate in quantitative terms the order of difference that can be encountered even in fields without ground cover or crops. The value under the best conditions (1:14) represents almost twice that observed under the worst conditions (1:23). Perhaps even more important is the realization of how small a proportion of the material in the plow-zone actually makes its appearance on the surface at any one time under even the best conditions. For every tile on the surface of the site, there are some 15 to 20 other tiles circulating within the plow-zone. What we are dealing with on the surface is only the tip of an iceberg, and a stochastic one at that. Where stochastic effects will come most actively into play is among those categories of artifacts that are rare or less abundant in the plow-zone. Due caution is thus called for when it comes to the analysis and interpretation of such categories of material, which often comprise the most indicative ones in cultural

16. The distance that a tile has moved from its starting line may be viewed as a vector representing one dimension of its displacement. There are two vectors to be considered and they are measured respectively by the two groups of replication rows. If one is interested in the full distance that a tile is on average being moved in two dimensions, one can think of the two vectors acting together to produce what is known as a resultant.

17. See, e.g., the discussion of surface conditions in Hirth, op. cit. (in note 1).

terms. One of the local factors that enters into the surface-to-plow-zone ratio is, of course, the depth of plowing. It is worth commenting that plowing done at the site in Calabria is relatively shallow in comparison with that in many other places in the world. When plowing is done to a greater depth, it is reasonable to expect correspondingly lower values for the ratio. It will be possible to state this expectation in quantitative terms when a wider corpus of results from experiments conducted in other parts of the world is available.

So far the discussion has concerned only material belonging to a single-size class. The real complication in the study of actual surface assemblages stems from the fact that different size classes of material will at any one time have different surface-to-plow-zone ratios. Pieces that are larger in size are represented in higher proportions on the surface of a site than smaller ones. Without going into the mathematics that are involved here, a multinomial formulation provides a means of characterizing the assemblage of pieces belonging to different size classes that is recovered from the surface of a site.[18] In order to begin to "calibrate" the size factor, it will be useful in future experiments to introduce a second or third size class.[19]

The results with regard to lateral displacement are both heartening in some senses and disturbing in others. The average distance that a tile moved through the first four visits is only a few meters, although it does seem to be gradually increasing over time. The point needs to be made here that even such modest displacement distances have implications when it comes to the estimation of site sizes (especially smaller ones) and the analysis of spatial patterns within sites on the basis of surface material. Observations made on the fifth and sixth dates suggest that slope as a local factor at a site can influence patterns of displacement in a major way. In fact, the spatial distribution of the tiles observed on the surface during the fifth and sixth visits is substantially different from the configuration of the tiles at the start of the experiment. One of the things that is clearly pointed up here is the need to conduct long-term experiments. It is likely that displacement distances are substantially underestimated in short-term plow-zone experiments.

In terms of our general outlook on surveys, the experiments in Calabria suggest that we need to replace the rather static view of surface material that many of us have traditionally held with a much more dynamic one. The surface of a plowed site as seen over time is a restless place. There has been an increasing awareness over the last 10 years that we need to return to basics in survey archaeology.[20] When this is done, at least in our own case, we are encouraged to adopt a much more complex view of survey work.

18. See note 14.

19. See the reworking of the data from Lewarch and O'Brien in note 7 as an example of the kinds of results that might be obtained. The value of the surface-to-plow-zone ratio for their largest class (0.111) is more than twice that for the smallest class (0.050). Since only three episodes of tillage were used in their experiment and conditions of equilibrium may not have been reached, these results should be regarded only as a rough first approximation illustrating the size factor.

20. Ammerman, op. cit. (in note 1) 81–83.

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