ORIGIN OF THE MIMA MOUNDS, THURSTON COUNTY REGION, WASHINGTON[1]

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ABSTRACT

There has been recent favorable consideration of the idea that the Mima mounds were made by gophers. The writer believes the evidence indicates that gophers function only in the reworking of the mound material, not in the primary construction. The plausibility of the earlier glacial or periglacial theory has been increased by recent knowledge of permafrost and of the deposits made by combined water and ice in cold climates. The gopher theory, as it has been applied to the Mima mounds, contains internal disharmonies and ignores significant field evidence supporting the earlier idea.

INTRODUCTION

In the southern Puget Sound region, south and southeast of Olympia, the outwash prairies of the Vashon glacial stage are marked by fields of strong natural mound formation (fig. 1). The mounds are among the most striking and best-known minor physiographic features of the Pacific Northwest. There have been great range and variety of hypotheses to explain the origin of these structures.

The hypothesis of gopher (*Thomomys telpoides*) construction of the Mima mounds was advanced by Dalquest and Scheffer (1942). Although an origin by gopher, mole, or ground-squirrel action has often been conjectured in discussions of the mounds, Dalquest and Scheffer's is the first publication of such a hypothesis of mound development in the United States. If gophers can make these mounds, they have a greater physiographic effect than heretofore supposed.

Bretz (1913) described the mounds in this region as belonging to two types, the Mima and the Ford. Only the Mima type is considered in this paper. This type is a uniform and symmetrical mound that apparently has but one general origin and habit, although there is a great variety of perfect and partial mounds. The principal features of the mounds are described briefly in this paper; the reader is referred to Bretz's excellent field observations for further details on the mounds and mounded areas.

The writer believes that the enigmatic origin of these mounds constitutes a continuous embarrassment and a challenge to geological science. Since 1942 the gopher hypothesis has been a popular thesis and is being projected indiscriminately elsewhere—to the Columbia Plateau by Larrison (1942), to the California mounded areas, and to Europe. Because it is believed that any such projection should be preceded by adequate establishment in the type area, the writer here maintains that many of the principal points of the gopher hypothesis are erroneous and argues for a return to the earlier concept of periglacial or glacial origin.

CHARACTERISTICS OF THE MIMA MOUNDS

MATERIAL

Mima mounds are composed entirely of black silt, sand, and pebbly gravel

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mixed in all proportions (pl. 1, *A*). The material is friable, loose, and lacking in clay or plastic constituents. The pebbles in the slit have a maximum diameter of about $1\frac{1}{2}$ inches.[2] The black carbon stain is attributed to the prairie-type vegetation that the silt characteristically supports (Nikiforoff, 1937). The black silt of the mounds is essentially the same in composition, texture, and structure as that which mantles most of the Vashon outwash prairies of the region, including those on which no mounds exist.

TABLE 1

DIAMETER OF TYPICAL MOUNDS

Writer	Reference	Limits (Feet)	Average (Feet)
Bretz (1913)	Text, p. 82	6–60	.....
	Map, p. 96 (71 mounds)	21–55	42
	Photographs, pl. VIII	....	40
Dalquest and Scheffer (1942)	Photograph, fig. 5 (1 mound)	60–65	.....
	Text, p. 69	6–40	20
Newcomb	Measured (400 mounds)	10–70	47
	Map, fig. 2 (17 mounds)	20–50	38

[2] Seven cobbles and boulders are reported to have been found in the mound soil (A. M. Ritchie, "Hemispheroidal Thawing and Erosion of the Mima Mounds," oral presentation, Northwest Science meetings, Spokane, Washington, December 29, 1950).

Generally, the last and lowest channels of each prairie are partly devoid of this silt mantle and are lacking in good examples of these mounds.

SIZE

All observers agree that in height the Mima mounds vary from low, barely recognizable forms to a maximum height of 7 or 8 feet. The large size of some Mima mounds is frequently cited as an objection to the gopher hypothesis. Because mound diameters given by Dalquest and Scheffer do not agree with Bretz's or the writer's observations, some data on average diameter of typical mounds are given in table 1.

SHAPE

The most nearly typical mound is the flatly hemispheroidal form commonly found near the center of mound groups. Its ground-plan outline is roughly circular but generally has some pronounced straight facets. Its surface profile passes laterally to the level of the gravel intermound surface with a gently upwardly concave curve. In general, the higher the mound, the more abruptly its slopes meet the intermound gravel floor. In profile some of the high mounds in central lower Rocky Prairie resemble giant downturned sauce bowls. Blanks in the pattern, dwarfs, and double- and triple-tied mounds are common (see map, fig. 2).

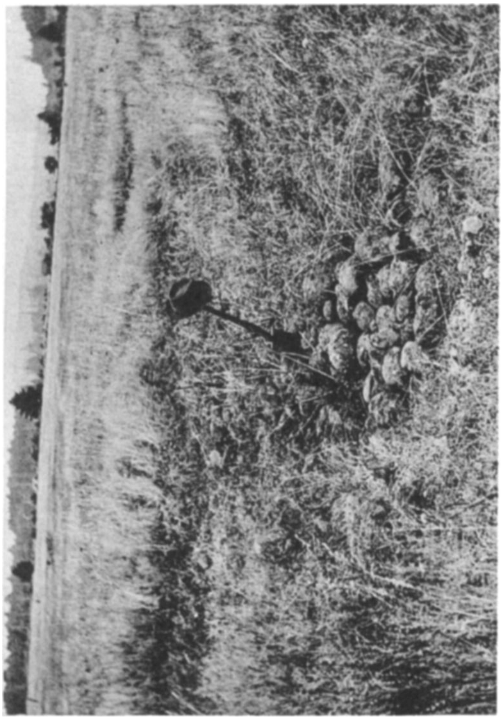
PLATE 1

A, The pebbly black silt of a mound overlying the gravel outwash (exposed in road bank on Rocky Prairie just west of Offut Lake).

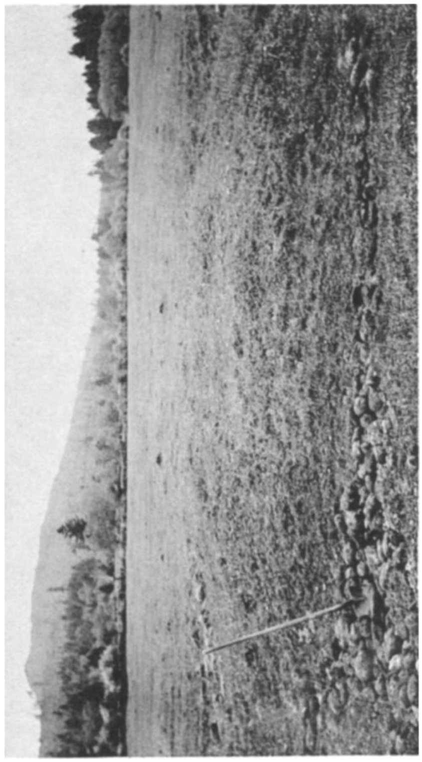
B, A pronged depression in an unmounded portion of Frost Prairie. Prong reaching toward right background rises to prairie surface level but aligns with prong from the depression visible in the background. Flat prairie surface largely preserved in interdepression segments such as that to the right and to the left rear of the spade.

C, Linear exposures of cobbly submound gravel in polygonal pattern about a Mima mound on Frost Prairie. This type development adjoins and grades into the pronged depression type shown in *B*. The writer finds it difficult to entertain even a hypothetical gopher exposure of such intermound areas.

A



B



C

Features of the Mima Mound area, Washington

STRUCTURE

The typical mounds consist of a flat-bottomed spheroidal segment of black unstratified pebbly silt, rising above the outwash surface. Rarely, and where the mound lies on the finer phases of the submound material, the outwash beneath the mound is marked by a black-stained downward extension of the black prairie soil. The color and general soil characteristics of this downward extension are continuous with those of the structureless black silt of the mound proper, but this extension in many places shows pebble stratification similar to the adjacent submound material. The depth to which this black coloration extends into the underlying material is roughly proportional to the thickness of the black mound soil above, thus forming the lens, or biconvex cross-sectional shape, observed in some mounds by Bretz.

RELATIONS TO TOPOGRAPHY AND UNDERLYING MATERIALS

The outwash sands and gravels of the Vashon valley trains underlie the mounded prairies and mark the early southward outlet channels of the meltwater of the thick Puget Sound lobe of

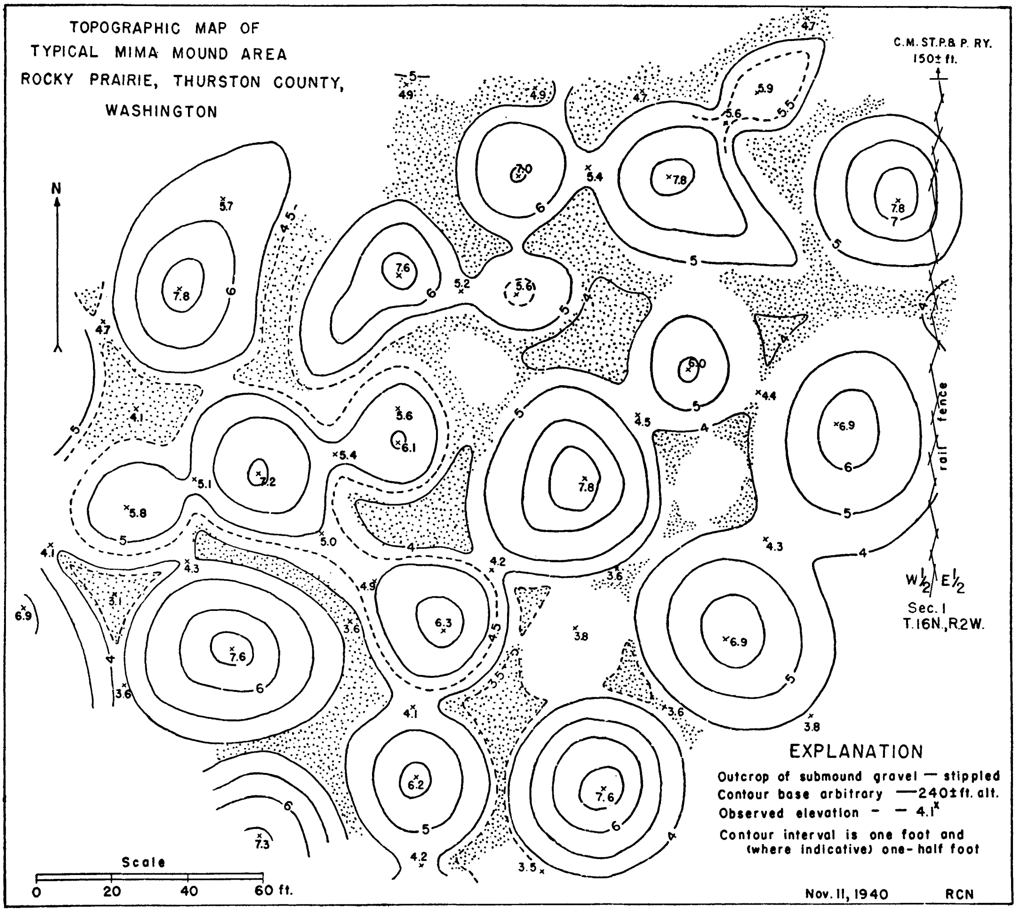


FIG. 2.—An incompletely mounded average area inhabited by gophers. It is suggested that any subsequent growth, if present, might in the future be measured by resurvey.

the Vashon glacier. The master-bedding dips downstream toward the Chehalis Valley (the trunk outlet) essentially parallel to the land surface, which slopes about 8–10 feet per mile (Bretz, 1913, p. 83).

At any one place the top beds of the outwash sand and gravel may be either strongly cross-bedded or accordant with the master-bedding. Thus the prairie soil commonly lies upon the beveled cross-beds of the subsoil sand and gravel. Each prairie surface commonly has several levels which step successively downward over sharp terrace descents toward the last outwash stream channel. On nearly every terrace the black silt soil, generally 1–3 feet thick where unmounded, overlies the outwash gravels and sands. Postmound erosion has been negligible. Many fields of mounds have been leveled by farmers.

The precipitation sinks into the loose outwash materials and drains off internally; however, on the lower terraces during the rainy season the intermound exposures of the outwash sands and gravels may discharge ground water, which flows off in integrated stream nets along the intermound swales.

Commonly, each group of mounds has a central area of complete hemispheroidal, symmetrical mounds, with wide, bare, intermound areas. Many of these mature mound areas are bordered by areas of less perfectly formed mounds as well as by peripheral zones of incipient or fragmental mounds adjacent to the unmounded prairie. In some areas immature mounds have a flattish segment located about halfway between the gravel surface and the tops of the mounds. It may represent the general premound level of the prairie surface.

The origin of the mounds can be studied much more advantageously in these areas of imperfect mounds around the edges of the mound groups than amid the billowing perfection of the more perfect mounds.

EXCEPTIONS TAKEN TO DALQUEST AND SCHEFFER'S PRESENTATION

ON FIELD OBSERVATIONS

1. *Size of mounds.*—Dalquest and Scheffer (1942, p. 69) asserted that "their basal diameters do not vary greatly from 20 feet." The writer found that 40–45 feet is a fair average and that the common range is from 10 to 70 feet.

2. *Spacing of mounds.*—On the subject of spacing, Bretz (1913, p. 83) observed as follows: ". . . The Mima type mounds are usually closely set. There is but rarely an intermound area with a diameter greater than that of the larger mounds of the vicinity." That statement is borne out by measurements from his map (pl. VIII), which show an aggregate average of some 53 feet between mounds.

Dalquest and Scheffer (p. 72) observed: "There is absolutely no regularity of spacing . . ."; but later (p. 80): "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. . . ."

Newcomb (1940) contended that the intermound spaces were a reticulate network, having a general polygonal, mainly hexagonal, pattern, and he inferred thereby that a spacing at least roughly uniform within any one group was the normal disposition of the mounds. This regularity of spacing, as well as some of the mound alignments, is actually shown in Dalquest and Scheffer's aerial photographs (their fig. 1).

This pattern and spacing in the Dalquest and Scheffer aerial photo and in the writer's vertical aerial photos of the

Mima-mound prairies are markedly similar to the pattern shown in Péwé's (1948) vertical aerial photos of the present ice-wedge mound fields near Fairbanks, Alaska.

3. *Relation of the mound soil to the submound gravel.*—Dalquest and Scheffer (p. 72) reported that the base of the "silt-gravel," where it is curved convexly downward in the biconvex mounds, truncates the stratification of the underlying gravel. Bretz (1913, pp. 95-96) stated that strata pass through the convex basal portion of the black silt. The writer also has observed[3] stratification in these convex basal portions and considered the lower part of the biconcave lens shape to be merely blackened portions of the underlying materials. Thus, if the downwardly convex segment beneath some mounds is to be considered part of the mound, it is erroneous to refer to the mound materials as "entirely unstratified," as do Dalquest and Scheffer (p. 73).

4. *Origin of the assorted character of the black prairie-soil materials.*—Dalquest and Scheffer (p. 84) considered the structureless soil of the mounds to be "evidence of gopher action." But the black silt on the mounded prairies, on the unmounded portions of the mounded prairies, and also on unmounded prairies of the region is as structureless and unsorted as that in the mounds.[4] Despite the structureless character common to both the mounded and the unmounded prairie soils and despite Dalquest and Scheffer's supposition that gopher action accounts for the assorted character of the mound soil materials, they asserted (p. 82) that certain unmounded prairies ". . . yield no traces of gophers."

5. *Exploratory burrows.*—This is the agency, according to Dalquest and Scheffer, by which the gopher transfers the material to make the mound. The excavations which they mentioned (p. 79) were limited to four 10-foot-long burrows. They considered that all the soil from two burrows and half the soil from two others had been taken into the mound to fill abandoned burrows. The evidence that this particular quantity of soil was "actually transported into the mound" was that it was not observed to be on the surface. Other possible dispositions for this material seem not to have been considered.

6. *Vegetation on the mounds.*—Dalquest and Scheffer (p. 77) observed: "It might be argued that gophers attracted to, and therefore feeding more intensely in the vicinity of their living 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)." However, this may well be the consequence of the originally deep mound soil and the thin soil in intermound areas.

The writer has observed that, where depths of mound and intermound soil are comparable, the vegetation on the mound is no heavier or "more luxuriant" than on the intermound or nonmounded areas. He is also convinced that gophers do devastate the vegetation of the mounds. In October, 1940, at the extreme northeast end of Rock Prairie north of U.S. Highway 99, the gophers were stoping the grass root-crowns and had converted to a fallow condition fully half of each of the many mounds; also they were ac-

[3] Well shown in the Northern Pacific Railway cut through Rocky Prairie, 1 mile west of Offut Lake.

[4] A good section of the black prairie soil of the unmounded areas is shown by Nikiforoff (1937, p. 208, fig. 6).

complishing a slight flattening action on these mounds by virtue of their raising of soil on the mound slopes. Nikiforoff (1941) observed a similar flattening effect by ground squirrels on mounds in the Great Valley of California.

7. *"Mound cobbles."*—Dalquest and Scheffer (p. 75) observed: "An irregular layer of mound cobbles often lies beneath the base of the mound lens. The mound cobble layer, as well as the intermound cobbles, is found only where cobbles of approximately the same size are present in the underlying 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 gravel, mound cobbles and intermound cobbles are correspondingly scarce or absent." That statement is largely paraphrased from Bretz (1913), p. 103) with the exception of the term "mound cobbles," which Dalquest and Scheffer used but did not define. Their observation and the coining of the term "mound cobble" would be unobjectionable if they did not later (p. 78, l. 21; p. 80, l. 6; and p. 83, l. 11) use it as a keystone evidence, or inference, of gopher origin. The true relation of the gravel and cobbles of the outwash gravel to the overlying black silt was well stated by Bretz (1913, p. 106): "Cobble strewing of the prairie surface is known at least locally to have antedated the formation of the mounds and requires no place in the conception [of mound origin]."

8. *Relations of Mima and Ford mounds.*—Dalquest and Scheffer (p. 73) observed: "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." And also (p. 82), in taking exception to Bretz's hypothesis, they said: "Mima mounds, however, may occur on the flanks or tops of Ford mounds (fig. 2)." It seems that these observations must be faulty; for, if Mima mounds can lie on Ford mounds, then Ford mounds cannot be identified by their criterion.

9. *Relation of Mima mounds to other minor relief features.*—Dalquest and Scheffer observed that the Mima mounds occur upon the "grosser types of relief" (p. 82) and concluded therefrom that only gophers can effect this conformity to topography (p. 84, ll. 10–13). It is the writer's belief that other mound-making agencies (for example, ground-ice) can accommodate to gentle topographic variations, though the resulting mounds probably would not be so perfect as on plain surfaces. Such is the actual character of the Mima mounds found on steep or uneven slopes.

10. *Areal distribution of mounded prairies.*—Dalquest and Scheffer (pp. 81, 82) observed that the areal distribution of the prairies which carry Mima mounds and also gophers indicates accordance with their "gopher-origin" hypothesis. They listed as examples: Quillayute Prairie, which they considered analogous but for gophers, and Bush Prairie, analogous except for soil depth, in neither of which prairies did they find Mima mounds. Quillayute Prairie, on the northwest side of the Olympic mountains, is not comparable climatically now—and probably was not closely so in glacial times—with the mounded prairies. Its average annual rainfall is some 85 inches as compared to about 50 inches for the mounded prairies. It does not seem proper to observe such contrasting climatic situations as comparable sites for the delicate ecological processes postulated by Dalquest and Scheffer. Bretz (1913, p. 95) has stated that the Mima mounds are, with one exception,

confined to the outwash prairies of the eastern and lower lobe of the Vashon glaciation, only one faint occurrence being known for the western lobe.

Bush Prairie, 10 miles north of Tenino, also differs considerably as to soil and glacial history from the area in which Mima mounds occur. The Mima mounds are unique, and their absence from any distant place is irrelevant to the question unless it is first established that the place concerned has sustained the same geological, biological, and meteorological history since early Vashon times.

ON LOGIC

As Dalquest and Scheffer's hypothesis is largely developed by deduction and inference, it is necessary to examine some of their logic. The distinction between plausibility and proof is necessary to the evaluation of the gopher hypothesis. The reader is confronted with trains of thought such as are embodied in the following successions.

1. *"Exploratory burrows" as the method by which gophers accumulate the mound material.*—Dalquest and Scheffer, after developing the hypothesis that the mounds are the established centers of accretion (p. 78, ll. 23–24; p.79, ll. 4–6, 9–12), attempted to explain why mounds do not exist in areas having a deep soil. They averred (p. 80, ll. 24–27) that "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." It is faulty logic to call the exploratory burrow the *cause* of the barren area (p. 79) ("accounts for the sunken contour of the intermound area") and on the succeeding page to declare the exploratory burrow to be the *result* of the barren area.

It seems more logical to accredit Dalquest and Scheffer's last observation (p. 80, ll. 24–27) that "exploratory burrows" are confined to "areas rich in food plants [i.e., the mound] surrounded by relatively barren areas [i.e., intermound area]" and to conclude therefrom that the "exploratory burrow," where present, is evidence only that gophers now living in the mounds have simply adapted their burrows to a situation they never created.

2. *Hypothetical permanent centers of soil accretion.*—Dalquest and Scheffer deduced (p. 80): "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." When this statement is applied to the region of the Mima mounds, the reference "even when food is abundant in the surrounding territory" can conceivably mean only the deep soils (such as Bush Prairie) which Dalquest and Scheffer said are inhabited by gophers but are not mounded, for at no other gopher "centers" are there postulated peripheral conditions "where food is abundant." Then below, while developing an explanation for the lack of mounds or near-by areas of gopher-infested deep soils, they conjecture: "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." Thus, in one sentence, gophers are inferred to be areally restricted by habit even in areas of abundant food (deep soils) and a motivating reason for the mounds is inferred, then it is said that mounds are not formed in aforesaid deep soils because there are no areal restrictions whatsoever to cause a locus of accretion ("nesting center").

It is fundamental for the reader of Dalquest and Scheffer's hypothesis to realize that no field observations are known which record that the gopher concerned has ever systematically or accidentally continually accumulated earth about any center of accretion. The writer has observed that these gophers, the region over, in settings like the mounded prairies or in other places, are entirely fortuitous in the direction of aggregate ultimate movement and discard of their excess excavations.

3. *Mound materials.*—In Dalquest and Scheffer's summary of evidence for gopher origin of the Mima mounds they stated (p. 81): "The Mima mound is constructed entirely of soil materials small enough to be moved by gophers." But when one notes that such soil also composes some of the nonmounded prairie soils (Dalquest and Scheffer, 1942, p. 69, ll. 10, 11) which these authors say were not gophered, this argument fails to support their conclusion. They state also: "Materials too large to be moved by gophers appear beneath the mound or in the intermound region." This seems irrelevant, as Bretz (1913, pp. 102–106) described such occurrences:

> The intermound cobbles were probably not deposited or aggregated by the agency which formed the mounds. They have not gravitated to the intermound areas from an original equitable distribution subsequent to formation of the mounds. Cobbles of the intermound type are not known to occur in the gravel and silt of the mounds, but are found in the stratified gravel immediately below them. Where the cobbles are large, the gravel below contains large stones, and where the cobbles are lacking or represented only by large pebbles, the subjacent gravel is deficient in fragments of cobble stone size.

4. *Age of the mounds.*—Dalquest and Scheffer (p. 76) considered the mounds to be definitely younger than the kettles which in places occur in the outwash prairies. But the case for a prekettle age is equally good, for, within definite kettle depressions, there are poorly formed mounds which could reasonably have been altered by the settling incident to the formation of the kettles.

The melting-out of a deeply buried ice block probably would not have destroyed all the mounds in such places. There are many kettles devoid of recognizable mounds, although they occur in the midst of well-mounded prairie levels. The kettles in the prairie surface just south of Old Muck Post Office on Fort Lewis Reservation are examples of this type.

ON OMISSIONS

The following points are considered pertinent to the problem of mound origin but are not mentioned by Dalquest and Scheffer.

1. *Degree of completion of the mounds.*—The perfection of the true spherical shape and symmetry has been observed by the writer to be greater toward the centers of strongly mounded areas and to be less perfect outward to the peripheral zones, where partial or immature mounds may predominate.

2. *Aberrant types of mounds which obviously do not fit the gopher hypothesis.* (*a*) *Low, thin mounds.*—The low, thin mounds that are in places less than 1 foot high and are surrounded by peripheral swales devoid of the silt soil occur at the western end of Grand Mound Prairie and on the sloping eastern margin of upper Mima Prairie. The conception of these low, flat mounds (where in places the soil is scarcely deep enough to cover a large gopher) as gopher accumulations and "homes" seems incongruous.

b) *Ringed mounds.*—Ringed mounds, such as those found on the prairie south of Old Muck Post Office (Bretz, 1913,

p. 90), lie widely spaced and are surrounded individually by a band of submound gravel exposed in the lower intermound zone, which, in turn, is surrounded by a peripheral ridge raised to the height attained by the mound. No agent or process advanced by Dalquest and Scheffer could conceivably be postulated for these peripheral ridges.

c) Pronged depressions.—Pronged depressions occur in some unmounded areas adjoining mound areas. On Frost Prairie north of Bucoda, in an otherwise even, unmounded part of the prairie, there are linear branched hollows, abruptly sloped, angular in ground plan, and up to 4 feet deep,which expose gravel without a soil cover. They commonly have three branches whose bottoms rise outwardly within some 10–20 feet to the prairie level. The branches line up with those from neighboring hollows to form a polygonal network of linear depressions incompletely surrounding flattish-topped segments of the general prairie level (pl. 1, *B*).

In other cases the depressions are larger and are fully interconnected, with the resulting enclosed hillock possessing a more or less spheroidal shape. All stages can readily be discerned, from the first sharp depressions in an otherwise unmounded prairie to the complete typical mound area (pl. 1, *C*). These depressions are genetically related to the principal mound-building process which, when carried further, has produced a typical mounded area. These depressions are not compatible with Dalquest and Scheffer's hypothesis. They were not mentioned by them.

3. *Mechanics. (a) For removal of soil from wide bare intermound zones.*—Some intermound swales expose the clean stratified submound gravel for a width of 20–40 feet. There is little or no vestige of silt soil on these strips and no evidence of its having been eroded away or having penetrated into the gravel below. The agency which formed the mounds must have been responsible for some of these wide intermound areas. Dalquest and Scheffer failed to explain how their hypothetical "exploratory burrow" agency could effect this complete soil removal (in some places it would have had to accomplish a virtual sweeping action). It is difficult to imagine gophers having done this.

b) For sharp separation of mound from intermound.—Likewise, it is hard to visualize how any such "exploratory burrow," or other gopher system, could produce the sharp, even margin separating the mature mound from its intermound strip.

ORIGINS PREVIOUSLY POSTULATED

Bretz (1913, pp. 105–106), after reviewing all earlier opinions, suggested a tentative hypothesis consisting of a modification of the "concentration of washed drift in holes in a melting ice sheet." This hypothesis, he indicated, could hardly explain more than a part of the mound occurrences, and its details must await the detection of similar processes in existing piedmont glaciers or ice sheets. He considered the origin as not fully explicable on the basis of data then available. In summarizing his "limitations of a successful hypothesis," Bretz (p. 105) said:

> Agencies which might have operated under the limitations above enumerated are practically limited to ice and water, either of which may have been standing, or moving, or both. . . . If ice was present it obviously was in fragmental masses from the adjacent glacier or had formed on the surface of standing water beyond the ice.

That such a process can, in some cases, form Mima-like mounds is now known. Similar mounds formed on the flood plain of the Colorado River below DeBeque, Colorado, during the winter of 1945–1946. There, during a period of subzero temperatures, ice formed upstream from the DeBeque Canyon dam. Subsequent flow into the reservoir repeatedly flooded over this ice and froze, thus building up a considerable thickness of dirty ice. After the thaw and spring breakup, very dirty ice from 6 to 10 feet thick was left stranded on the margins and on the upstream gravel bars. These ice remnants cracked into separate pieces in a roughly systematic pattern, and flood currents washed between them. As the river stage subsided and the ice blocks melted, the dirt from each ice block accumulated in a pile which sloughed down to a low mound of roughly circular plan. These mounds are largely silt with some sand and gravel. Some of the more symmetrical mounds reach a height of 4 feet and a width of 12 feet (Wayne M. Felts, personal communication, 1946).

A somewhat similar process, forming moundlike "kames," has been observed by Nichols (1936) in Maine, where stream outwash was deposited over the accumulated snow of one winter.

It seems possible that such a process may have operated repeatedly and on a large scale toward the close of the melting of the early eastern lobe of the Vashon ice, as postulated by Bretz.

The growth of two marked mounds as reported by Koons (1948) lacked evidence of either growth or gopher construction. They can hardly be taken as evidence for the construction of mature Mima mounds in five years, as stated recently by Price (1949). Likewise, the ground swells and sags reported by Bailey are not believed to be the evidence they are alleged to be by Price.

A partially developed hypothesis ascribing the origin of the mounds to the deposition and erosion work of outwash streams was advanced in a personal communication in 1947 by R. L. Lupher. He cited the general uniformity of mound heights within any one mound group, the common alignment of mounds along terrace escarpments, and the distribution of mound prairies only along outwash prairies that stem from glacial moraines as evidence favoring an origin connected with meltwaters.

A vague water-and-wind origin has been proposed recently for these mounds by Krinitzsky (1949), but his reasoning springs largely from study of aerial photos of the Mississippi Valley mounds and lacks a factual basis for the Mima mound occurrence.

Newcomb (1940) postulated an origin somewhat similar to Bretz's tentative hypothesis but used as the activating force local areas of late Vashon ground-ice of the fissure-polygon type, such as Leffingwell and Nichols have described, and which is now in places forming mounds and tortoise-shell topography in northern Canada and Alaska. Under this hypothesis it was postulated that during the early stages of the wasting of the Vashon ice a periglacial climate permitted the development of ground-ice of the fissure-polygon type in the surficial pebble-silt mantle.

Ice wedges, polygonal in pattern, might have thickened laterally and thrust the silt into center spaces, where it remained and sloughed down into mounds upon the melting of the ice wedges. The principal objections listed by the writer were the great width of the intermound spaces in the low, widely set mounds and the lack of corroborative evidence of the former existence of such a periglacial climate. Both these objections implied that the hypothesis might become more tenable as research extended our knowledge of periglacial agencies.

The impetus of wartime construction in areas of permanent frost brought out several important contributions to our knowledge of permafrost, among them Taber's (1943) description of the Alaskan polygonal ice-wedge occurrences. Taber rather satisfactorily established that the growth of ice wedges is due to simple additive crystallization rather than to the freezing of liquid water which had run into shrinkage cracks in the ice wedge. This correction simplifies the mechanical explanation of ice-wedge phenomena as a possible constructional agency for the Mima mounds.

The writer visualized the ice-wedge thrust as producing an over-all bulging of the mound area, not the throwing-up of a marginal ridge, as implied by Dalquest and Scheffer (p. 83, l. 21). It is noted that in a recent publication on present mound-forming ice wedges at Fairbanks, Alaska, Péwé (1948, fig. 1) shows pictures of ice-wedge-formed pronged depressions, which show that an over-all interwedge swelling must have taken place in the incipient mound areas.

The concept of the frost polygon as a possible Mima mound-building agency must assume that the wedges widened and thickened above outwash gravel to a maximum height possibly greater in places than the present height of the largest Mima mounds. That such magnitude is possible was suggested by Leffingwell, who noted Maydell and Toll's descriptions of vertical inclusions of earth in heavy bodies of ice at Siberian localities and suggested that these might represent an advanced stage of ice-wedge growth.

Dalquest and Scheffer raised several "objections" to the frost-polygon hypothesis. Among them were: the failure of the ice-wedge hypothesis to account for "mound cobbles," etc.; the belief that ice wedges could hardly have formed mounds at the bottoms of kettles, tops of Ford mounds, and lips of terraces; the observation that in some cases not all silt is removed from some intermound areas; the presence of isolated mounds without any surrounding polygonal ridge; the difficulty in visualizing how ice wedges could have formed imperfect mounds; and the failure of the pebbles to show the shattering supposed to be a consequence of a periglacial experience.

The writer thought that the periglacial hypothesis adequately explained all the mound features which are accountable by the normal vagaries of ice wedges—such as imperfect mounds, partially constructed mounds, and poorly built mounds on uneven slopes. Contrary to Dalquest and Scheffer's statements, it is believed that the topographic distribution of the Mima mounds conforms quite well to that of the recorded habit of ice-wedge developments. The pebble shattering is similar to that in gravels of similar lithology in the regions of present permafrost. There are but minor amounts of schistose, sedimentary, or other foliated pebbles in these gravels, and the massive granitics, basalts, quartzites, and similar types are no less shattered than in many regions of present periglacial climate.

There may be some evidences of a former periglacial climate in that area. For example, on the gravel terraces, just east of the Mima-Gate road at a point about 4 miles south of Mima station and nearly a mile east of Gate, there are, in the unmounded soil, linear and polygonal concentrations of pebbles which the writer takes to be stone-stripe effects of periglacial origin. Though the forest soils could scarcely be expected to preserve the periglacial structures and there are few areas in the region devoid of forests, careful search may in the future reveal other evidences of a former periglacial climate.

In view of the inconsistencies in the gopher hypothesis as presented by Dalquest and Scheffer and the above factors favoring a glacial or periglacial origin, the writer believes the true origin of these widely known mounds can best be sought by returning to the requirements listed by Bretz and applying our increasing knowledge of glacial and periglacial agencies.

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