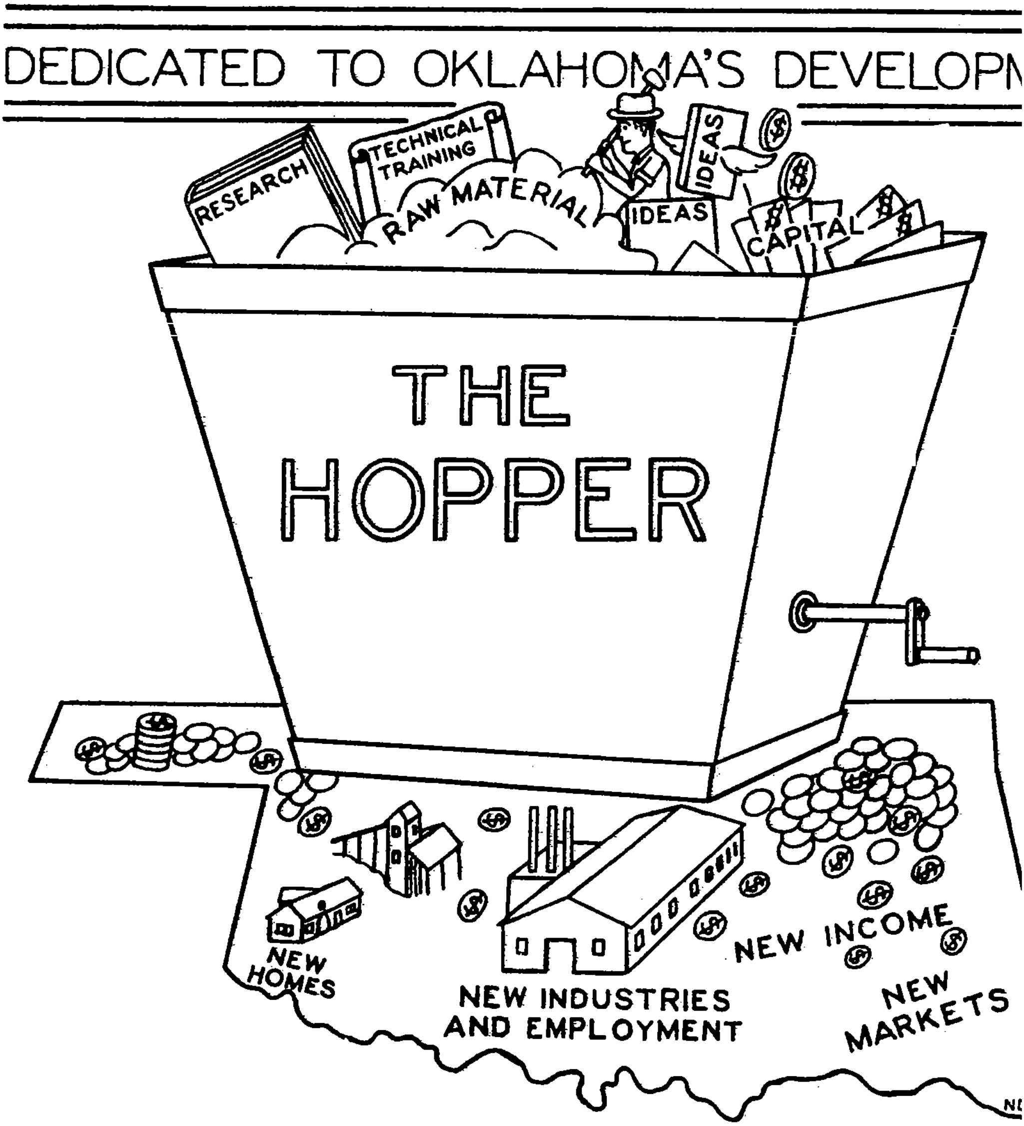


PUBLISHED IN THE OFFICE OF THE
OKLAHOMA GEOLOGICAL SURVEY
NORMAN, OKLA.

Vol. 14
No. 7

July, 1954.

## EDITORIAL NOTE

Those who have noticed the "pimple mounds" of eastern Oklahoma have wondered about their origin. Dr. Melton had discussed these mounds in a paper published in 1929. The periodical in which his paper was published had small circulation and did not issue author's separates.

In order to make Dr. Melton's interesting and important paper available, this number of The Hopper is devoted to reissuing the 1929 paper. Dr. Melton has provided new illustrations, a short discussion of work since 1928. and additions to his earlier bibliography. The Oklahoma Geological Survey gratefully acknowledges his interest in making the new studies and his financial contribution in paying for the figures in this issue.

# "NATURAL MOUNDS" OF NORTHEASTERN TEXAS, SOUTHERN ARKANSAS, AND NORTHERN LOUISIANA 1/

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## Part I. General review of previous publications.

### INTRODUCTION

The apparently inexplicable "natural mounds" have been the subject of much controversy, some of which has been at the same time humorous and absurd. In the Gulf Coastal Plain and in the older Mississippi delta region the "natural mounds" are small hillocks, which in the main are composed of very fine sandy soil and which are remarkable for their uniform circular outline and for their symmetrical dome-shaped profile. Their diameters range from 10 to about 100 feet, though the majority have diameters from 30 to 50 feet. Their heights range from about 1 foot to 6 feet, and the majority rise 3 to 4 feet above their surroundings. They are most abundant on strata of Pleistocene age, though they are found on different geologic terranes ranging in age from Cretaceous to Pleistocene. They occur at many places throughout the state of Louisiana, in southern and eastern Texas, in southern and eastern Arkansas, and in southeastern Missouri.

In addition to the above occurrence, mounds have also been reported from the following places: southwestern Missouri, eastern Kansas, eastern Oklahoma, Arizona, in the San Joaquin valley of California, on the sea-terrace near San Diego, California, in eastern Oregon and Washington, on the Yelms and Mima prairies south of Tacoma, Washington, near

From University of Oklahoma Bulletin, New Series No. 456, pp. 130, Nov. 15, 1929, Proceedings of the Okla. Acad. Sci., Vol. IX, 1929. pp. 119-130.

Logan, Utah, on the high plateau of Mexico, and in the Argentine Republic. In most of these places they occur on low flat lands; but on the high plateau of Mexico they were found by Hill nearly 7,000 feet above sea-level. These mounds may or may not have the same origin as the majority of those on the Gulf Coastal Plain and the upper Mississippi delta.

In spite of the obvious fact that these simple features can be formed in a variety of ways, many writers on this subject have persisted in advancing a single hypothesis for their origin. On account of this, the subject very nearly, if not actually, became a laughing **matter** in 1905-06 and -07. The writer, therefore, steps forward warily. Though some of the contributors felt the sufficiency of, and so offered, just one hypothesis for the origin of the so-called "natural mounds," most investigators realized that in different places they must be of different origin.

## HYPOTHESES OF ORIGIN

So far as the literature shows,*the hypotheses which the largest number of investigators favored were those which attributed the origin of the "natural mounds" to the following:

I. Ant hills.
II. The work of burrowing animals.
III. Early human work.
IV. Spring and gas vents

Other hypotheses, not so favorably considered referred their origin to the following:

V. Mounds left by uprooted trees after the wood had decayed.
VI. Sand dunes.
VII. Fish nests.

VIII. Large sized concretions or segregations of mineral matter.
IX. Differences in settling of coarse and fine beds.
X. Protection from erosion by resistant caps, as ordinary disintegrated concretions of limestone in shale, etc.
XI. Fossil "mud-lumps."
XII. Chemical solution.
XIII. The work of glaciers.
XIV. Stream erosion-gullying.

Following is a brief summary of the critical and admissible evidence, advanced in support of and in opposition to the fourteen hypotheses prior to 1925.

I. Ant hills. Supporting this hypothesis it has been pointed out that some mounds are small enough to be comparable with ant hills built by the "Atta" leaf-cutting ants, which at places in Texas now attain a diameter of 40 to 50 feet and a height of 1 to 2 feet. In Cuba the Atta ant hills often reach a height of 10 to 12 feet and a diameter several times as great (31 and 32). Also, mound-building varieties of the so-called "white ants" (termites) are notably developed in the tropical parts of South America, Africa, and Australia. There they have a conical or bee-hive shape, height of 6 to 20 feet, and diameter of 50 feet or more. They are composed of mud mixed with vegetable matter; which by decaying could well give rise to the high porosity found in the mound soil in the Gulf region. The ant hill hypothesis together with the following one (II) were considered by some to

* Reference No. 33, by M. R. Campbell, in the bibliography at the end of this paper, contains the best sho[rt] summary of the discussion up to 1906 which is available, and Reference No. 35, by J. H. Bretz presents a valuable review of the early literature dealing with the mounds south of Puget Sound in Washington.

be supported by the supposed elimination of all other hypotheses (33).

On the other hand, the fact that ants, with very few exceptions, do not now occupy the mounds is an important contradiction to this hypothesis. Evidences of former occupations, such as chambers, passages, etc., have never been found on a scale commensurate with that required. The material of these features, furthermore, has not been as highly selected with respect to size of grain as one would expect, judging from present ant hills. Also an enormous increase of ants over the present number would be required; and this in turn would imply that theclimate in recent times was much warmer than now- a conclusion for which there seems to be little other evidence.

II. The work of burrowing animals. In support, it was shown that a few of the mounds in southern Arkansas are covered with gravel (31-32). And, together with hypothesis I, it was considered by some to be supported by the supposed elimination of all other hypotheses (33).

Nevertheless, at present the burrowing animals of the region are certainly not numerous enough to heap up the mounds. Many cross sections exposed in railroad and highway cuts do not reveal passages, chambers,or other excavations made by these animals. Moreover, this hypothesis would require concerted action of a large number of animals, and the ground squirrels, gophers, and prairie dogs of today in the construction of their mounds are not noted for concerted work of sufficient importance.

III. Early human work. A few mounds have been found in Oklahoma, Arkansas and Louisiana which show unmistakable signs of human occupation, e. g. charred timbers, artifacts, pottery, bones,

Figure 1—Stereo pair. North is at left.

Natural mounds on partly eroded terrace of the Arkansas River at Tamaha in T. 11 N., R. 22 E., Haskell Co., Oklahoma. Bedrock is McAlester formation.

Figure 2—Oblique

Natural mounds near Smackover, Arkansas, on a terrace of the Ouachita River. They are present in forested areas as well as in cleared land.

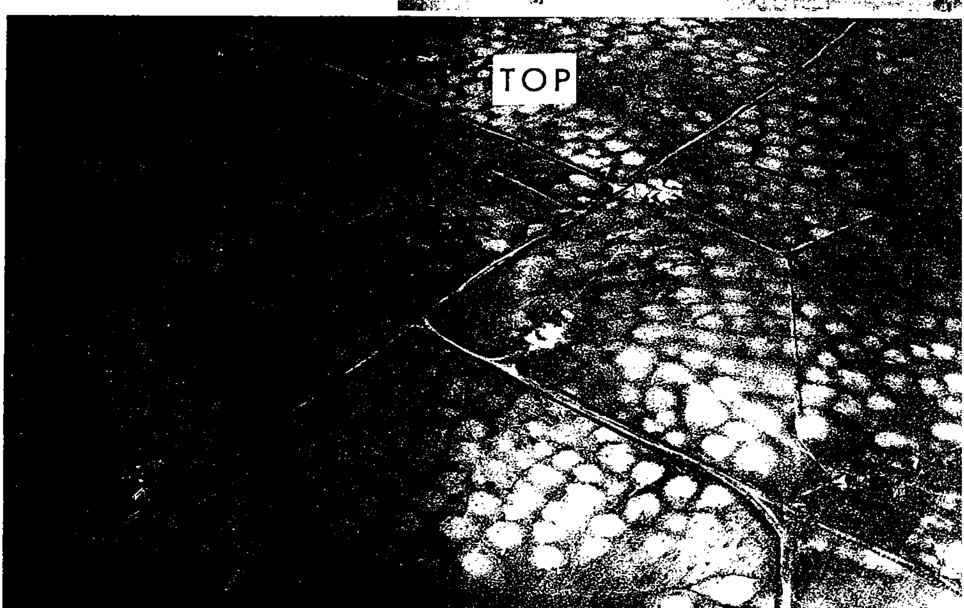
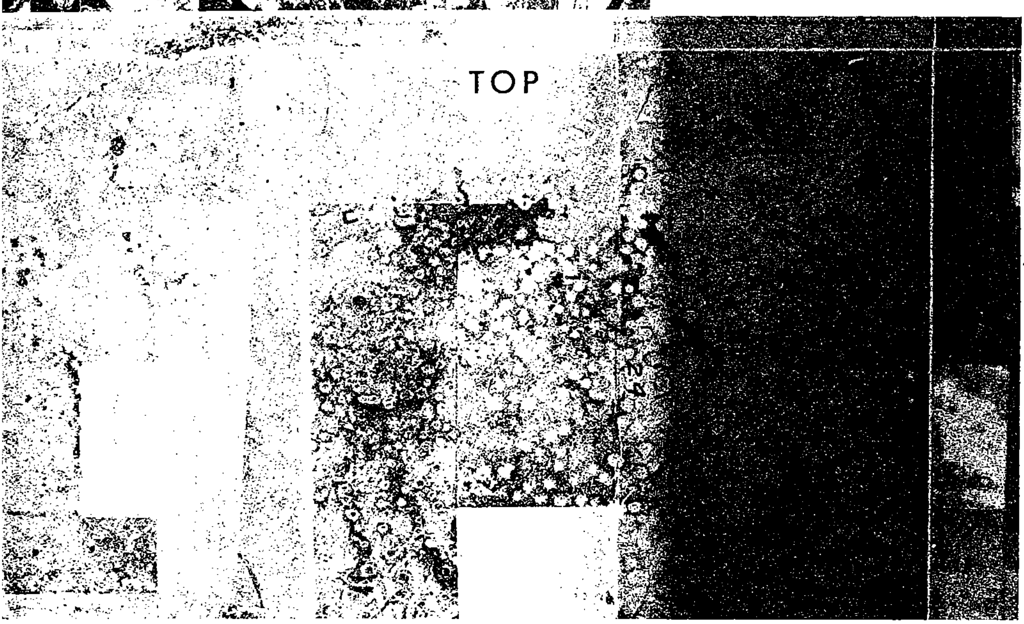


Figure 3—Single Vertical. North is at left.

Natural mounds in Arkansas River terraces 2 to 3 miles SE of Vian, Sequoyah Co., Okla. Straight and curved rills or rivulets are common.

Figure 4—Single vertical. North is at right.

Mounds near McGee Creek in Ouachita Mountains. Section 24, T. 1 N., R. 14 E., Atoka Co., Okla. Straight and curved rills separate the mounds at many places. Bedrock is Stanley shale.



etc. (16-17-24). But such definitely human remains are very rarely found considering the great number of mounds. Frequently mounds have also been found in low swampy ground which is suited neither to dwelling sites nor to agricultural purposes. They are almost totally absent from the present flood-plains of streams and rivers; whereas the early American Indians did not consistently avoid flood-plains as sites for their villages. Even if individual families moved often and built many mounds for various purposes, the enormous number of these features would require a very dense population- much denser than known human remains indicate. Moreover, it is probable that elevations which were already in existence were used as camp sites by the early American Indians because of their relative dryness in times of rain. Such mounds might seem to later observers to have been constructed by human beings.

IV. Spring and gas vents. As supporting evidence it has been mentioned that near Sulphur City, Louisiana, and near Teneha in northeastern Texas, in regions covered with mounds, a number of low cones a few inches in height and a few feet in diameter are now being formed. The fine sand of the cones is being brought to the surface by a flow of gas and water from the center of the cones (31-32). Also, in the early days gas is said to have escaped from mounds which are found near the salt-dome-mounds of Texas and Louisiana, such as Spindletop, Dayton and others. In the vicinity of Dayton salt dome the gas stopped escaping from these mounds as soon as active drilling was begun (36). Furthermore, a few of the mounds near these salt domes have been drilled and found to be "pipes" of sand, at least to the depth of the first thick sand stratum. It has been reported that where no sand occurs at shallow depths in the vicinity of these salt domes there are no mounds (36). In addition, low spring-cones in southeastern issouri have been described (18); and low cones of sand were produced by water and gas eruptions during the New Madrid earthquake of 1811-12, and during earthquakes in many other places (18-34).

The Port Hudson formation or Beaumont clay (Pleistocene) of southern Texas and Louisiana is noteworthy in comparison to older formations for the large number of mounds it supports. It is also noteworthy for the large quantities of recently decayed and carbonized wood which it contains. Older fomations do not contain wood in these quantities.

In opposition, however, it may be said that craterlets are practically never found in the mounds of the Gulf Coastal Plain and elsewhere with the exceptions noted. Then, too, "pipes" or "necks" of sand continuing downward from the mounds and presumably connecting them with an underlying sand horizon, have not been observed in the great majority of cases where mounds have been cut through and exposed for study. In northern Louisiana, southern Arkansas, and northeastern Texas the mounds are present in large numbers at some places. Yet the conditions of the Port Hudson formation farther south are not duplicated, i.e. there is no unusually large amount of decayed and carbonized wood buried at shallow depths to furnish an abundant supply of gas.

7. Mounds left by uprooted trees. It is a matter of common knowledge that after large uprooted trees decay, the soil weathers down and sometimes forms small mounds. Nevertheless present trees are much too small to form mounds 50 to 100 feet across and 4 to 6 feet high. This hypothesis makes it necessary to assume that trees as large as the giant sequoias formerly grew in the Gulf Coastal Plain.

VI. Sand dunes. In support, it has been said that most of the Gulf Coastal Plain mounds are largely composed of very fine sand.

Yet the very uniform distribution of the mounds over the surface, where they are best developed, is not in harmony with the known distribution of sand dunes in other areas; and the total absence of mounds with the barchane type of outline is quite significant. Furthermore, the uniformly circular outline (plan) possessed by the great majority of these elevations militates against the dune hypothesis. Dunes are seldom so. The uniformly dome-shaped profile is not in agreement with usual dune profiles; and neither is the soil of the mounds cross-bedded, as one would expect if they were dunes. Dreikanter or other abraded and buried objects, such as those commonly found in sand dunes, are not found in this region. Dunes are not forming at the present time; and a hypothetical arid climatic fluctuation of sufficient intensity, in latest Pleistocene or early Recent time, is not supported by other evidence.

VII. Fist nests. Certain mounds formed by fishes in shallow water resemble those under investigation in plan and profile. With very few exceptions, however, the areas where the mounds are found have not recently been beneath water.

VIII. Large scale concretions or segregations of mineral matter. This hypothesis was suggested because of the supposed failure of all other hypotheses (25). However, most examinations made without any reference to the concretionary hypothesis showed no marked differences between the soil of the mounds and of the intermound spaces.

IX. Differences in settling of coarse and fine beds (26). No supporting evidence was offered.

Moreover, the uniform distribution of coarse and fine beds and the circular plan, would then require explanation instead of the topographic features.

X. Protection from erosion by resistant caps, such as ordinary disrupted concretions of limestone in shale. In southwestern Missouri chert concretions in limestone have given rise to mounds by their great resistance to stream erosion (21). But protective caps and covers of gravel, or other resistant material, are rarely found in the Gulf Coastal Plain.

XI. Fossil "Mud-lumps." The "mud-lumps" which have been formed by escaping gas on the lower Mississippi delta have a similar shape to the mounds (20). Of opposite significance, however, is the fact that the characteristic "onion-skin" structure of the clay of the "mud-lumps" is not found in the sandy soil of the mounds (20). Likewise, craterlets are found in the tops of mounds only rarely; and the great majority of these features which have been examined in cross section, do not show "pipes" or "necks" connecting them with lower formations-as previously stated.

XII. Chemical solution. There seems to be a total lack of supporting evidence for this suggestion.

XIII. The work of glaciers. Though the hypothesis that glacial action of some sort is responsible for the mounds may merit examination in some regions, the fact that Pleistocene glaciation did not extend as far south as the Gulf Coastal Plain eliminates it from consideration in this paper.

XIV. Stream erosion-gullying. On the Yelms and Mima prairies south of Tacoma, Washington, the mounds are composed of thick, fine, black soil which rests on a nearly flat surface of clean, coarse, "open" gravel. The thin, black surface soil between the mounds is strewn with pebbles and cobbles; the mounds are not. This suggested to Le Conte that stream erosion had removed the soil and concentrated the surface pebbles in the low places (8-10).

Counterbalancing the foregoing evidence from Washington, most references agree in maintaining that the mounds are too uniformly distributed - in some places they are even arranged in lines for short distances - to be the divides between rivulets or gullies. It has also been held that the uniformly circular plan and the symmetrical dome-shaped profile of these elevations removes them at once from the class of such residual erosional features as divides. As additional contradictory evidence it has been shown that the elevations of surface soil which constitute the mounds are not reflected in the surface of the sub-soil, which is practically flat and has nearly the same elevation under the mounds as it has beneath the adjacent, low, inter-mound spaces. On Yelms and Mima prairies the sub-soil is a coarse, open, unindurated, glacial-outwash gravel. It has been stated that this subsoil is too porous to allow surface streams to flow more than very short distances without disappearing in the ground (35), and hence that small rivulets could not flow far enough to erode the necessary gullies.

Part II. The "natural mounds" of northeastern Texas, southern Arkansas and northern Louisiana.

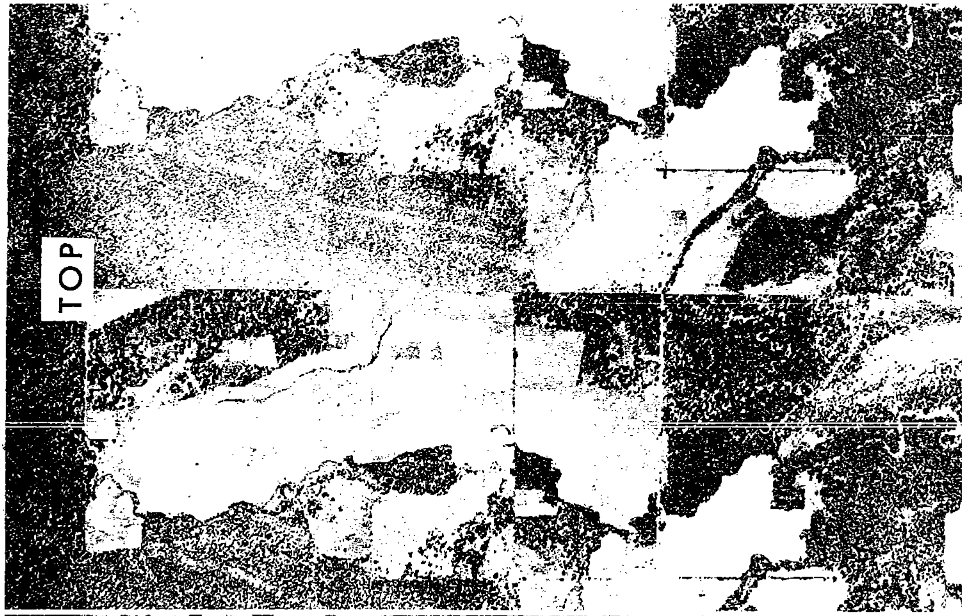
The writer was introduced to the "Mounds" problem by aerial photographs made of the Columbia terraces, or so-called "second bottoms" of several of the prominent rivers of the northern Gulf Coastal Plain, and also by photographs made over areas of Mesozoic and Cenozoic rocks elsewhere in the three states mentioned above. These Columbia terrace deposits are the time equivalent of the Port Hudson formation, or "Beaumont clay", of Pleistocene age, which outcrops in a band parallel to the Gulf Coast farther south.

Oblique aerial photographs made over the Columbia terraces near Smackover, Arkansas, are given here. The mounds are visible as light spots in the cotton fields and also in the uncut timbered lands. It is obvious that they antedate the settlement of the region by the present inhabitants. Identical spots, which are no doubt mounds, have also been seen on aerial photographs near Shreveport, Louisiana, near Poteau, Oklahoma, and near the following places in northeastern Texas: Winnsboro, Texarkana, Pittsburg, Mineola, Mount Pleasant, Longview, Grand Saline, Dangerfield, Bryan, Bagwell, Big Sandy. They are found in a nearly continuous strip from Texarkana to Paris, Texas.

## ORIGIN OF THE MOUNDS IN THE AREA UNDER DISCUSSION

In the investigation of this problem many hypotheses have been tested. All but five of the above theories-those which attribute the origin to large-scale concretionary or segregative action of mineral matter, to spring and gas vents, to sand dunes, to "root-mounds" and to gullying by surface streams or rivulets-have been found insufficient for reasons identical with those given. These reasons were advanced by others prior to the present investigation. They were, in most cases, writing about different parts of the Gulf Coastal Plain.

The work of the present ants has no observable definite relation to the mounds; and evidence of



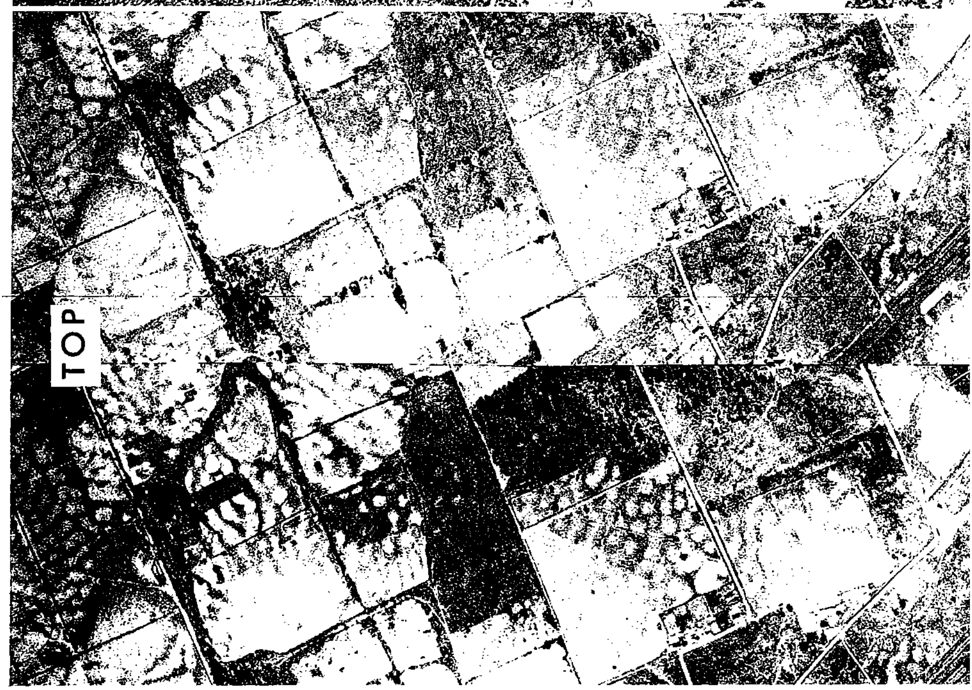
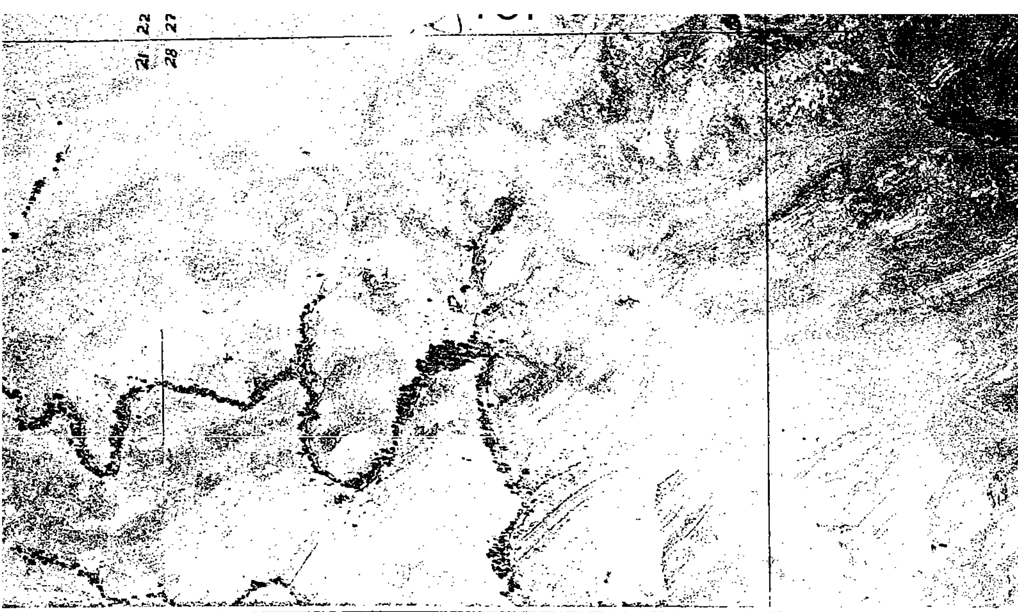




Figure 5—Stereo pair. North is at left as viewed

Mounds in lowland eroded on Stanley shale. Sec. 17, T. 2 S., R. 15 E., Oklahoma

Figure 6—Stereo pair. North is at left as viewed.

Mounds in Upshur Co., Texas, on terrace of Cypress Creek. Bedrock is of Eocene



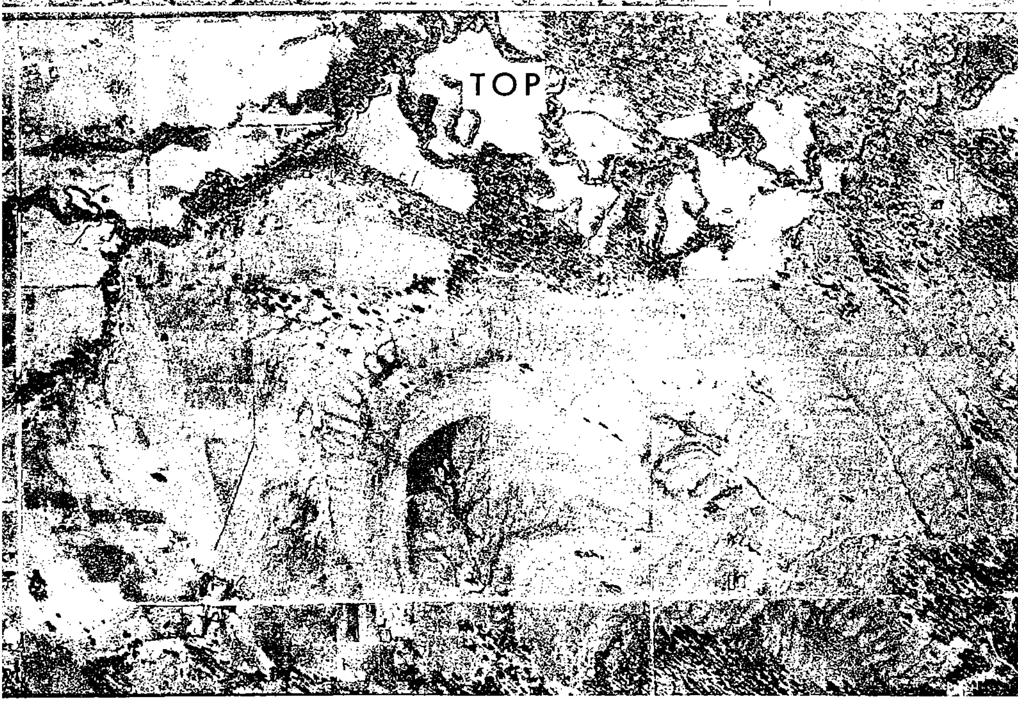



Figure 7—Single vertical. North is at left.

Residual chert mounds in outcrop of the Cool Creek formation of the Arbuckle group. Sec. 28, T. 2 S., R. 4 E., Murray Co., Oklahoma.

Figure 8—Single vertical. North is at left.

Weathered outcrop of jointed thin sandstone beds in the Stanley shale; resembles mounds of Quaternary terraces. Sec. 23, T. 1 N., R. 15 E., Oklahoma. Courtesy Tobin Aerial Surveys, San Antonio, Tex.

of earlier excavations by ants on a very large scale are totally wanting. The mounds examined by the writer show, furthermore, no evidence whatever that burrowing animals piled up their excavated material in such a way and in such quantities as to form these features. Several days spent in examining cross sections of hundreds of mounds revealed no trace of early human artifacts or of dwellings. So the theory of human origin was also laid aside. In the case of the five hypotheses mentioned above, on the other hand new evidence was sought for and discovered.

## CONCRETIONARY HYPOTHESIS

One of the first hypotheses which was suggested by the aerial photographs was that of large-scale concretionary deposition of mineral matter by ground-water. The very uniform distribution of the mounds over nearly the entire landscape except the bottoms of the larger ravines, the overwhelming majority of mounds with a circular plan, and their undoubted occasional arrangement in lines, all seemed to point toward the action of ground water. By no means least among the things which the aerial pictures revealed was a pattern which had never within the writer's experience been observed to result from erosion by streams or rivulets in homogeneous rock. So far as the first impressions went, the pattern of the lower interspaces between the mounds looked like anything but stream erosion. Concretionary action seemed more plausible. Accordingly this hypothesis was tested by field investigations twice in the fall of 1927.

Composite samples were taken from the top of the unweathered sub-soil beneath thirty characteristic mounds and from the top of the sub-soil beneath thirty characteristic inter-mound low spaces. These two composite samples were thoroughly mixed and analyzed chemically. The residue after boiling in concentrated hydrochloric acid was examined carefully with the microscope. The results of the analysis are shown by Table I.

TABLE I

Results of chemical analyses of two composite samples of sub-soil and one composite sample of surface-mound-soil. Analyses were made by Prof. C. A. Merritt, University of Oklahoma.

| | No. I Composite sample of subsoil from 30 mounds | No. II Composite sample of subsoil from 30 inter-mound spaces | No. III Composite sample of surface soil from 6 mounds |
|---|---|---|---|
| $CaCO_3$ | 0.01 | 0.02 | 0.02 |
| $Fe_2O_3$ | 3.51 | 4.72 | 2.16 |
| Residue after boiling in concentrated HCl | 96.41 | 95.22 | 97.79 |
| | 99.93% | 99.96% | 99.97% |

The residue is essentially quartz, but it contains small quantities of other minerals insoluble in HCl. They probably do not exceed 1.0%. All of the quartz grains are semi-rounded. They are mostly very small--in the neighborhood of 0.05 mm. in diameter-though occasional larger grains reach 0.8 mm. in diameter.

It is at once apparent from the table that neither of the compounds which might act as cementing agents vary enough from the mound to the inter-mound areas to cause the concretionary effect postulated. Furthermore the percentage of $Fe_2O_3$ is greater by 1.2% between the mounds than it is beneath them. The $CaCO_3$ is present in such small quantities that it could hardly be supposed to act as a concretionary matrix between the grains of sand. Also, the greatest percentage of $CaCO_3$ is found between the mounds instead of beneath them, just as in the case of the $Fe_2O_3$.

The textural similarity of the sub-soil at most places was one of the outstanding observations of the field examination. This fact, too, seems to invalidate the hypothesis which attributes the mounds to large-scale concretions or segregations.

Close examination failed to reveal large or prominent joints in the subsoil, along which circulating ground water might have operated to build up concretions. Zones of weathering, leaching, discoloration, or of mineral deposition, such as one might expect to find along prominent joints, were nowhere seen in the area examined.

In view of the above facts, especially in view of the evidence furnished by the chemical analyses, it seems sensible to disregard the concretionary hypothesis.

## SPRING AND GAS VENT HYPOTHESIS

The brisk circulation of water and gas which would have been necessary to form the present mounds was not supported by the writer's field work. No vertical joints filled with sand, or "sand-pipes," were found. Neither were craters nor craterlets in evidence. Where the contact between the surface soil and the sub-soil was found exposed in road cuts, it was easily recognizable. The contact was fairly definite, yet a uniform and consistent gradation from one to the other was always noted. The lack of any prominent joints or fissures, which might have acted as channels for the circulation of water and gas, also stands in the way of acceptance of this theory.

Hobbs' belief (34) that future work would disclose an arrangement of mounds along prominent joints or faults, the result of gaseous and aqueous emanations-expecially during times of earthquakes-is altogether at variance with the field data as well as with the evidence from the aerial pictures. Such joints or faults were nowhere found; and the mounds shown in the pictures are in no case arranged in lines for more than a fraction of a mile. Hobbs' paper, which appeared in 1907, contains a comprehensive summary of places where gas and spring mounds have been formed during earthquakes. But as a contribution to the problem of the "natural mounds" of the Gulf Coastal Plain, it is a good study in wishful thinking.

For the above reasons the spring and gas vent theory is held to be untenable in the area studied by the writer. It is admitted, though, that there probably are many places in this region-especially farther south where escaping gas and spring water have built, and are now constructing, mounds quite similar in appearance to those under discussion.

## SAND DUNE HYPOTHESIS

The sand dune hypothesis, likewise, fails signally to explain the mounds of the entire Gulf Coastal Plain. Most of the evidence which the writer considers pertinent in the area which he studied, has also been suggested by others who were studying the mounds farther south in southern

Louisiana and Texas. The conclusion that they are not sand dunes-either fresh or anchored--can therefore safely be extended to the entire region of the western Gulf Coastal Plain and the upper Mississippi delta.

The reasons why the sand dune hypothesis fails to find support in the northern Gulf region are as follows: (1) There is no source of sand adequate for the demands of such widespread features. (2) No cross-bedding of any kind was seen by the writer in the soil of the mounds. (3) The surface soil of the mounds grades downward uniformly and completely into the subsoil- it is definitely "in place." For seven additional lines of evidence against the sand dune theory see above.

## UPROOTED TREES

The present trees in the area studied by the writer are much too small to turn up a mound of earth five feet high and fifty feet in diameter when blown down. The diameter of the largest trees which can be found today is about 2 feet; and trees much larger than this would be required to turn up sufficient soil as they fell. Neither can it be contended that the larger trees have, by means of near-surface roots or otherwise, held the surface soil allowing the low places to be eroded out between them. A count of the trees with trunk diameters definitely larger than one foot, in uncut timber patches by the road side near New Boston in Bowie county, northeastern Texas, showed a random distribution with respect to the mounds. This hypothesis was also abandoned.

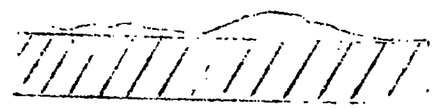
## HYPOTHESIS OF STREAM EROSION
## GULLYING BY RIVULETS

By a process of elimination we are brought to the hypothesis that some phase of stream action is responsible for their origin. On examination it is found to be not without evidence for its support.

One photograph is an aerial picture made near Tyler, Smith County, Texas. In the foreground the numerous gullies which are advancing up the slopes from the larger streams are dissecting the light colored surface soil into long strips with a certain degree of parallelism. These long strips of light surface soil are obviously being further dissected and cut into numerous smaller segments by a series of gullies of the second order. In the lower part of the picture, to the right of the center, these segments are indistinguishable from the mounds of the Smackover area. Several other pictures which show this same relationship between rows of mounds and long straight gullies have been found, and the writer believes that they settle the question of origin of the so-called "natural mounds" for the area investigated. Additional studies may or may not show that the mounds farther south in Texas and Louisiana are due to the same process.

In 1906 Campbell (33) considered the hypothesis of surface erosion (gullying), as well as many other hypotheses, and concluded that it was not a satisfactory explanation for the "natural mounds."

Text Figure 1. The relationship of surface soil to unweathered sub-soil is shown. Diagonal ruling represents sub-soil.
The mound at the right has a ratio of height to diameter of 1 to 7.



Text Figure 1 gives the relations of soil to sub-soil as Campbell's investigations showed them to be. He called particular attention to the fact that where the mounds are closely spaced the low places have the normal profile of stream valleys or ravines, i. e. concave upward. Where the mounds are widely separated, however, the profiles of the low places are not like those of normal stream valleys or ravines, but are flat. Here the profile of the low lands is not concave upward as one should expect if they have been worn out by the stream erosion which left the mounds standing as residual hillocks. Campbell maintained, instead, that it is "always flat." Furthermore, the surface of the sub--soil, as shown diagrammatically in Figure 1 is equally uniform and level beneath them. The surface of the sub-soil is flat regardless of the number or size of the surface mounds. But the most significant thing of all, Campbell held, was the fact that the soil of the mounds is invariably thicker than the soil of the low places, but of the same quality and presumably of the same origin. This, he says, "proves conclusively that the mound was built, and is not a residual left by erosion or solution."

The field observations of the writer support the observations of Campbell. Wherever studied, the surface soil was derived from the sub-soil just beneath it. There is a direet gradation downward from surface to sub-soil, wherever the writer saw the contact. The surface soil is in place. The surface of the sub-soil is a relatively smooth and level surface compared to the surface of the ground. It does not rise beneath the mounds and fall beneath the inter-mound areas, as a rule. The soil of the mounds is similar in texture and composition to the thinner soil of the low places. If it were not for the darker color of the soil in the low places, which is due to a higher percentage of decayed vegetation, they would appear to be identical. Where the mounds are widely separated the interspaces are comparatively flat-- such situations are not difficult to find, especially in the wooded areas.

The conclusions of the writer are not, however, in agreement with those of Campbell. These are very significant facts; but it is believed that their import is other than has been previously held. It is impossible to rely on temporary local base-levelling down to the level of the inter-mound spaces to account for the flat surface of the sub-soil. If this ever occurred it would mean that the local cycle of erosion was practically complete. In that event the mounds, as well as other portions of the surface, would be reduced unless in some abnormal way they were protected from the action of erosion. But such protection as by a cap of gravel, disintegrated boulders, concretions, etc., is not to be found in the Gulf region except in a very few sporadic cases if one is to rely on the published accounts. The writer has never seen such a protective covering. The true explanation seems to rest on the fact that the top of the sub-soil is a relatively resistant surface, compared with the weak, porous, sandy soil. Freshly exposed faces of the sub-soil are harder, and they stand with steeper, more rugged surfaces than freshly exposed faces of the surface soil.

In short, it is necessary to suppose that in these relatively unindurated sandy strata weathering has produced a weak sandy soil several feet in depth. Slight rejuvenation of the main streams has started an episode of rapid gullying in these soils. The sides of the gullies being too weak to stand vertically for long, have rounded off by rain wash and slumping.

Where these mounds are found on geologic formations that are well indurated and fairly resistant, one must assume a longer time of relatively slow erosion in the recent past with consequent deep weathering and the production of a weak porous soil. Slight increase in the activity of the streams would rapidly remove the soil. During removal, such mounds as we now see would be found.

The darker color and greater fertility of the inter-mound soil find ready explanation in the larger water content of the low soil than that of the higher soil of the mound surface. Peculiar dark rings immediately sourrounding a large number of the mounds have been seen on certain photographs made near Kaufman, in eastern Texas. The dark color does not cover the inter-mound space, but is concentrated in definite rings just at the foot of the mound slopes. The dark color of these rings may be due to a higher stand of the vegetation or to a darker color of the soil, or to both of these. It is almost surely richer soil than that on the mounds, and this is possibly due to the slight concentration of rain water here.

This theory which ascribes the origin of "natural mounds" to gullying in very weak, sandy soil, finds no objection in the existence of comparatively flat interspaces. The time honored objections that the individual mounds are (1) too symmetrical in outline and profile, (2) that they are too uniformly spaced, and (3) that they are "due to processes not now in operation in the region," the writer holds are largely due to preconceived notions about the erosional patterns that ought to result from gullying in very weak soil supported by a more resistant sub-soil. Such features are too small to be represented on all save the most exceptional topographic maps, and geologists who are not familiar with the face of the earth as seen from above have, therefore, little opportunity to become familiar with an erosional pattern which is no doubt rather common.

The objection (4) that the downward continuation of the sand (sandpipes) points to a spring or gas vent origin, has no weight in the area studied by the writer since careful search failed entirely to reveal any such "pipes" of sand. Likewise (5) Hilgard's objection (Reference 20) that the soil of the inter-mound areas is "quite distinctly in horizontal layers," does not find support in the writer's field observations, nor in the other literature on the subject which the writer has examined. In fact, Campbell and others point out that the inter-mound soil is identical with the soil of the mounds.

It is probably true that spring and gas vents, ants, wind, up-rooted trees and the work of man do in some places produce mounds which must very closely resemble those discussed in this paper. Perhaps the dominant mode of formation is different in different regions. In the area studied, however, the writer believes the correct explanation is gullying.

If the so-called "natural mounds" of this area are truly erosional remnants, as they seem to be, it is not fitting that they should be designated as mounds. The more suitable term of residual soil hillocks is offered.

## REVIEW OF LATER OBSERVATIONS, WRITTEN IN 1954

Since the foregoing paper was published in 1929, many additional papers have been written by soil scientists, biologists, geologists, and others. An extensive but incomplete bibliography of post-1929 papers is given below.

I. Only one radically new theory of mound origin (c.f. Knechtel 1952) has come to the writer's attention. It suggests the possibility that the mound pattern is a geometric shrinkage pattern-- the inter--mound swales and rills being eroded dessication or shrinkage cracks comparable to the "frost polygon" pattern of the deeply and permanently frozen ground of the Arctic. Basaltic columnar jointing would be somewhat similar.

Without pretending to give a complete analysis of Knechtel's theory, the writer offers the following points of criticism:

1. Considering the very common occurrence of "soil stripes" which have been isolated by rill or stream erosion and later segmented into lines of mounds (c.f. Figures 1, 5, 13, 14, 15, 16.) the concept of "shrinkage pattern" does not seem to be realistic.

2. The large and well-developed frost polygons of the Arctic are commonly found in marsh areas (especially salt marsh and lake marsh) where the ground is saturated with water. The "mounds" of this paper (as distinct from shrub-coppice sand dunes - see below) on the other hand are practically never found on water-saturated soil. They are chiefly found on the river terraces and associated low erosional

benches. In the southern Mississippi valley states they are almost entirely missing on modern floodplains and do not commonly occur in swamps and marshes.

3. The well-developed frost polygons are related directly to the depth of the frozen ground and thus to the depth of the alluvium, where it is not too great. The mounds in the south-central United States are not noticeably related in size or prominence to the depth of the alluvium which underlies them. Mounds in shallow alluvium in mountain valleys may be as large or larger than those of the deeper alluvium of the terraces of the Red River and its tributaries.

4. The shrinkage cracks (but without the natural mounds) found in the Playa de los Pinos an inter-mont plain near Lordsburg, New Mexico (Figures 3 and 4 in Plate 1, 2 in Plate 2 in Knechtel's paper) are indeed present there but they are rare elsewhere in the United States. The writer knows of no other inter-mont plain in the United States where they are to be found, though they are to be expected.

II. In the writer's opinion (now modified only slightly from that expressed in the 1929 paper reprinted above) there are two common geological processes which acting separately and together in different degrees, have formed the great majority of the natural mounds under discussion. One process is small stream or rill erosion followed by the rounding effects of rain wash and soil creep. The other is the entrapment of dune sand in small clumps of growing vegetation. Various combinations of these common processes will account for most of

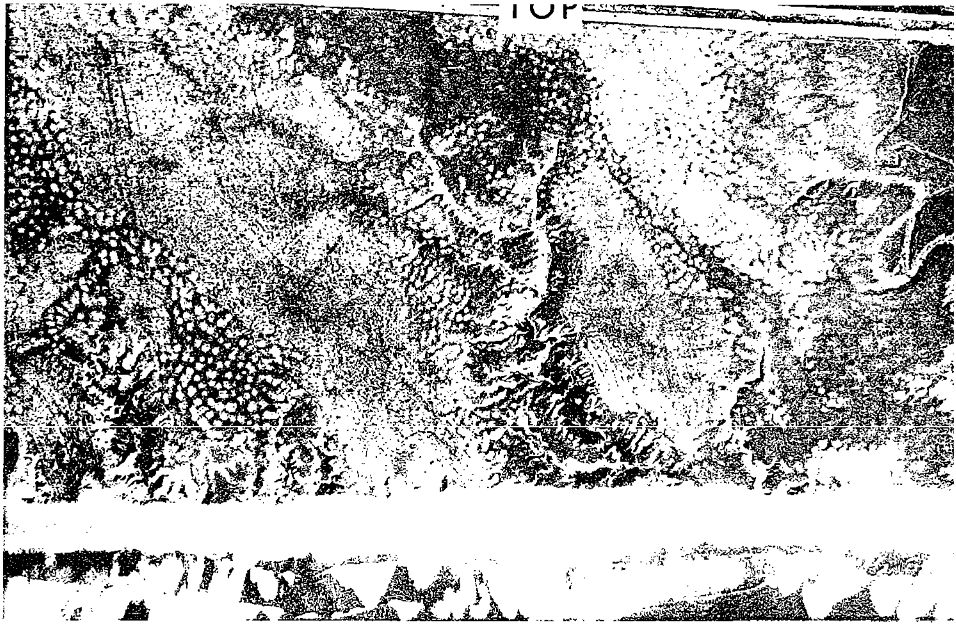


Figure 9—Single vertical. North is at left.

Mounds on marine terrace near San Diego, California. Rill-erosional origin as evident as elsewhere. Cf shrub-coppice dunes in text. Fairchild Aerial Su Los Angeles, California.

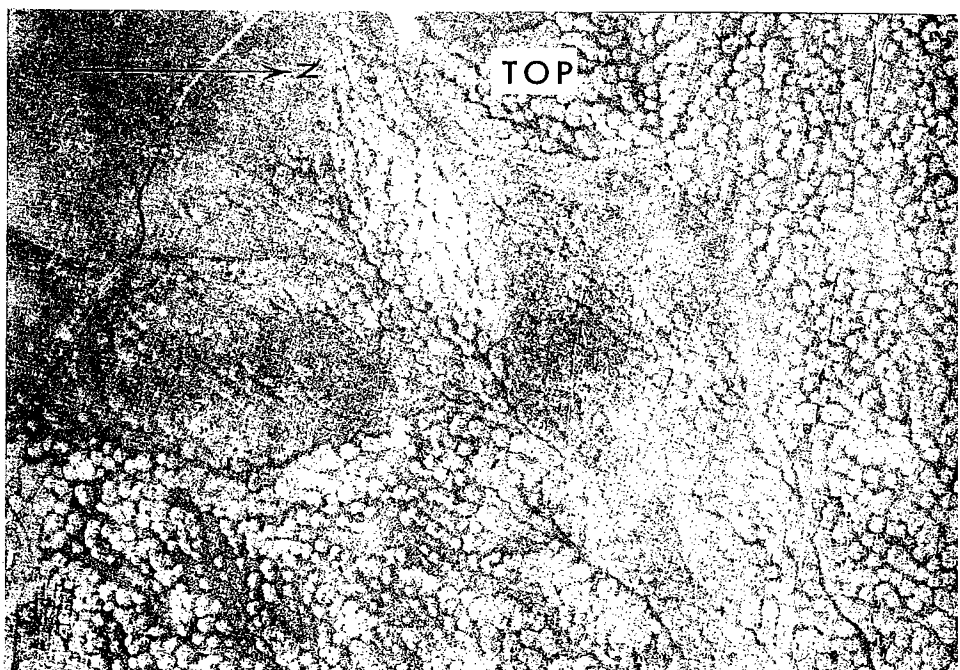



Figure 10—Single vertical.

Shrub-coppice dunes (?) built on natural mounds of rill-erosional origin. Near Bakersfield, Calif. Fairchild Aerial Surveys, Los Angeles, Calif.

Figure 11

Shrub-coppice dunes in clumps of mesquite bush. Near Carlsbad, New Mexico. Many of the "natural mounds" are modified by this kind of wind deposition. Looking northeastward, downwind.


Figure 12

Low altitude vertical photograph of mounds in Fannin Co., Texas. One inch = 600 feet. North is at left. Fairchild Aerial Surveys, Los Angeles, Calif.

the mounds to be found. For example:

(1) Rill and small stream erosion, etc. with a later but slight accumulation of wind-blown sand and silt in clumps of vegetation growing on the mounds, will account for the Oklahoma, Arkansas and East Texas mounds of Figures 1, 2, 3, 4, 5, 6, 12, 13, 14, 15, and 16.

(2) Rill and small stream erosion, etc., followed by considerable accumulation of wind-blown sand and some **dune migration**1/of the mound-shaped dune with its growing clump of vegetation will account for the mounds of Figure 10 in the San Joaquin Valley of California. Common types of clump vegetation found on these dunes are grasses, mesquite bush, shinnery oak bush and others.

(3) The accumulation of wind-blown sand in clumps of vegetation without any stream or rill erosion will explain the shrub-coppice dunes of Figure 11. The bush is mesquite. Rich, John L. (1934) suggested the role of clump vegetation in the origin of natural mounds.

III. Various authors2/attribute the natural mounds of the southern Mississippi Valley and adjoining regions as well as the San Joaquin Valley of California and elsewhere to the constructive work of

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1/ Melton, F. A. 1940

2/ Arkley and Brown (1954); Price (1949); and others pocket gophers (<u>Geomys bursarius and Thomomys talpoides</u>). These writers do not, in the writers opinion, give adequate attention to geological causes--discussed above. But there are other valid arguments against too-broad an application of the gopher-mound theory:

(1) A large gopher mound formed today, would be 1 foot high and 3 feet in diameter. Contrast this with the average mound size in Sequoyah County, E. Oklahoma, which is approximately 3 feet high and 40 feet in diameter. Similar and larger dimensions are found on the average mounds of different localities in Oklahoma, Arkansas, E. Texas, and Louisiana.

(2) Recent gopher mounds do not endure more than two or three years; rainwash eliminates them rapidly.

(3) Gophers, prairie dogs, and other burrowing animals are capable of selecting the mounds under discussion as a favorable site for their activities--their presence is probably the result and not the cause of the existence of natural mounds.

(4) The gopher mound theory of origin of the natural mounds necessarily involves the assumed former existence of fantastically great numbers of the animals. For in the southern plains the remarkable uniformity in size, development, and general appearance of the mounds strongly suggests a relatively quick origin, and one of essentially the same date at all places. The supposed architects of these mounds must have occupied a region of the order of 100,000 square miles almost instantaneously-geologically speaking. Contrast this with the

known migration of burrowing animals in historic time. Not much is known about small mammal populations, but Mohr (1927) cites from various authors, pocket gopher populations ranging from a minimum of 2 per acre to a maximum of 15 per acre. These figures are of course local averages, but they point to a very great discrepancy between known gopher populations and those required by the gopher-mound theory of origin of the countless natural mounds.

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The writer is indebted to Prof. Paul R. David of the Zoology Department of the University of Oklahoma for certain references, and to Dr. Maxwell J. Wilcomb, Jr. of the Zoology Department of the University of Oklahoma for references and assistance in collecting data on the small mammals.

Frank A. Melton.

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Figure 13—Stereo pair. North is at bottom.

Mounds on eroded terrace of Cypress Creek, Upshur Co., Texas.

Figure 14

Oblique view of mounds of at least partly rill-erosional origin on terrace of Sulphur River, near Mineola, Wood Co., Texas. Looking north. Fairchild Aerial Surveys, Los Angeles, Calif.

Figure 15—Single vertical. North is at bottom.

Mounds of partly rill-erosional origin in Titus Co., Texas. Courtesy Southwestern Aerial Surveys, Austin, Texas.

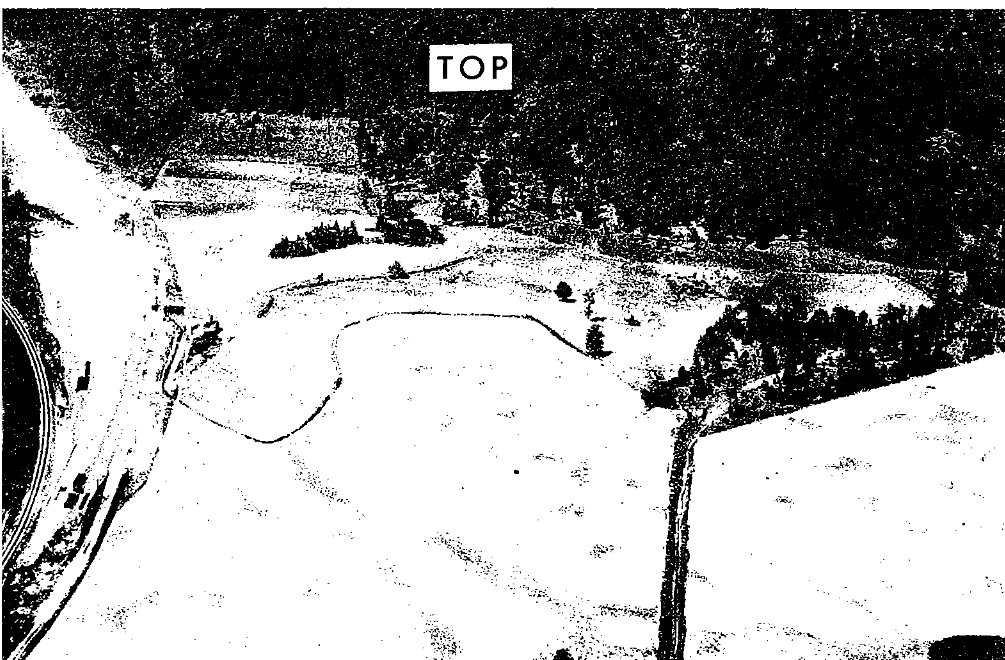


Figure 16

Low elevation oblique of mounds of partly rill-erosional origin. North is to the right. Near Pittsburg, Camp Co., Texas. Fairchild Aerial Surveys, Los Angeles, Calif.

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