THE ORIGIN OF THE MIMA MOUNDS OF WESTERN WASHINGTON

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ABSTRACT

The Mima mounds occur on certain prairies of glacial outwash in western Washington. The mounds are closely spaced, round or oval, from 10 to 40 feet in diameter, and from 1 to 7 feet in height. The typical mound is a double-convex lens of loose, unstratified, black silt-gravel set in a shallow pit in stratified yellow outwash gravel. Mounds are found only where a thin layer of soil overlies a compact bed of gravel, not on deep prairie soils.

The Mima mounds are formed by pocket gophers (*Thomomys talpoides*) over long periods of time. Gopher activity in any particular place destined to become a mound site starts with intensive burrowing, such as that required in the construction of a nest, which loosens the soil and stimulates the growth of vegetation. The vegetation, in turn, furnishes food for the gophers and encourages them to concentrate their activities in the vicinity. A stage is reached where the gophers find sufficient food on the mounds to maintain them the year around, making it unnecessary for them to forage, except at rare intervals, into the intermound depressions.

In deep burrowing to create living quarters gophers dig a shallow pit in the stratified gravel beneath each mound. The smaller elements in the stratified gravel removed by deep burrowing become mixed with silt to form the substance of the mound lens. Stones too large to be moved by the gophers are undermined and settle to the bottom of the mound.

In shallow exploratory burrowing in the peripheral zone the gophers do not undermine large stones but remove soil from about them, eventually leaving them exposed on the surface of the ground.

INTRODUCTION

The Mima[1] mounds of western Washington were first reported by Charles Wilkes[2] nearly a century ago. The explorer was impressed by the flowing symmetry of the mounds and investigated them in an attempt to discover their origin, which was thought to be of an artificial nature. The many hypotheses offered in ensuing years to explain the mounds have been fully and ably summarized by J Harlen Bretz.[3]

[1] From Mima Prairie, pronounced *mī' mȧ*.

[2] *Narrative of the United States Exploring Expedition during the years 1838, 1839, 1840, 1841, 1842* (Philadelphia, 1845), Vol. IV.

[3] "Glaciation of the Puget Sound Region," *Wash. Geol. Surv. Bull. VIII* (1913), pp. 97–106.

DESCRIPTION OF THE MOUND PRAIRIES

The Mima mounds are most abundant on certain prairies formed by the outwash of the last continental ice sheet (Vashon). These mound-bearing prairies are most numerous in Thurston County but are found also in Pierce, Lewis, Grays Harbor, and Mason counties.

The mound prairies are underlain by *stratified outwash gravel*, whose materials vary in size from sand to small boulders, most of the pebbles ranging from the size of a pea to that of a walnut.[4] The thickness of the stratified gravel is unknown, but it is locally at least 50 feet, as revealed by a railroad cut on Mima Prairie.

A *silt-gravel* layer composed of fine silt, sand, and small pebbles covers the surfaces of both mound prairies and mound-free prairies. It is dark brown or black in color, contrasting strongly with the yellowish color of the underlying stratified gravel. It is rather soft, lacks stratification, and varies in depth from a few inches to several feet. The contact between the silt-gravel and the stratified gravel is usually abrupt.

The silt-gravel was doubtless laid down as an overwash by glacial streams, although any original stratification has disappeared as the result of organic action—penetration of grass roots and the burrowing of moles, gophers, and other animals. The silt is now thoroughly mixed with the gravel. The dark color is due to a high humus content and is typical of native prairie soils in the Northwest.

Vegetation on the mound prairies is sparse and is characterized by annuals, grasses, and mosses which dry up in the summer. A species of moss, *Rhacomitrium canescens* var. *ericoides*, imparts the dominant brown color to the summer landscape. Trees do not occur on the prairies except where they have invaded in recent years.

DESCRIPTION OF THE MOUNDS

The outlines of the Mima mounds are smooth and flowing, giving the impression of great spheres nearly buried in the earth (Figs. 1, 3). Their basal diameters vary from 8 to 40 feet, although on prairies where the mounds are best developed their diameters do not vary greatly from 20 feet. In height the mounds range from less than 1 foot to 7 feet. They reach their maximum size on Mima Prairie,

[4] C. C. Nikiforoff, "The Inversion of the Great Soil Zones in Western Washington," *Geog. Rev.*, Vol. XXVII (1937), p. 212.

FIG. 1.—Glacial outwash prairie two miles southwest of Tenino, Washington, covered with typical Mima mounds. A shallow channel appears in the middle distance. Mound sections appear along a road cut in the foreground. March 10, 1941.

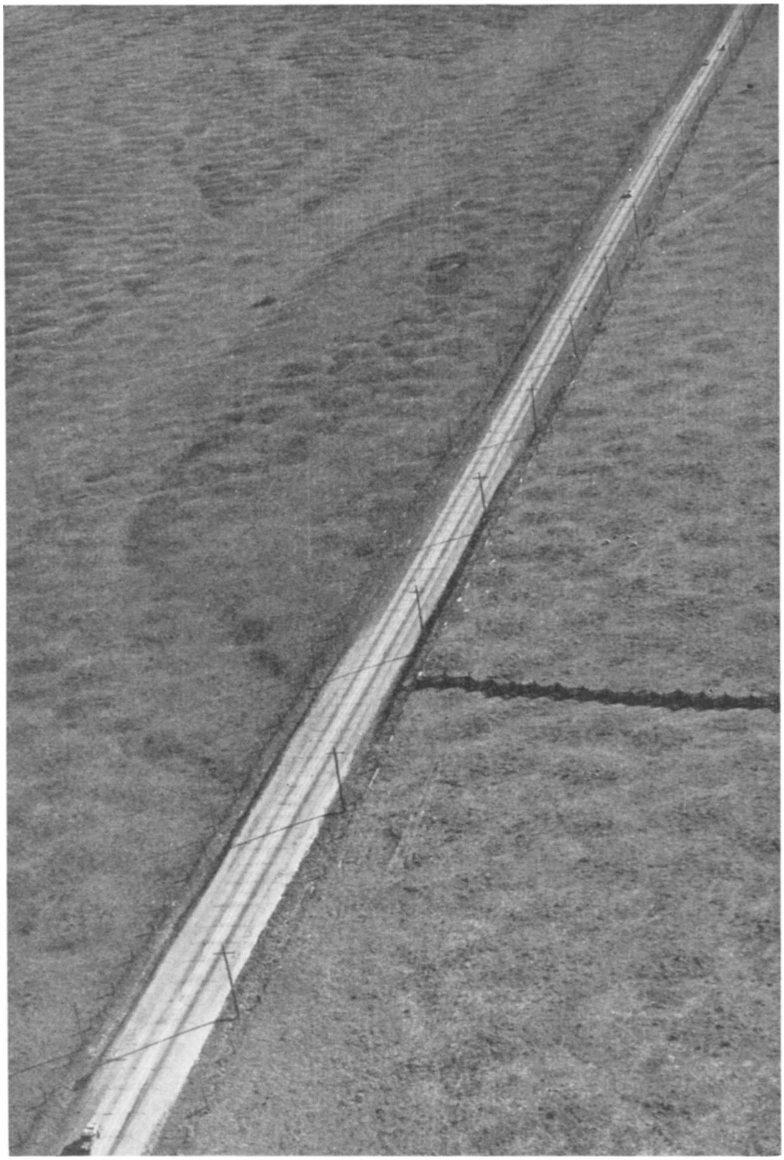

FIG. 2.—Mima mounds on outwash channels and terraces on a prairie two miles southwest of Tenino, Washington. Individual gopher "hills" appear as small dark spots on the mounds. March 10, 1941.

Thurston County—the type locality—although some mounds on Rocky Prairie, near Tenino, are nearly as large. Seen from above, the Mima mounds are round or slightly oval in shape (Fig. 2). In a few instances two mounds are joined together by a low saddle, and, very rarely, three are joined together in the shape of a rude L. Most of the mounds in any one locality are of approximately the same size.

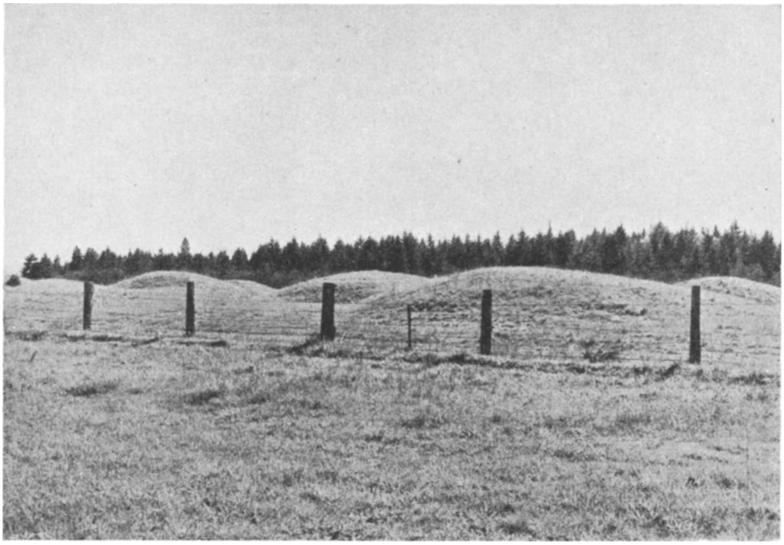

FIG. 3.—Profile view of Mima mounds on the type locality, one and one-half miles S.E. of Bordeaux, Washington. The field in the foreground has been leveled for agricultural use. Height of mounds ranges from six to seven feet. April 18, 1941.

The symmetry and regularity of size of the mounds often give the observer an impression of regular spacing, which tends to disappear on closer inspection. There is absolutely no regularity of spacing nor are the mounds oriented in any direction. The long axes of oval mounds lie at various angles to one another and have no consistent relation to the slope of the ground. In the few triple mounds seen the two intermound saddles lay at nearly right angles to each other.

Certain other unrelated topographic features occurring on the mound prairies should be mentioned. These include channels, terraces, kettles, and Ford mounds.[5] Ford mounds are large, irregular

[5] Bretz, *op. cit.*, p. 87.

masses of gravel formed by outwash between two or more kettles and are not to be confused with Mima mounds, although in some cases there is a superficial resemblance. Ford mounds are composed of yellowish, coarse, irregularly stratified gravel, while Mima mounds are composed of unstratified black silt-gravel. A Ford mound may quickly be recognized by the fact that compact stratified gravel lies but a few inches below the surface of the mound, while in a Mima mound it lies several feet below. The surfaces of Ford mounds are often strewn with cobbles of various sizes, while cobbles never occur on the surfaces of Mima mounds.

The prairie surface between the mounds is usually not level but slopes gently, lending emphasis to the symmetrical, flowing contour of the mounds. Many intermound spaces are closed depressions, i.e., rimmed about by mounds and intermound saddles. On some prairies small but typical Mima mounds rise from a flat surface.

The intermound areas may or may not contain exposed cobbles. Where present, the *intermound cobbles* generally form an irregular layer of stones in the deep part of the depressions and are most abundant where the intermound areas are deepest. Intermound cobbles weigh up to 50 pounds but on most prairies are about the size of a football (Fig. 4).

Cross sections of Mima mounds appear along road cuts and in gravel pits (Fig. 5). The shape of the basal contact of the mounds varies with the size of the mound. The *smaller* mounds are generally double-convex lenses of silt-gravel resting in a depression in the stratified gravel. For example, on Scott's Prairie the basal convexity of the average mound is greater than the surface convexity. In *larger* mounds—as, for example, those on Rocky Prairie, Thurston County—the basal contacts dip downward only slightly in the center. The amount of curvature of the base of the mounds on any prairie seems to be inversely proportional to the average size of the Mima mounds. The low, wide mounds tend to have shallower basal convexities than high, narrow mounds. Individual variation, however, is great.

The strata of the coarse outwash gravel do not bend downward under the bases of the silt-gravel mound lenses or intermound depressions but are truncated abruptly by the latter.

FIG. 4.—Exposed cobbles in an intermound depression on Rocky Prairie, three miles north of Tenino, Washington. The largest cobble here weighs approximately twenty-five pounds. April 17, 1941.

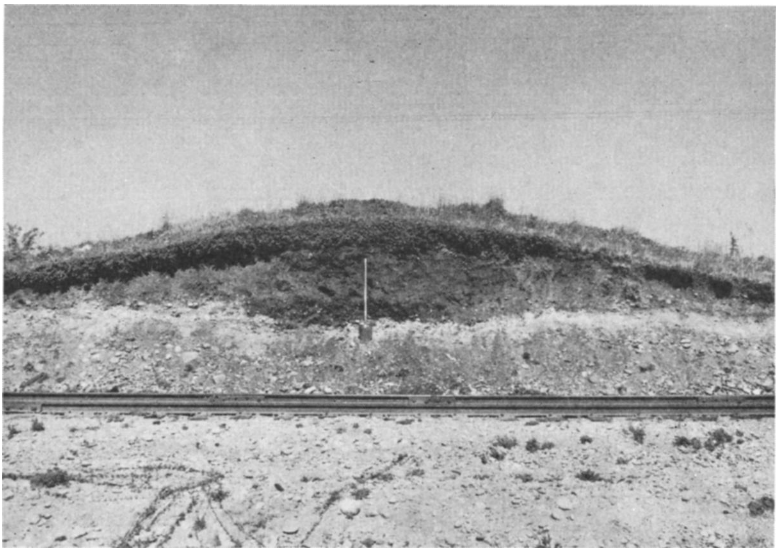

FIG. 5.—Characteristic section of Mima mound, exposed by railroad cut three and one-half miles N.N.E. of Tenino, Washington, showing lenticular body of black silt-gravel lying in bed of yellow stratified gravel. The section is about three feet in front of the vertical axis of the mound; overlying slump and vegetation have been cleared away; the shovel is five feet long overall. April 18, 1941.

An irregular layer of *mound cobbles* often lies beneath the base of the mound lens. The mound cobble layer, as well as intermound cobbles, is found only where cobbles of approximately the same size are present in the underlying stratified gravel. Where cobbles are abundant in the latter, mound cobbles and intermound cobbles are abundant. Where cobbles are scarce or absent in the local stratified

FIG. 6.—A Mima mound "root" along the basal contact of black silt-gravel and yellow stratified gravel, exposed by a road cut on Mima Prairie. The root lies halfway between the vertical axis of the mound and the edge of the mound; it is four feet below the surface of the mound; the scale mark is one foot long. April 18, 1941.

gravel, mound cobbles and intermound cobbles are correspondingly scarce or absent.

The basal contact of the Mima mound is irregular. Here and there small extensions of silt-gravel project downward into the stratified gravel (Fig. 6). These extensions are roundish in cross section and vary from 2 to 6 inches in diameter. They twist and turn, some of them at right angles. They do not taper to points but end with flat or bluntly rounded ends. Rarely the terminus is distinctly swollen. Some of them lead from the mound into the stratified gravel and up again into the mound without ending. These extensions were referred to by Bretz[6] as "mound roots."

PRESENT THEORY OF ORIGIN

We deduce that the Mima mounds have been formed by the localized activities of pocket gophers (*T. talpoides*) over thousands of years. We have seen what we consider developmental stages of "growing" mounds, i.e., mounds in the process of formation at the present time, as well as fully formed or "mature" mounds. The essential conditions necessary for the formation of Mima mounds are (1) *the presence of gophers* and (2) *a prairie area consisting of a thin layer of silt overlying a dense layer of gravel unfavorable to the growth of plant roots.*[7]

INITIATION OF THE MOUNDS

Pocket gophers presumably migrated northward into western Washington in postglacial or interglacial times to occupy extensive grasslands. The gophers in western Washington do not and apparently cannot exist in timbered areas. With the invasion and spread of forests the gophers were crowded on to the treeless outwash prairies. With a few exceptions, discussed later, pocket gophers and Mima mounds occur together.

At the close of the last ice age the outwash prairies were quite smooth (except for low-relief terraces, kettles, and channels) and were covered with a thin layer of silt overwash left by the streams of the Vashon glacier.[8] Gophers invading the prairie were restricted in burrowing to the thin upper silt layer and did not burrow extensively into the hard stratified gravel, except here and there for nesting and living quarters. Once a deep burrow was so constructed in the stratified gravel, the area penetrated thenceforth offered easier burrowing. Earth removed in digging the burrows was thrown to the surface in gopher "hills."[9] The increased depth, looseness, and water-holding

[6] *Ibid.*, p. 84.

[7] We suspect that in other parts of the country a clay hardpan or bedrock may substitute for the dense gravel.

[8] Cf. J. Hoover Mackin, "Erosional History of the Big Horn Basin, Wyoming," *Bull. Geol. Soc. Amer.*, Vol. XLVIII (1937), p. 826.

[9] Small piles of earth, rarely exceeding 1 cubic foot in volume, that are thrown up in a few hours or overnight.

capacity of the earth in the vicinity of the nest burrows resulted in a more flourishing growth of vegetation. The roots of this vegetation served as food for the gophers and tended to concentrate them in this vicinity. It might be argued that gophers attracted to, and therefore feeding more intensively in, the vicinity of their living

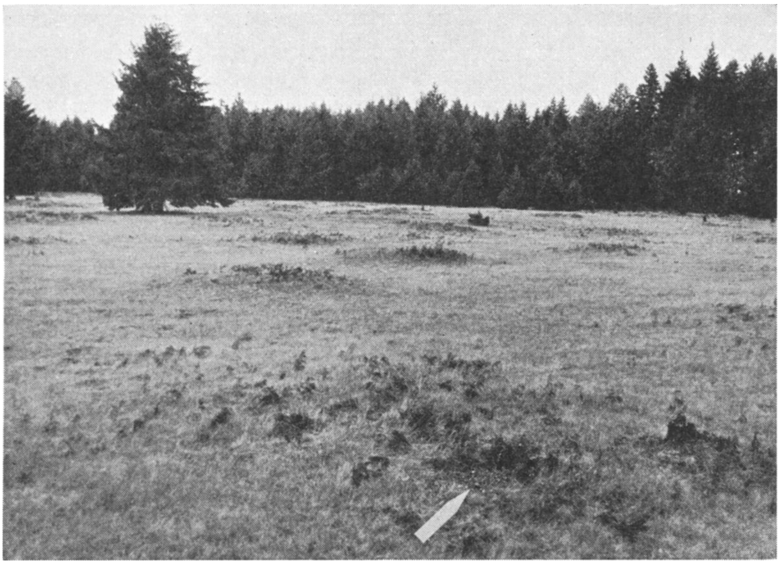

FIG. 7.—Prairie one mile southwest of Tenino, Washington, showing more luxuriant growth of vegetation on top of Mima mounds than on intermound areas. The dark-colored plant is bracken fern. Arrow indicates a gopher hill thrown up near the top of the mound. January 25, 1941.

quarters would *reduce* the vegetation rather than increase it. Actual observations, however, of mounds where gophers are actively working at the present time indicate that the vegetation *is* more luxuriant on the mounds than elsewhere in the vicinity (Fig. 7). Root-cutting by gophers is apparently not intensive enough to counteract the stimulating effect upon plant growth of a loosening of the soil by the animals.

GROWTH OF THE MOUNDS

To explain clearly the accumulation of earth on the mound sites, it is necessary to describe in considerable detail the *earth-carrying* *habits* of the gopher, for the accumulation is dependent upon minute and not readily apparent differences in the rate of exchange of earth between the mounds and the surrounding areas.

When digging burrows, gophers dispose of earth in two ways: either they throw it out on the surface forming the familiar gopher hills, or they deposit it in abandoned burrows. Evidence of the latter action is best seen in areas of heavy snowfall where gophers construct burrows through the snow and subsequently fill them with earth. When the snow melts in the spring the filled burrows are exposed as long casts which attest the distance to which gophers will transport earth (Fig. 8).

When a gopher in digging a deep burrow encounters a stone fragment too large to handle, it burrows around and beneath the stone, allowing it to settle. The earth removed is eventually thrown out on the surface of the ground, thus burying the rock. The settling of stones and logs by gophers has been discussed by Joseph Grinnell.[10] This sinking of stones accounts for the layer of cobbles at the base of the mound. The largest pebble found in several fresh gopher hills examined by us weighed 137 grams. Pebbles of this size and smaller are commonly mixed throughout the silt-gravel of the mound, while larger pebbles are found in the mound cobble layer at the bottom of the lens.

Gophers construct what may be called *exploratory* burrows which radiate from the mounds. The exact reason for their construction is unknown, but they are probably made by gophers that prospect some distance into the intermound area for food before they become discouraged and turn back. On Scott's Prairie we found nineteen exploratory burrows leading out from one small "growing" Mima mound. These averaged about 10 feet in length. All were solidly plugged at the point where they entered the mound but were otherwise open. Many had partially collapsed or had been broken into by the feet of cattle, and all were obviously in disuse. Five of the nineteen were of relatively recent construction, for earth thrown out as gopher hills along their length was not yet covered with moss. Along one of these five burrows we found enough earth thrown out on the

[10] "The Burrowing Rodents of California as Agents in Soil Formation," *Jour. Mammalogy*, Vol. IV (1923), pp. 137–49.

surface as gopher hills to account for all the earth removed in tunneling. Along two others about half the earth had been brought to the surface. Of the remaining two only a trace of the earth was found exposed on the surface. Almost the entire quantity of earth removed in the construction of two burrows, and about half from two more, had actually been transported back into the mound where it was

FIG. 8.—Cast of earth formed by a pocket gopher. Dirt removed in the process of digging a ground tunnel was transferred to a tunnel in the snow, later exposed when the snow melted. Yakima Park, Mt. Rainier, Washington, July 6, 1933.

probably used to fill abandoned burrows and might, at a later date, have been brought to the surface of the mound as a gopher hill.

This shuttling of earth, long continued, accounts for the sunken contour of the intermound area and for the greatest part of the volume of the Mima mound. The volume of certain small Mima mounds, as on Scott's Prairie, where the surface of the intermound area is nearly level, is attributed primarily to the "fluffiness" of the gopher-worked soil of the mounds.

Intermound cobbles are exposed in the removal of earth to the mound. When a gopher making an exploratory burrow encounters a stone too large to handle, it removes the earth from about the stone. Year after year earth is removed and carried to the mound, and the stone is eventually left exposed on the surface as an intermound cobble. It should be emphasized that in shallow *exploratory* burrowing the gopher has no incentive to dig under a large obstacle in its path and thus allow it to settle; in *deep* burrowing for living quarters the gopher attempts to tunnel under all such obstacles in order to reach a depth of several feet, at which this species of rodent habitually makes its nest.

The "mound roots" of Bretz are simply abandoned gopher burrows filled with earth. We have observed such roots in the stage of fresh, hollow burrows, as freshly filled burrows, and as burrows constructed and filled centuries ago by gophers long since gone from the area of the mounds.

The areal spacing of Mima mounds is about equal to the spacing of individual gopher "homes" or "territories" in other parts of the Pacific Northwest where soil conditions are such that mounds do not occur. The voluntary restriction of an individual gopher to a small area, even where food is abundant in the surrounding territory, has been mentioned by many writers.[11] We assume that the restriction is much more pronounced where surrounding areas are almost barren of food.

Where gophers are living in regions of deep soil, mounds are not formed, for burrowing is as easy in one spot as in another and nesting centers have no tendency to become fixed. Furthermore, exploratory burrows, i.e., shallow burrows radiating from a common center and shortly abandoned, seem to be formed only where gophers exist in areas rich in food plants surrounded by relatively barren areas.

We have stated that the necessary conditions for the formation of Mima mounds in western Washington are a bed of stratified gravel unfavorable and uninviting to the roots of plants, a thin layer of topsoil bearing sparse prairie vegetation, and gophers. A few supporting examples should be pointed out.

[11] Vernon Bailey, "Revision of the Pocket Gophers of the Genus Thomomys," *U.S. Dept. Agric., North American Fauna No. 39* (1915), pp. 1–25; Theo H. Scheffer, "Habits and Economic Status of the Pocket Gophers," *U.S. Dept. Agric. Tech. Bull. 224* (1931), pp. 1–27.

On Quillayute Prairie—a treeless island in the dense timber of the northwest Olympic Peninsula—there is a true, black prairie soil and an underlying bed of gravel. There are no gophers, or evidence of their former presence, in this isolated area and no Mima mounds.

On Bush Prairie, surrounding the Olympia airport and within ten miles of a mound-bearing prairie, the soil is deep and rich. Gophers are abundant here, and they do not build Mima-type mounds.

On Mima Prairie itself—the type locality of the mounds and the area in which the climax examples appear—there is, as we have stated, a typical silt-gravel layer over a thick gravel bed. In seeming contradiction to our hypothesis there are no gophers on this prairie. (Had gophers persisted on Mima Prairie to the present time their relation to the mounds would probably have been realized by earlier students.) We deduce, however, that gophers recently existed here, built the mounds, and for some unknown reason were exterminated. Gophers live on a prairie of the same geological origin about 1 mile to the southeast, separated from Mima Prairie by the Black River. The former occurrence of gophers on Mima Prairie is indicated by the evidence of silt-filled burrows or mound roots as well as by the composition of the mounds themselves. We are of the opinion that disease, a prolonged drought, a series of grass fires, or some other disaster eliminated the population and that the Black River and surrounding conifer forests have effectively prevented the reinvasion of gophers from neighboring sources.

RECAPITULATION OF EVIDENCE

Evidence that the type of microrelief known as a "Mima mound" is the concentration of soil by pocket gophers may be summarized as follows:

1. The Mima mound is constructed entirely of soil materials small enough to be moved by gophers.

2. Materials too large to be moved by gophers appear beneath the mound or in the intermound region.

3. Mound roots extending into the gravel bed correspond to the size and shape of tunnels and nest excavations occupied by living gophers, and roots have been found in various stages from the occupied burrow of a gopher to one long since abandoned.

4. Mima mounds are found only on prairies where gophers now live or quite certainly once lived but are absent from prairies which, though geologically similar, yield no traces of gophers.

5. The characteristic features of the mounds—namely, areal distribution, distribution with relation to grosser ground relief, size, and shape—are in conformity with the habits of pocket gophers.

REFUTATION OF PREVIOUS THEORIES OF ORIGIN

The lenticular shape, lack of bedding, and size of constituent materials of the Mima mounds immediately exclude the possibility of their formation through ordinary deposition by wind, water, or ice. Two modified depositional theories, however, have been considered.

Bretz[12] suggested that debris washed into pits on the surface of still or moving ice might have melted its way down and formed the mounds. Mima mounds, however, may occur on the surface of grosser types of prairie relief: on several terrace levels, *on the sides of terrace slopes themselves*, in the bottoms or on the sides of kettles or channels, or on the flanks or tops of Ford mounds (Fig. 2). In some places they actually cap the lip of a terrace slope, lying partly on the upper terrace level and partly on the slope. Elsewhere they may lie partly on the lower terrace level and partly on the slope. These factors plus the basal convexity and lack of stratification of the lens make the ice-debris theory untenable.

H. M. Eakin,[13] apparently referring to the Mima mounds, considered them to be periglacial stone-strip effects. Proof that the intermound cobbles of Mima mounds are not frost heaved is furnished by the fact that many cobbles lie a few inches beneath the surface of the stratified gravel of intermound depressions on Rocky Prairie, but between *unruptured gravel bedding*. The smoothly rounded, water-worn intermound cobbles are utterly unlike the angular, frost-shattered blocks which characterize stone strips or stone polygons. Furthermore, Mima mounds commonly occur where entire prairies are without intermound cobbles. The steep

[12] *Op. cit.*, p. 105.

[13] "Periglacial Phenomena in the Puget Sound Region," *Science*, Vol. LXXV (new ser., 1932), p. 536.

slopes upon which Mima mounds sometimes appear further invalidate the frost-heave theory.

R. C. Newcomb[14] advances an ingenious theory for the origin of the Mima mounds. Extremely cold weather causes a frozen surface silt layer to crack in huge polygons, 40–66 feet across. Thaw water enters the cracks, freezes, and expands. Further warming causes bulging of the center of the polygon. This process, long continued, results in accumulations of silt which, after the melting of the intermound ice wedges, forms the Mima mounds.

Several objections are at once apparent. First, the theory fails to account for the mound and intermound cobbles and for intermound depressions which extend down into the stratified gravel. Second, mounds could hardly have been formed at the bottoms of kettles, tops of Ford mounds, or lips of terraces in this manner. Third, widely scattered mounds, as on Scott's Prairie or in parts of Grand Mound Prairie (Fig. 7), have intermound areas composed of silt gravel 2 feet or more in depth; yet constantly widening cracks in frozen silt would extend at least to the surface of the stratified gravel, and widening of these cracks would force *all* silt to the center of the polygon. Mounds are sometimes found isolated from other mounds by more than 100 feet, yet no polygonal ridge surrounds the mound. Fourth, we cannot conceive of how double or triple mounds might be formed in this way. Fifth, the smoothly rounded intermound cobbles of rock materials most susceptible to frost shattering indicate an absence of a climate as cold as that postulated by Newcomb.

The large size of the pebbles in the mounds precludes the possibility that the latter were built by ants, although it is known that in other parts of the country ants are responsible for the construction of fairly large mounds.[15] We know of no ants in western Washington that construct earth mounds.

The mounds cannot reasonably be ascribed to the activities of prehistoric humans. A population extensive enough to account for the

[14] "Hypothesis for the Periglacial 'Fissure Polygon' Origin of the Tenino Mounds, Thurston County, Washington," *Geol. News Letter, Geol. Soc. Oregon County* (abstr.), Vol. VI (1940), p. 182.

[15] E. W. Hilgard, "The Prairie Mounds of Louisiana," *Science*, Vol. XXI (1905), pp. 551–52.

tens of thousands of mounds probably could not have been supported by the region. No traces of human artifacts have, to our knowledge, been found in the mounds. Early explorers in the Mima region found that the local Indians had no legends concerning the mounds.

Finally, the possibility that gophers have merely re-worked older mounds formed by other means must be considered. The evidence against such a hypothesis has been presented in the preceding pages, but its principal points may be summarized as follows: (1) the areal spacing of the Mima mounds is similar to that of individual gopher homes on mound-free prairies; (2) the Mima mounds have risen on slopes of varying degree on various types of greater prairie relief, indicating the virtual independence of the mounds of other topographic features; (3) no mounds of the Mima type which lack evidence of having been worked by gophers (mound roots, basal convexity, assortment of materials, etc.) have ever been found; and (4) on certain isolated prairies of western Washington, of an origin apparently kindred to that of the mound-bearing prairies but out of the range of pocket gophers, there are no mounds.

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