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Sorted Stone Nets and Circles of the Columbia Plateau: A Hypothesis

Abstract

On level to gently sloping surfaces of the Columbia Plateau, circles and networks of size-sorted stones are frequently found associated with large earth (Mima) mounds. These distinctive beds of stones have been regarded as either the product of periglacial freeze-thaw processes or of erosion. We examined circular stone beds around mounds of different size and mapped the relation of stone nets to mounds and recent pocket gopher activity areas. Our study plots were adjacent to the Lawrence Memorial Grassland Preserve, near Shaniko, southern Wasco County, Oregon. The degree of completeness of stone circles was directly correlated with mound diameter and height. Pocket gophers tunneled extensively in intermound areas with well-developed stone nets. Several species of fleshy-rooted perennial plants are largely confined to the stone net microhabitat, probably by more intense pocket gopher feeding elsewhere. The beds of sorted stones appear to be formed and maintained by the mining of the underlying soil by pocket gophers that dig foraging tunnels into rocky intermound areas in search of food plants. These observations suggest that pocket gophers are much more important in landscape and vegetational dynamics than previously recognized.

Introduction

Large areas of the Columbia Plateau are covered by earth mounds, known as Mima mounds, that are commonly 0.5-1.0 m in height and 15-25 m in diameter. A distinctive feature of much of this landscape is the presence of sharply defined beds of bare, sorted stones that partially or completely encircle the mounds and occasionally form intermound stripes and polygonal networks. Well developed stone circles and nets of this type have been reported from eastern Washington (Kaatz 1959, Tallyn 1980), southwestern Idaho (Malde 1961, 1964, Fosberg 1965), and north-central Oregon (Waters and Flagler 1929, Nelson 1977, Johnson 1982). Mounds surrounded by well developed stone circles also occur in Siskiyou and Shasta Counties, California (Masson 1949).

Kaatz (1959), Malde (1961, 1964), and Fosberg (1965) state that the beds consist of tightly packed stones ranging in size from pebbles to boulders. The stones are sorted by size, with larger elements predominating on top. Frost-shattered stones are common in the beds, and tabular stones are sometimes found packed on edge into the rock network, their long axis reportedly lying parallel to the border of narrow beds, or showing a random orientation in wider areas. The zone of soil-free stones tends to be less than 30 cm thick, and may rest directly on basaltic bedrock or overlie stony soil of variable depth. These beds are sometimes termed "gutters" by proponents of geological hypotheses of their origin (Goldthwait 1976).

Circular and polygonal nets are restricted to surfaces less than about two percent in slope (Malde 1964). As slope increases the beds transform into intermound stripes corresponding to drainageways, and these increasingly become oriented parallel to the slope, separating "beaded" lines of interconnected mounds (Malde 1961, 1964). Sorted stone stripes not associated with mounds, which may represent a different phenomenon, also occur on steep slopes of the Columbia Plateau (Pyrch 1973).

Two major hypotheses have been offered for the origin of these systems of mounds and stone networks: differential erosion and periglacial freeze-thaw dynamics. Waters and Flagler (1929) concluded that the mounds were the result of erosion of volcanic ash deposited over the surface of the basaltic rock, with the intermound zones being "erosion furrows" and the bare rock beds more heavily eroded "erosion channels." This view was supported by Knechtel (1952) and Washburn (1980). Kaatz (1959), Brunnschweiler (1962), Malde (1961, 1964), and Fosberg (1965) considered the mounds and sorted stone nets to be a consequence of periglacial processes. Kaatz (1959) postulated that the mounds were the remnant centers of ice-wedge polygons which suffered erosion when the climate warmed and the ice wedges melted. He considered the stone nets and stripes to have formed by frost-sorting action after the mounds had been defined. Brunnschweiler (1962) and Malde (1961, 1964) concluded that the mounds and stone networks formed simultaneously in the late Pleistocene due to processes of freeze-thaw and solifluction. Kaatz (1959) stated that the stone networks "defy any possible alternative to frost action for their formation" and Malde (1964) that they "are reasonably interpreted only by frost action." Fosberg (1965) inferred that the stone networks were the results of intense frost sorting, and may have formed prior to deposition of the soil material that was later eroded to form the mounds. More recent studies on the Deschutes-Umatilla Plateau of north-central Oregon (Nelson 1977, Johnson 1982) have tended to support the hypothesis of frost-sorting by showing that small-scale frost action still occurs.

In contrast, several recent studies (Cox 1984, Cox and Gakahu 1986, Cox and Allen 1987) have provided support for the hypothesis that North American Mima mounds are formed by soil translocation by pocket gophers. Past statements of this hypothesis have not accounted for the strikingly developed stone circles and nets of the Columbia Plateau, other than to suggest that large rocks are often exposed in intermound areas as a result of mining and removal of the soil by pocket gopher tunneling (e.g., Dalquest and Scheffer 1942, Scheffer 1947). We therefore investigated a typical mound and stone net site on the Columbia Plateau in north-central Oregon to determine if the stone nets 1) are so intimately associated with mounds as to demand a common mechanism of origin, and 2) if soil mining and translocation by pocket gophers can account for formation of sorted stone circles and nets.

Methods

Studies were carried out at the Lawrence Memorial Grassland Preserve, a 153-ha area near Shaniko, Wasco County, Oregon (44°57'N, 120°48'W), and on adjacent rangeland of the Priday Brothers Corporation. The preserve, a Registered National Natural Landmark owned by the Nature Conservancy, includes a portion of the Shaniko Plateau, formed of Columbia River Basalts, together with several ravines that slope steeply northward into the canyon of Ward Creek, 122 m below. The site has a cold semi-desert climate, with an average annual rainfall of 280 mm. The surface of the plateau is typically mounded "biscuit scabland," with numerous Mima mounds up to about 1 m in height and 20 m in diameter. The mound soils are classed as Condon aeolian silt loams, and the soils of intermounds as Bakeoven residual very cobbly loams. The vegetation of the mounds and deeper upland soils is dominated by Idaho fescue (*Festuca idahoensis*) and bluebunch wheatgrass (*Agropyron spicatum*), while the shallow intermound soils are dominated by scabland sagebrush (*Artemisia rigida*), Sandberg bluegrass (*Poa sandbergii*), seven taxa of biscuitroot (*Lomatium* spp.), and bitterroot (*Lewisia rediviva*). The northern pocket gopher (*Thomomys talpoides*) is abundant. A detailed physical and biotic inventory of the Preserve is given by Copeland (1980).

Our studies were conducted between 24 and 28 May 1986. Data were collected on two study plots. We measured and mapped mounds on a 90 x 150 m plot (1.35 ha) located on a level area of the plateau surface, using a surveying level. The degree of development of stone circles around all mounds on this plot was recorded. A second plot, 40 x 70 m in size (0.28 ha), was centered on a level intermound area about 20 x 50 m in extent, surrounded by eight well-developed mounds. This extensive intermound area exhibited a scattering of soil islands within a complex network of stone circles and polygons (Figure 1). We subdivided this plot with a 10 x 10 m grid and sketch-mapped the mounds, soil islands, and sorted stone networks, together with the locations of recent (to about 2 yr of age) pocket gopher heaps located in proximity to stone beds or within islands of soil and rock surrounded by stone polygons. Additional observations were made on the relationship of surficial evidence of pocket gopher activity to mounds and sorted stone beds at several other locations on the plateau top and on ravine slopes.

Plant names are based on Hitchcock and Cronquist (1973) and statistical procedures on Zar (1974).

Results

A close association existed between mounds and stone circles. A few mounds were completely encircled by stone beds, although on our 1.35-ha plot stone circles ranged from 0 percent to 85

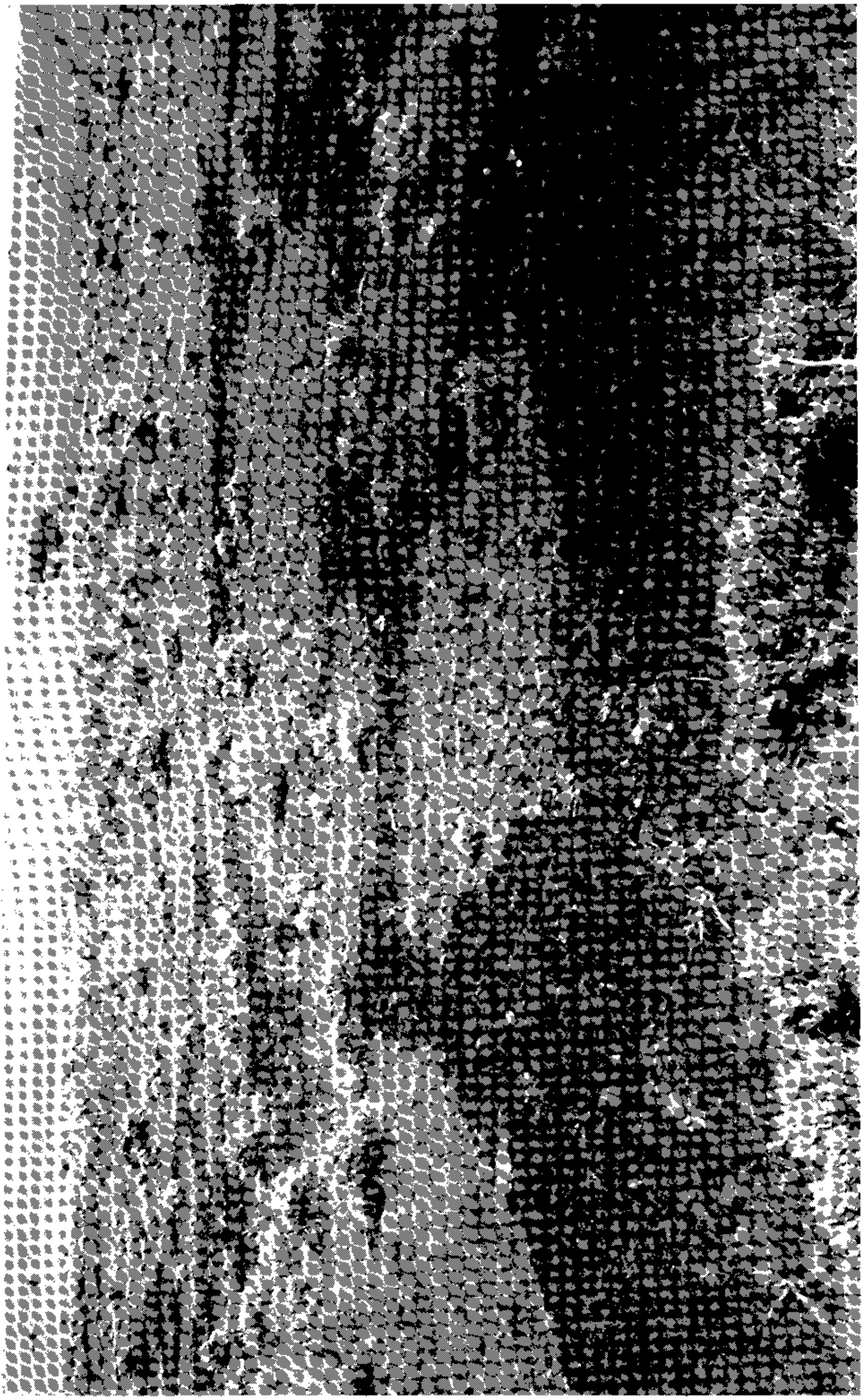

Figure 1. Sorted stone nets enclosing islands of soil and rock in a level intermound site adjacent to the Lawrence Memorial Grassland Preserve near Shaniko, southern Wasco County, Oregon.

percent in completeness (n = 37). A significant relationship existed between the size of the mound and the degree of development of the encircling stone bed. Percent completeness was highly correlated with mound height ($r = 0.479$, $P < 0.01$) and volume ($r = 0.472$, $P < 0.01$), and significantly correlated with mound diameter ($r = 0.348$, $P < 0.05$).

Where present, stone circles usually lay within 1 m of the base of the mound slope. On very slight slopes (< 2-3°), the stone beds were usually best developed on the downslope sides of mounds. For some of these mounds the stone beds on the downslope side appeared to bulge above the general level of the immediately adjacent intermound zone. On steeper slopes, stone beds sometimes closely encircled the upper and lateral sides of mounds, but diverged to create stripes extending downslope for a short distance (Figure 2A).

The stone beds typically showed a sharp boundary with both mound and intermound soils. The larger rocks of the central areas of the beds were densely encrusted with the black lichen *Lecidea cascadensis* (Rossman 1977) on their exposed surfaces, indicating long-term stability. In many locations, both on mound and intermound edges of stone nets, small pebbles and stones without strongly developed black lichen cover predominated. We did not observe unusual patterns of vertical packing or orientation of tabular rocks in these networks.

The mapped 0.28-ha plot exhibited stone beds that bounded or partially encircled the adjacent mounds, together with an extensive intermound network containing irregularly shaped islands of soil and rock ranging in area from about 1 m^2 to over 100 m^2 (Figure 3). The islands contained large stones, and appeared to differ from the surrounding stone beds only in the presence of finer textural material between and partially covering the larger stones.

Recent pocket gopher heaps were present throughout the intermound complex of stone nets and soil-and-rock islands. These heaps (n = 56) were concentrated at the edges of the stone beds (34), although many lay in the interior of the soil-and-rock islands (19). Three heaps, however, lay on the surface of stone beds. Numerous unmapped heaps were also present on the surfaces of

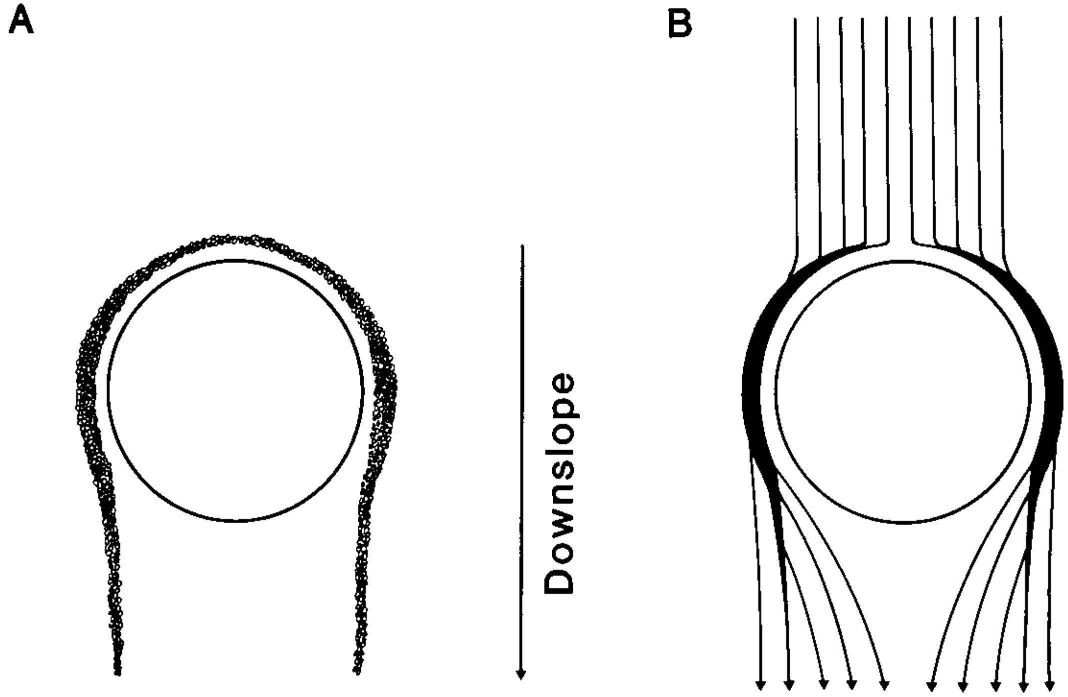

Figure 2. A. Arrangement of sorted stone beds bordering a Mima mound on a slope of 3-5° at the Lawrence Memorial Grassland Preserve, southern Wasco County, Oregon. B. Pattern of water movement and concentration in relation to the mound and stone net pattern shown in A.

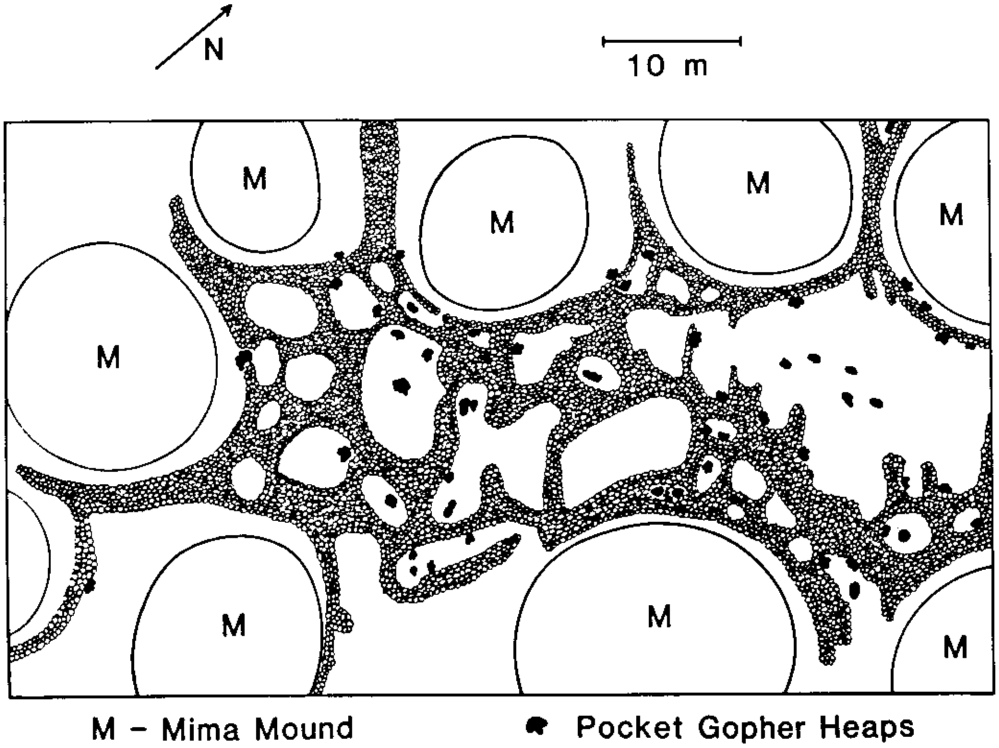

Figure 3. Pattern of Mima mounds, stone circles, intermound stone nets and islands of soil and rock on a 40 x 70 m plot centered on a large intermound flat on land adjacent to the Lawrence Memorial Grassland Preserve, southern Wasco County, Oregon. Pocket gopher heaps are shown only within and adjacent to the network of stone beds; heaps were also abundant on the mound surfaces.

the adjacent mounds. The pocket gopher heaps consisted of fine soil, gravel, and pebbles up to a maximum diameter of about 60 mm.

Discussion

The close proximity of sorted stone circles to edges of mounds and the significant relationship of stone circle development to mound size suggest that the mounds and sorted stone circles form concurrently, contrary to the suggestions of Kaatz (1959) and Fosberg (1965). Moreover, the presence of small, lightly weathered, lichen-free stones at the edges of some beds suggests that pavement formation is still occurring, or that, at least, these systems are to some degree dynamic.

We postulate that tunneling and the translocation of soil by geomyid pocket gophers, in addition to forming the mounds, create and maintain the sorted stone circles and nets that exist in association with these mounds on the Columbia Plateau. This hypothesis is outlined in detail below, and although we have formulated it specifically for the conditions prevailing at the Lawrence Memorial Grassland Preserve, we propose that it applies in principle to other Columbia Plateau localities.

Pocket gophers maintain their permanent nest and food storage chambers in the mounds because of frozen or waterlogged conditions of intermound areas during late winter and early spring. They tunnel extensively into the intermound zone during dry seasons. This tunneling is evidenced by the deposition of heaps on the intermound margins of stone networks and on islands of soil and rock enclosed by stone nets. The distribution of heaps also demonstrates that the animals commonly tunnel beneath the stone beds. The low frequency of heaps in areas of otherwise soil-free stone beds suggests that the animals are largely unable to penetrate the stone beds themselves.

Intermound tunneling is presumably carried out in search of food plants. Pocket gophers of the genus *Thomomys* consume a broad range of root and shoot tissues. Ingles (1952) noted that in the California Sierras the rootstocks of *Lewisia nevadensis* were harvested and stored in caches by *T. monticola.* In eastern Washington, Daubenmire (1970) reported that rodents (probably *T. talpoides*) dug extensively in scabland soils, presumably for subterranean plant materials such as *Lomatium* roots. In northern Oregon, Moore and Reid (1951) found that removal of *T. talpoides* from mountain meadows over an eight-year period resulted in a several-fold increase in *Lomatium leptocarpum,* together with *Taraxacum officinale,* the roots of which were considered to be the favorite food of the pocket gopher. Thus, when available, the corms and roots of perennial plants are important foods of *T. talpoides.*

At the Lawrence Memorial Grassland Preserve the frequency of geophytes and fleshy-rooted hemicryptophytes is greater in the intermound zone than on the mounds, but the sparse vegetation of the stone beds is heavily dominated by such plants. Winward and Youtie (1978), for example, found only three species of geophytic perennial forbs, with a combined frequency of occurrence of 17 percent, in the sample plots from the *Festuca-Agropyron* community that dominates the mounds. On the mounds, pocket gophers eat the whole root systems of *Agropyron* and *Achillea* (D. B. Lawrence, pers. comm., 1986), and have probably eliminated most fleshy-rooted perennials. In the *Artemisia-Poa-Lomatium* community of intermound scabland, however, five species of fleshy-rooted perennials with a combined frequency of 72 percent were recorded by Winward and Youtie (1978). They noted that four geophytes dominated the stone beds: *Lomatium cous, L. minus, Delphinium nuttalianum,* and *Allium macrum.* The predominance of these species in intermound areas, and especially the stone beds, may result from lower accessibility to pocket gophers.

We suggest that the tunneling of pocket gophers in search of fleshy-rooted plants in the stony intermound soils is the primary mechanism that forms and maintains the sorted stone networks. The tunnel space created by tunneling beneath the stone nets and through the shallow intermound soil during dry periods is obliterated by settling of material from above during wet seasons. The downward movement of material is size-selective, the soil and smaller stones filtering downward most easily. The relatively greater downward movement of smaller stones creates the size-sorting that characterizes the beds. The soil fines and smallest stones (to the maximum size commonly mined and moved by pocket gophers) are ultimately removed and deposited on the mound surfaces, at the edges of stone beds, or on soil-and-rock islands, thus maintaining the fine textural composition of these areas. The lightly weathered, lichen-free stones that are present at the borders of many stone beds result from this deposition. Once a mature bed of stones larger than those that pocket gophers can mine has been formed it remains stable, and animal activity simply removes fine soil materials that are carried into the bed by erosion.

On level or nearly level sites, this mechanism leads to the formation of an encircling bed just beyond the mound edge, since animal activity is mound-centered, and soil conditions are similar in all directions. Where broad intermound areas form, because of thin soils that limit proximity of mounds to each other, polygonal nets may develop in which islands of soil and rock represent locations of less intensive tunneling and occasional deposition of soil mined from beneath the sorted stone beds.

How the mechanics of this process change with increase in slope is less clear. We suspect that it involves an intensification of the process responsible for the downslope pattern shown in Figure 2A. For a mound on a slope of few degrees, soil waterlogging during winter and spring will vary in severity around the margin. A mound impedes the movement of water moving downslope through the soil system, forcing the flow to become more concentrated along the sides of the mound (Figure 2B). Thus, the upper edge and sides of the mound will exhibit the wettest conditions, and the lower side will show a "moisture shadow." Excavation by pocket gophers appears to be greatest when and where soils are moist (Cox and Allen 1987), and thus the removal of soil may be greatest on the wetter lateral edges of mounds on slopes. The downslope extension of the lateral beds may reflect the downslope continuation of a wet soil zone that favors soil mining and moundward translocation. This process may lead to the linkage of lateral stone beds of neighboring mounds up- and downslope, as well as to the linkage of the mounds themselves, creating the pattern of mounds and stone stripes commonly seen on slopes.

We therefore postulate that the origin of sorted stone circles and nets is intimately associated with that of Mima mounds on the Columbia Plateau, and that their formation and maintenance result from an interaction of soils, pocket gophers, and fleshy-rooted perennial plants.

Acknowledgments

We thank Catherine MacDonald, Oregon Land Steward, Nature Conservancy, for permission to carry out studies at the Lawrence Memorial Grassland Preserve, and for providing background information about the site. Annan Priday gave permission to collect soil samples from areas on the Priday Brothers ranch adjacent to the Preserve. Donald B. Lawrence provided advice and suggestions on the study and reviewed the manuscript in detail. We also thank R. F. Daubenmire, P. C. Lemon, T. L. Péwé, A. L. Washburn, and B. Youtie for criticism and suggestions on the manuscript. This study was supported by NSF grant INT-8420336 and by grant 211187 from the San Diego State University Foundation.

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Received 5 December 1986
Accepted for Publication 29 March 1987.

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